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Intellectual Property Rights in the Software Sector: Issues on Patents and Free/Libre Open Source Software

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Declaration

This dissertation is the result of my own work, except where explicit reference is made to the work of others, and has not been submitted for another qualification to this or any other university.

Francesco Rentocchini

Contents

“Writing in English is the most ingenious torture ever devised for sins committed in previous lives.”

— James Joyce

Introduction

Background

In the last 30 years the world economy has been characterised by an increased importance of high tech sectors as drivers of economic growth. In addition to this, international division of labour led advanced countries to specialize their economy exactly in these sectors. This last pattern has gone hand by hand with an overall increase in the role of Intellectual Property Rights (IPRs) as means of protection for the results of invention activity at the firm level. This has spurred some authors to underline a deep transformation of modern capitalism, defining it as intellectual capitalism (Granstrand 2000). This last term points out the paramount importance of intangibles in the competitiveness of firms around the world. Not only productive capacities mainly relying on technical inventions take a central role in world economy, but also the capacity to protect the idea, or the expression through which it takes place, is gaining more and more relevance.

Indeed, the protection of results of inventive activity has not been confined only to the realm of new technologies but the impressive increase in the call for protection has mainly concentrated in biotech and Information and Communication Technologies (ICTs). This has been witnessed by the number of patents applied for which have been characterised by a striking upsurge. Taking a closer look at the phenomenon reveals that this dynamic has been mainly driven by the number of patents published in two main fields: biotechnology and Information and Communication Technologies (ICTs).

The higher level of protection of inventive output has not been driven by a comparable increase in the inputs of the inventive activity (mainly R&D spending). This fact poses a set of different questions that will shade light on the intimate nature of the knowledge economy. First of all, is the increase in the output of inventive activity the effect of a higher level of productivity for R&D spending? Second, is this pattern due to the increase in the easiness through which the results of inventive activity is protected? This fact calls for a proper analysis of the regulatory changes taking place inside a country, such as the modifications of the patent system and of copyright law. Third, are IPRs increasingly used as competitive means in order to gain monopoly position over the market? Fourth, is it always correct to rely on means of protection in order to spur inventive activity? Are there any cases where knowledge openess rather than its strictness is the best solution? Indeed the advance of the knowledge economy has not taken place exclusively through the role of Intellectual Porperty protection. On the contrary, there are cases where a set of institutions are promoting openess as a mean to achieve innovation and hence economic growth. One of them is surely the realm of open science (Dasgupta and David 1994) according to which the inventors respond to a different set of incentives (free circulation of the results of the research activity, peer to peer review, etc) compared to the proprietary technology one (). Furthermore, in the past there have been numerous cases of open technologies as well. For example the case of collective invention in the metallurgical industry in the Lancashire (Allen 1983) and that of the Cornish pumping engine (Nuvolari 2001). More recently, a renewal in the interest for collective invention based on knowledge openess has been experienced by several sectors. Among them, the software sector witnessed the emergence of Free/Libre Open Source as an alternative method of production of software, challenging in this way traditional means of protection.

All of these research questions have not properly addressed by the literature and, when this happened, the United States have always been the centre of the analysis. The present work wants to be the first systematic attempt to address the mentioned issues in the European context.

Outline of the Thesis

1. *A survey of the literature on patents.* In this chapter economics literature on patents is reviewed and contributions coming from different streams of the literature are put together in a innovative way. In particular, we have individuated four main macro-areas of interest: patent-race models, normative models, empirical contributions and strategic patenting models.

2. *Software patents.* In this chapter economic literature on the Intellectual Property Rights (IPRs) in the software sector has been reviewed. In particular, the survey has been conducted from two different points of view: both legal and economic. The analysis is concentrated on three main typologies of IPRs pertaining software: copyright, patent and open source licenses.

3. *Software Patenting in the European Union: Empirical Insights.* Given the gap inbdividuated in the economic literature we decided to conduct a an empirical analysis in order to quantify software patenting in the European Union. The study is based on an original dataset containing software patents accorded at the European Patent Office (EPO) in the last 20 years. The database has been coupled to another one made up of relevant information at the firm level. In this way, we have been able to determine factors affecting software patenting at the micro-level. The work refers to the period 2000-03 and the particular nature of the data available called for the implementation of sound econometric methods, namely non-linear panel data.

4. *Open Source Software in the Public Sector: Results from the Emilia Romagna Open Source Survey (EROSS).* In this chapter we have collected data on open source software adopted by Public Administrations (PAs) in Emilia-Romagna region. Emilia-Romagna municipalities together with adopted software have been the main object of the analysis. Gathered data have been integrated with other information coming from different data sources. In this way, we have been able to trace the identikit of average municipality adopting open source software and, at the same time, we have put forward the relationship linking open source and PA's performance.

Chapter 1

A survey of the literature on patents

But patenting activity needs particular attention given its specific nature: first of all patent is an institution in the sense of North(North 1990): it is the State that, through the Patent Office, grants a period of monopoly over the invention to anyone who fulfills given requirements (i.e. it is recognised as the inventor). Secondly, given its institutional nature, patent characteristics are country specific: each country has different patterns in patent length and scope [1], in procedures for lawsuit and infringement, and so on. Finally, it is the most used measure for the output of inventive activity (UNESCO, 1970). Although, neither all inventions are patentable, nor they are patented [2], although patents may differ as indicators of "quality" of different inventive outputs, patents are however the most reliable and used instrument for measuring output of the R&D process. This is mainly due to the fact that they are available, related to inventiveness and constitute a slightly fixed standard (Griliches 1990). Given its widely composite nature it would be very useful to give account of how the economic literature has faced the central problem posed by patents. Although it may sound good that the inventor must be rewarded for the financial effort dedicated to the inventive process the problem remains about the length, breadth and application of the patent tool. Which is the optimal length of a patent in order to let the inventor to recover money and time spent? Which is the breadth of a patent useful both to the inventor and followers? Once found, are the optimal length and breadth of a patent equally applicable to all sectors and technologies? To answer these questions I turn my attention in the following.

[1] for example one of the main difference between USA and EU is the possibility for the former of patenting software

[2] consider the case of SMEs which rely more on informal or co-operative ways of performing inventive activity and that are not able to patent inventions due to financial constraints

1.1 Patents: an historical account

The first type of privilege similar to a patent was granted to Johannes Teothonicus for a grain mill in 1323 by the Republic of Venice. Venice was an advanced city from a technological point of view and it financed a high number of inventors to accomplish modern mining and water structures. The legal instrument used was to accord rights to the inventors (i.e. a share of mines output or prohibition of imitation) in exchange of the technical contribution provided. Concession of privileges continued for a long time (more or less for half a century) in Venice. During this period technology imports remained the most important cause for patent concession, but another reason for patenting became more and more common which was the desire of fostering innovative activity allowing the inventor to rip part of economic outcome. Most of the times it was permitted through licensing rights: imitations were strongly forbidden, while inventors could license if reasonable royalties were offered in exchange. The Senate of Venice finally decided to codify this well established practice; in 1474 when it issued what can be thought of as the first general patent law(David 1992). This formal patent code assured ten years long protection to workable and useful inventions. In this exception, the primary aim of a patent was to confer to the inventor a monopoly right on his invention in order to incentivate him to bring his/her skills and knowledge to the Republic of Venice, but also to spur inventive activity from all artisans living in Venice.

The first Government issuing a patent regime was the English one in 1623, when what has been defined as the National Patent Era was burn(Granstrand 2000). Two features characterize this new period. First, before this date patent laws were issued only by single cities or narrow localities, while from now on it was the country as a whole to adopt a unique patent regime referring to the whole national territory. Second, it is the national government that accords the patent and not the sovereign anymore. In fact, in 1623 the English Parliament issued the Statute of Monopolies which assured to the inventor exclusive monopoly rights for 14 years on the discovery made.

In 1790 USA adopted a patent legislation enacting a Federal Patent Law. This date must be regarded as crucial given that USA became one of the country relying most heavily on patents during the following two centuries. The decision by the American government arrived after a period in which copyright and patent protection were legally coupled. The former was assigned to protect "books", while the latter to protect "machines"(David 1992). The distinction in treatment came with the Federal Patent Law which assured different statutory bases for the two types of Intellectual Property

Rights (IPRs).

Another important landmark in the historical development of patent is the adoption in 1791, by the new France Republic of a patent system. This system, contrary to previous one, was grounded on citizens natural rights following the Enlightenment guidelines. Even if the patent was seen as a privilege as in previous cases, the legal foundation changed referring no more to the power of the sovereign, but to the rights embedded into the citizenship.

In 18th and 19th centuries the importance of patent systems grew faster and faster, in a way directly proportional to the importance acquired by innovative activities. While firms began to invest more and more financial resources into the development of new processes and products via their R&D laboratories, the appropriability of innovation results became important and the defense of innovator rights were strengthened at both national and international level. In fact, both 19th and 20th centuries witnessed the movement toward the harmonization of the patent system at the supra-national level with the Paris Convention of 1883, the creation of the World Intellectual Property Organisation (WIPO) and that of the European Patent Office (EPO).

Finally, during the last decades a new phenomenon was observed: the broadening in patent scope and strength. Patentability in new areas of the economy was possible, with the USA as the leader: in 1980 the US Supreme Court admitted the patentability of micro-organisms; in the same year Bayh-Dole Act was enacted which enabled universities to patent inventions coming from research funded via federal money; in 1994 patents were extended to software and in 1998 to business methods. In addition in 1982 the Court of Appeals for the Federal Circuit (CAFC) was formed, that broadened the interpretation of patent scope. As it is commonly known, in order to obtain a patent an inventor must satisfy three main requirements: novelty, technical content and non-obviousness[3]. The latter refers to the fact that the invention do not have to be obvious for a person skilled in the art to which the invention refers. Some authors (Cooley, 1994 and Hunt, 1999) highlighted how the creation of CAFC relaxed the tightness of the above mentioned standard. The Court was also prone to sustain large damage awards(Kortum and Lerner 1999) and to permit a wide use of preliminary injunctions[4] to patentees (Lanjouw and Lerner, 2001)

[3]

[4]Preliminary injunction is a temporary order made by a court at the request of one party that prevents the other party from pursuing a particular course of conduct until the conclusion of a trial on the merits. In this sense, preliminary injunction allows the plaintiff, before a trial, to prevent the defendant from acting in a way that will irreparably harm ability to enforce his rights.

1.2 Patent System in Schumpeter Analysis

Given that Schumpeter was the one who concentrated most his focus on the analysis of innovation as the most important factor in the composition and functioning of the economic system, it seems quite strange that Intellectual Property Rights (IPRs) in general, and patents, in particular, has not been analysed in his seminal contributions. He places innovation at the center of the scene: it is the basic rational on which the functioning of the entire economic system relies. And so why did such an important author disregard the analysis of the patent system? It is worth noting that to the "first" Schumpeter(Schumpeter 1934) a population of Small and Medium Enterprises (SMEs) was regarded as the most suitable market structure in order to foster innovation. Such a pattern of innovative activity, that has been defined "Schumpeter Mark I"(Nelson and Winter 1982) (Kamien and Schwartz 1982), sees a patent regime as a nearly useless institutional tool because inventive activity is exogenous to the system; it is mainly due to frequent entry of dynamic firms with new entrepreneurial ideas[5] and exit of inefficient ones. A "Second" Schumpeter changed his mind and indicated as very important a more concentrated market structure(Schumpeter 1942). This second pattern of innovative activity, defined as "Schumpeter Mark II"(Nelson and Winter 1982)(Kamien and Schwartz 1982), is characterised by the presence of big firms which can rely more on Research and Development (R&D) departments and on financial resources and, in this way, may contribute to the innovative activity of the whole economy. The lack of patent system analysis in "Second" Schumpeter can be seen as a gap, but such a gap can be explained referring to the historical period in which Schumpeter lived. A period when the patent system, although it was gaining importance, was not as important as it is today.

1.3 Patent Race Models

1.3.1 Introduction

Since Schumpeter's contribution economic theory holds that there is not a unidirectional path between market structure and innovation performance, but rather firms try to influence market structure through innovative activity(Schumpeter 1934). This means

[5]At this regard it is interesting to note the importance of the role of the entrepreneur in Schumpeter analysis (Schumpeter, 1912; Schumpeter, 1993).

that there is space for strategic interactions among actors. Since Arrow's seminal contribution (Arrow 1962), several authors have tried to model such a kind of phenomenon concentrating on how firms strategically interact in order to change market structure, having as final aim the maximisation of their objective functions.

The economic literature trying to achieve such a result can be organised under the heading Patent Race Models. In fact, the basic rationale of these models is that at the end of the strategic interactions among firms the winner of the innovation race takes all, meaning that only one will obtain a patent on the invention. In these models, the typical Neoclassical assumptions are made, among which these are:

1. Perfect rationality. All economic actors treat technology as information. This means that it is freely available, it has reproduction costs equal to zero and it diffuses easily among all actors engaged in the race.

2. The second assumption has a methodological content: in fact, with the exception of few cases, Game Theory's used to model strategic interactions [6].

Hence, they differ in several features from mainstream theoretical models, in particular a couple of assumptions are relaxed with respect to orthodox theory:

1. Even if technology is treated as information (see 9), it is only partly appropriable which means that not all information reaches economic actors and that not all actors rely on the same quantity and quality of information. There are problems that hinder information diffusion.

2. Uncertainty characterises the output of innovative activity, which means that in some cases it is very hard to attach a probability to certain events.

The above assumptions make patent race models "hybrid", in the sense that, even if maximising and perfect rationality assumptions are made as in standard Neo-classical models, uncertainty and limited appropriability of technology can be seen as partial incorporations of contributions from some authors outside the mainstream literature(Schumpeter 1934) Knight, 1921(Nelson and Winter 1982).

[6] The first contribution in game theory is the one of Von Neumann (von Neumann 1997) who presented the Minmax Theorem for a solution of a non-cooperative game. Other two important contributions are the one from Nash (Nash 1997a) (Nash 1997b). For a review of game theory see, for instance, Gibbons (Gibbons 1997) Fudenberg and Tirole(Fudenberg and Tirole 1991).

I will present formally the model of Arrow(Arrow 1962)(Tirole 1988) which is the natural starting point of all patent race models. Then I will introduce a refinement of the model, taking into account the possibility of potential competition. After presenting the limits of the model I will describe the subsequent contributions which try to overcome Arrow model problems. The following sections rely mainly on three important review of the literature in models of patent race(Tirole 1988)(Reinganum 1989)(Malerba 2003) but i integrate them, in parts that i reputed of low clarity, with contributions from reviewed authors. In addition i will add a work that is rather recent with respect to patent race literature but that, at all effects, can be incorporated in such a stream of literature (Panagopoulos 2004).

1.3.2 The Arrow Model

Introduction

The work of Arrow is important because all patent race models depart from his seminal contribution(Arrow 1962). His final result asserts that market structures as monopoly and perfect competition are sub-optimal in allocating the resources for invention and from this he concludes that we end up in a well known situation of market failure, in which public intervention is necessary. Some hypotheses are common to all market structures and are:

1. All markets face the same demand curve which is downward sloping $q = D(p)$ where p is the price of a given product and q its quantity.

2. The introduction of an innovation has the effect of lowering the cost firms face in producing it from $\bar{c}$ (cost before innovation introduction) to c^{**} (cost after innovation introduction), hence we can consider it as a process innovation.

3. Let indicate with V the incentive to innovate.

In order to show how monopoly and perfect competition behave with regard to innovation activity ad how they are sub-optimal Arrow starts his analysis from the situation for a social planner.

Social Planner

If we indicate with v^s the additional net social surplus per unit of time and assume that the social planner incentive to innovate V^s is equal to the discounted present value of the additional net social surplus per unit of time, we can write:

$v^s = \int_{c^*}^{c^{**}} D(c)dc$[7]

$V^s = \int_0^\infty e^{-rt} v^s dt = \int_0^\infty e^{-rt} \int_{c^*}^{c^{**}} D(c)dc$

$z = e^{-rt}$, differentiating $\frac{dz}{dt} = -re^{-rt}$, arranging $dt = \frac{-dz}{re^{-rt}}$ and substituting:

$\int_{c^*}^{c^{**}} D(c)dc \int_0^\infty e^{-rt}(-\frac{dz}{re^{-rt}}) =$

$\int\limits_{c^*}^{c^{**}} D(c)dc \int_0^\infty -\frac{1}{r}dz =$

$[\int_{c^*}^{c^{**}} D(c)dc][-\frac{1}{r}][e^{-r\infty} - e^{-r0}] =$

we find that the incentive to innovate in presence of a social planner is:

$$V^s = \frac{1}{r}\int_{c^*}^{c^{**}} D(c)dc \tag{1.1}$$

From a graphical point of view:

Monopoly

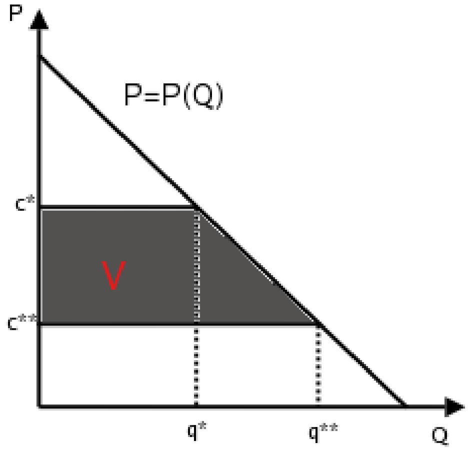
In the case of monopoly the incentive to innovate V^m is given by the difference between the stream of profits gained after innovation introduction and the stream of profits obtained before, that is:

$V^m = \int_0^\infty e^{-rt}[\Pi(c^{**}) - \Pi(c^*)]dt$

following previous methodology of solution we find:

[7]The demand curve $q = D(p)$ can be written as $q = D(c)$in the interval $[c^*; c^{**}]$given that we are referring to the part of demand where cost has changed.

Figure 1.1: Incentive to Innovate (V^s) in presence of Social Planner



$V^m = \frac{1}{r}[\Pi(c^{**}) - \Pi(c^*)]$

But $[\Pi(c^{**}) - \Pi(c^*)]$can be written as the negative increment of the profit due to the infinitesimal increase in cost of production $(-\frac{d\Pi}{dc})$, so:

$$V^m = \frac{1}{r}\int_{c^{**}}^{c^*}(-\frac{d\Pi}{dc}) = \frac{1}{r}\int_{c^{**}}^{c^*} D(p^m)dc \tag{1.2}$$

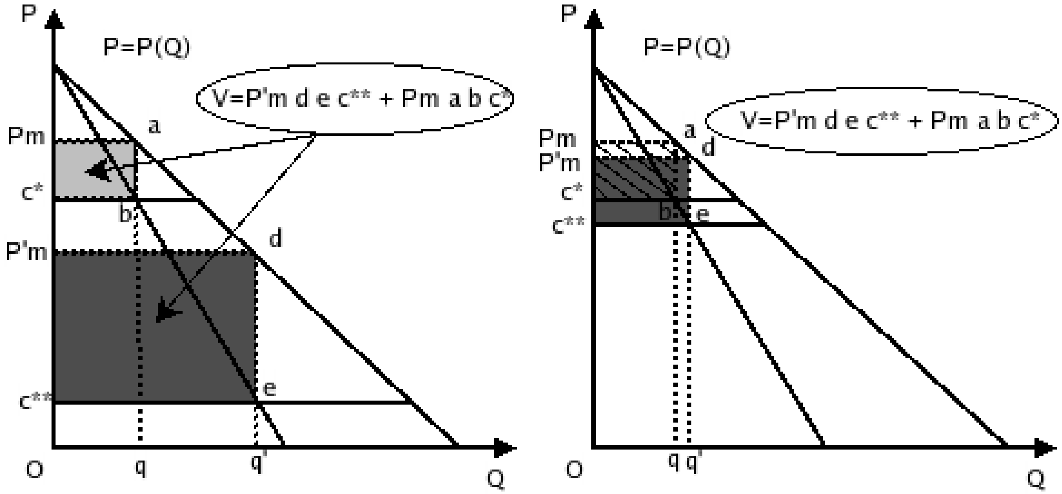
where p^m is the monopoly price [8].

Comparing monopoly (1.2) with social planner results (1.1) we note that $p^m > c$ and so $V^m < V^s$ which means that the incentive of the monopolist to innovate is lower than the optimal one.

From a graphical point of view:

[8] $D(p^m)$ is found differentiating Π^m, which is the monopoly profit, with respect to the cost of production c. Hence, $\frac{d\Pi^m}{dc} = -D(p^m)$.

Figure 1.2: Incentive to Innovate in Monopoly with (a) and without (b) Drastic Innovation



Competition

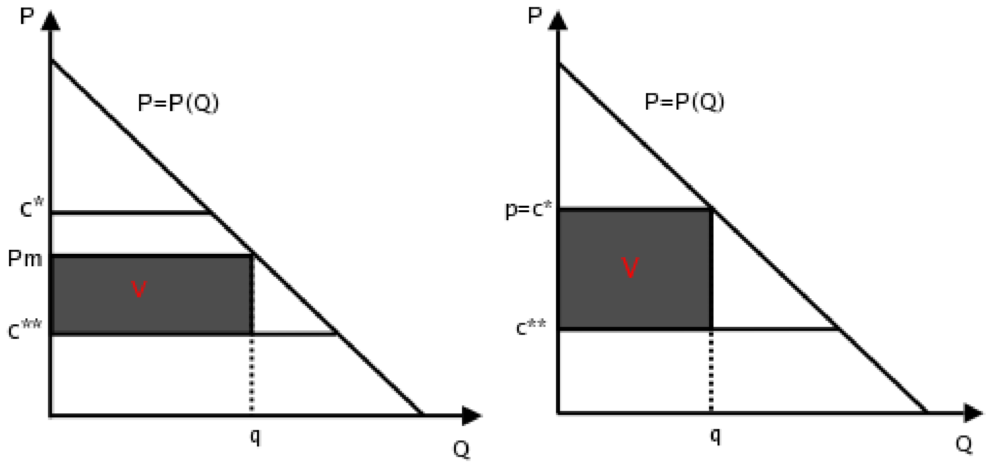
In a competitive market with a high number of firms producing homogeneous goods and competing via prices *a la Bertrand* (Pindyck and Rubinfeld, 2000) all firms earn profit equals to zero and market price is set at c^*. After that a firm has introduced an innovation it obtains a patent and set its price at a monopoly level $p^m$and its cost of production lowers at c^{**}. In this situation we need to distinguish between two cases: drastic innovation and minor innovation. We define a drastic innovation as an innovation that makes the innovator to set $p^m \leq c^*$ and in this way it is the only firm that produces; while in the minor innovation case ($p^m > c$) innovator sets his price equal to the one of other firms $p = c^*$.

In drastic innovation case we have that the innovator decides the price and sets it at a monopoly level $p^m$and the incentive to innovate, given that $\Pi(c^*) = 0$ and $\Pi(c^{**}) = [p^m(c^{**}) - c^{**}]$ and solving the integral, is:

$$V^s = \int_0^\infty e^{-rt}[\Pi(c^{**}) - \Pi(c^*)]dt = \frac{1}{r}[p^m(c^{**}) - c^{**}] \tag{1.3}$$

While in minor innovation case we find:

Figure 1.3: Incentive to Innovate in a Competitive Market with Drastic Innovation (a) and without Drastic Innovation (b)



$$V^c = \frac{1}{r}[c^* - c^{**}]D(c^*) \tag{1.4}$$

In both cases we note that $V^s > V^c > V^m$.

This is the main result of Arrow analysis and it refers to the fact that in a monopolistic market an innovator has less incentive to innovate than in a competitive or socially optimal one mainly because innovating for a monopolist means replacing himself into the market (replacement effect).

From a graphical point of view:

Monopoly threatened by entry

Until now we have treated the incentive to innovation only as a technological one, but in reality there is another type of incentive to innovation that may arise, it is the strategic or pre-emption one(Gilbert and Newbery 1982). If we suppose to be in a situation in which a monopolist is threatened by a potential entrant we can analyse the strategic interaction among incentives of the two firms to innovate. In addition to previous cases, firms not only must consider benefits connected with the innovation (technological incentive to innovate) but also the changes that the potential competition can produce on the profits earned (strategic incentive to innovate).

Maintaining the same hypotheses of the Arrow model (see paragraph 1.3.2 on page 10), if the monopolist adopts a new technology the resulting situation is equal to the monopoly case in the Arrow model. Instead if the new technology is adopted by the potential entrant, he enters the market obtaining a duopoly profit of $\Pi^d(c^{**}, c^*)$ and reducing the profit of the monopolist to the duopoly one $\Pi^d(c^*, c^{**})$. Pre-emption incentives to innovate for the two firms are then $V^c = \frac{\Pi^d(c^{**},c^*)}{r}$ for the competitor and $V^m = \frac{\Pi^m(c^{**})-\Pi^d(c^*,c^{**})}{r}$ for the monopolist. Intuitively $\Pi^m(c^{**}) \geq \Pi^d(c^*, c^{**}) + \Pi(c^{**}, c^*)$[9] and so the final result is that the incentive for a monopolist to innovate is greater than the entrant's incentive to innovate entering the market(Gilbert and Newbery 1982).

The above analysis shows how there are two opposite effects shaped by two different incentives to innovate. The former (replacement effect) refers to the fact that a monopolist which innovates is replacing itself into the market providing in this way a disincentive to innovate with respect to others market structures. The latter (pre-emption effect) refers to the fact that a monopolist, which is threatened by another firm entry, has an incentive to innovate in order to keep its profits above the duopoly level. The result of the two effects taken together depends on which effect is bigger.

Arrow model limitations

Apparently Arrow reached an opposite conclusion compared to Schumpeter who, in his mature contributions, attributed to large monopolistic firms a higher level of innovative activity. But the analysis of Gilbert and Newbery(Gilbert and Newbery 1982) showed how, if one considers a monopolistic market threatened by entry, Arrow conclusion may not be valid and that the level of innovation in a monopoly market structure can be higher than in a competitive one.

The model of Arrow and its extension of Gilbert and Newbery are not "pure" patent race models because no race actually takes place. Models that follow concentrate more on R&D competition among firms and they try to overcome some limitations contained in the Arrow model. Indeed, some authors argued that Arrow analysis has the following important drawbacks:

[9]The profit of a monopolist introducing an innovation is surely bigger than (or equal to) the one of two non-colluding duopolists.

1. There is absence of R&D competition among different actors. We have seen that the introduction of a potential entrant changes the conclusions of the model. Hence, what happens if instead of a single competitor there are a plurality of actors competing among themselves?(Dasgupta and Stiglitz 1980).

2. The inventive process has a discrete nature. Changes in the components of the frontier of inventive possibilities are not taken into account but factors as R&D costs, risk and speed of invention must be analysed in order to make an exhaustive picture of the innovative process(Dasgupta and Stiglitz 1980).

1.3.3 Memory-less Models

The subsequent generation of patent race models that depart from the contribution of Arrow has been defined memory-less models. In these models firms compete in R&D investment among themselves in order to maximise the actual value of expected profit. What characterises these models is the fact that the investment in R&D that any firm decides at a given point in time is independent from past decisions and that the probability of success of such an investment depends only on current investments and not on past ones. The most important consequence of such an hypothesis is that firms do not learn from past experiences and so "learn by learning" is useless (Lundvall and Johnson, 1994).

Memory-less models can be subdivided in two sub-groups: symmetric and asymmetric models. The former are characterised by firms with similar patterns, in particular as far as cost structure, innovative capacity and product characteristics are concerned. The latter differentiate firms with regards to these elements.

Models which belong to the first group, overcoming limitations posed by Arrow, arrives at the conclusion that the size of the market is positively correlated with R&D expenditure(Dasgupta and Stiglitz 1980)(Loury 1979). To the opposite conclusion arrive Lee and Wilde(Lee and Wilde 1980) who assume that the probability of success is exponential, as in Dasgupta and Stiglitz and Loury models, but it depends from the expected return on the investment (given by the intensity of research) and not from the amount invested (the scale of the R&D lab). In fact they conclude that, in equilibrium, an increase in the number of rivals is associated with an increase in the intensity of R&D.

The second group of memory less models hypothesises that there are asymmetries

among firms inside a market, mainly due to diversity in innovative performances. For example the model of Gilbert and Newbery[10](Gilbert and Newbery 1982) defined as a deterministic one, hypothesises that a firm innovates when a given level of R&D expenditure is reached. In this auction model a monopolist must choose the best R&D investment x that permits him to maximise his objective function. Given an objective function equals to $P^j e^{-rT(x_i)} - x_i$
where P^j
is the value of innovation in different markets ($j = m$ for a monopolistic market, $j = e$ for an entrant in an oligopolistic market or $j = i$ for the incumbent in the same market) and $T(x_i)$
is the date of completion. Given that $P^m \geq P^e + P^j$
the incumbent wins the auction bidding x^*, which is the value that maximises monopolist objective function and sets the entrant one equals to zero. The final result is that, as in the simple model case, if we are in a situation of monopolistic market threatened by possible entrants the monopolist has an incentive to remain the only one in the market. Hence he/she patents his/her innovation forbidding other firms to enter the market. This result is consistent with recent findings on "sleeping patents" and "submarine patents" (Cohen *et al.*, 2000; Graham and Mowery, 2004). In fact a situation in which an incumbent must patent in order to exploit monopolistic rent spurs patenting of inferior processes or products only to avoid investment from competitors.

A second example of asymmetric models is the one proposed by Reinganum (Reinganum,1983) in which the innovation process is stochastic in the sense that firms invest in research and improve their probability to innovate but, at the same time, the probability of patenting, hence of winning innovation race, is not equal to one. This means that the probability to innovate that a single firm faces is independent from other firms probability. Thus firm investing more in research may not result as the patent race winner. In fact the presence of uncertainty means that the time, costs and results of economic activity are not known at the time of the investment decisions, leading to different outcomes. Reinganum starts from the assumptions of the deterministic model and adds uncertainty through an hazard function $h(x)$ [11]. Following the contribution of Dasgupta and Stiglitz she relates stochastically the rate of investment x_i of firm i to the

[10]Gilbert and Newbery were interested to the persistence of monopoly threatened by competitors. They first introduce a simple model descending from Arrow one which has already been presented (paragraph 1.3.2 on page 14) and then they introduce a more complex model with asymmetries.

[11]Hazard function $h(x)$
is defined as the fraction between the probability function and the survival function: $h(x) = \frac{P(x)}{S(x)}$ where $S(x) = P(X > x)$.

random success date $t_i(x_i)$ and she indicates the probability that a firm i is successful by date t as $P[t_i(x_i) \leq t] = 1 - e^{-h(x_i)t}$ via an exponential distribution. But given that being the first to innovate does not imply to be the innovation winner it must be added the probability that firm i wins at any date t that yields $h(x_i)e^{-\sum h(x_j)t}$.

From this Reinganum calculates firm i payoffs, the best response functions and related Nash equilibrium strategies showing how the existence of challengers incentivates incumbent to invest more. But the main result which is reached by Reinganum is that if innovation is drastic and the revenue flow of incumbents is positive ($R > 0$), then the outcome of the incumbent is lower than that of the competitor [12]. This means that the entrant has a higher incentive to invest, and hence to innovate, than the incumbent. Contrary to the Gilbert and Newbery model if one models for uncertainty, as Reinganum does, it is the efficiency effect that is equal to zero and so the replacement effect brings the incumbent to invest more in research. This descends from the fact that if a reduction in investment in research is considered the incumbent probability of innovating and obtaining the patent decreases but it receives a certain stream of profit R and so it decides to reduce investment while the challenger, in the same situation, does not earn R and so continues to spend in research.

Till now we have worked under a tight assumption: firms could not learn from past research experiences. We turn now to analyse contributions that allows for this more realistic assumption.

1.3.4 Models with experience

While in the previous models a firm decided once and for all the amount of resources to invest in research, now it is the stock of knowledge accumulated during time that becomes the most important element. We move to a multi-stage game in which the decision on the amount of the investment x^i_T at time T by a firm i depends on the amount invested $x^i_{T-1}$by the same firm in the previous stage. This means that the stock of knowledge accumulated at time T is:

$$K^i_T = \sum_{t=0}^{T-1} x^i_t \qquad (1.5)$$

[12] $x_I^{N(c,R)} < x_C^{N(c,R)}$ where c is the new cost associated with the innovation.

in this way the probability of discovering descends from the stock of knowledge, and hence from past investment strategies, that the firm decides to take.

Starting from this assumption, Fudenberg *et al.* (Fudenberg and Tirole 1985) show how even a small advantage for a firm results in a secure leadership in the market. Assuming that firm a has a small advantage ε on firm b, because of its previously accumulated stock of knowledge, then at any given point in time the former will invest in research an amount $x_t^a + d\varepsilon$ yielding a profit $\Pi_t^a(x_t^a + d\varepsilon) > \Pi_t^b$ where Π_t^b is the profit of firm b at time t. It must be noted that ε can be very small, even $\varepsilon \to 0$, and the leader has still an advantage over the follower; it is from this feature that this kind of model has been defined as ε-pre-emption given that even a very small value of ε give the leader firm the possibility to pre-empt the follower from winning the race. The above conclusion recalls the one presented when speaking about the persistence of monopoly. It is in fact its generalisation if we imagine the leader as the monopolist which has an advantage in term of market shares over a follower/challenger wanting to enter the market. Fudenberg *et al.* (1985) then introduce into the model the possibility of information lags which means that a firms observe their rivals R&D investment with some delay. This makes it possible leap-frogging for an initially laggard firm. Assuming that each firm decides its level of R&D spending and that, due to information lags or inability to respond quickly, at time t a firm is able to see R&D that rivals perform at time $t-1$, the outcome of the race may be not the one seen before when the firm, with even only a small advantage, is able to win the race. Now it may be possible for the follower to leapfrog the leader thanks to informational lags.

A further improvement in models with experience is put forward by Harris and Vickers (1987) who introduce asymmetries regarding firm cost structure and valuation of the patent. In Fudenberg *et al.* (1985) all firms face the same cost conditions and they value equally the patent reward; Harris and Vickers show that changing these conditions brings to different outcomes depending on assumptions made. In particular there are 4 possible equilibrium outcomes depending on different initial position of two hypothetical firms A and B:

1. Firm A wins investing in research as if it has no rivals, firm B invests 0;

2. Firm B wins investing in research as if it has no rivals, firm A invests 0;

3. Neither firm wins and they both invest 0;

4. The first mover wins.

Hence, Harris and Vickers complicate much more the analysis and show how, allowing for different starting assumptions, quite different outcomes can be obtained.

What has been clear so far is that in patent race models the final aim of firms is to be the first to patent in a logic in which “winner takes all”. However, this assumption implies duplication of efforts along the same line of research, correlation in research activities and choice of risky projects. All these topics have been analysed as normal outcomes of patent race literature (Dasgupta and Maskin, 1986). Given that a firm wins a race only once it obtains a patent that provides it with protection from competition of other actors, the main objective of all firms engaging in the race becomes that of getting a patent. There is a strong incentive for firms to engage in similar projects, because, assuming that there are only two firms A and B that compete for obtaining the patent, there could be four possible outcomes:

1. Both firm A and B innovates but only one wins the patent race;
2. Both firm A and B do not innovate and nobody wins the patent race;
3. Firm A wins and firms B does not;
4. Firm B wins and firms A does not.

From this one can notice that the single firm incentive is to perform similar research projects in order to minimise possible negative outcomes, while from a social point of view pursuing different projects is optimal given that if one is not successful its rival will be.

1.3.5 A tournament model

A recent and interesting contribution to patent race literature is the one by Panagopoulos (Panagopoulos 2004) who models a race for a patent through a tournament structure. Actually the game does not end, as in standard patent race models, after a firm obtains the first patent; on the contrary the model, which is of a multi stage type, endogenise patent instrument and allows for further innovations thanks to new possibilities furnished by previous patents (if patent protection if not too tight). In fact firms can use information that spillovers from past patents in order to push their innovation effort further. The main result reached by Panagopoulos derives from the introduction of patent protection as an independent variable into the model in the form of patent breadth which is defined as the "re-innovation that is allowed to take place within the boundaries of legal protection"(Panagopoulos 2004, p.3). A higher patent breadth has three different effects on innovative activity by firms that engage into the tournament:

1. An increase in patent breadth calls for an increase in tournament competition (more re-innovation is allowed to rivals) and hence it hinders innovation by the previous innovator. In fact, the innovator realizes that its expected profits will be reduced and hence employs less workers and innovates less.

2. An increase in patent breadth allows competitors to re-innovate around innovator past inventions, due to information spillovers regarding innovation, and so it fosters possibilities for new innovations.

3. An increase in patent breadth in a way in which the tournament becomes a high competitive one (defined as N-N tournament[13]) allows firms to compete only on risk. A high competitive tournament means that firms have a similar starting point (in terms of technology and possibility of winning) and hence the major tool remained in order to compete is to finance risky projects.

Hence the outcome of the model differs depending on the level of competition of the market:

1. In a low competitive market, if patent breadth increases even if it incentivates firms to innovate due to possibility for the patent holder to preserve innovation from rivals' imitation, at the same time it hinders tournament competition which diminishes knowledge spillovers and brings firms to choose less risky strategies. Hence, an increase in patent protection causes less innovation activity.

2. In a high competitive market (a N-N tournament), instead, an increase in patent breadth incentivates firms to rely more on risky strategies which increase innovation.

Hence, Panagopoulos model has characteristics peculiar to models with experience where present innovation relies on past investments (Fudenberg *et al*, 1983; Harris and Vickers,

[13]N-N tournament stands for Neck-Neck tournament which refers to a highly competitive market where each innovator feels breath behind his back due to similar competencies and technologies that all firms share.

1987) and where risk is treated as a independent variable of the model (Dasgupta and Maskin, 1986). At the same time, he does not close the model to the first patent obtained, but allows for a tournament to take place where past patents are endogenised into the race through spillover effects. His final result is that a U relationship exists between patent protection and incentive to innovate.

1.3.6 Conclusion

From the review presented so far it emerges that Arrow model and the "pure" patent race models bring to quite different results. The former asserts that there will be always an underinvestment in research both in a competitive and a monopolistic market, mainly because innovative activity produces positive externalities from which other economic actors benefit without compensating innovator effort (the private benefit deriving from a monopolistic or competitive market is always less than the social benefit of the social planner). The latter, however, describe a different form of inefficiency, and namely that firms tend to over-invest in research: over-investment is mainly due to the fact that firms want to patent for first (because only the first to patent is the winner of the game obtaining a monopolistic rent) and so they are ready to invest an extra amount of resources (even more than the optimal level) in order to achieve such a result.

It is worth noting that, from the analysis conducted so far, patents play a minor role, while decisions about how much to spend in R&D are the crucial variable and patenting is the only goal firms want to achieve. In addition, patent race literature focuses mainly on positive aspects, concentrating on market structure and level of R&D spending, and normative issues are left aside, and so questions such as which is the optimal patent length and breadth or the importance of knowledge spillover once a patent is introduced are not taken into account. Given the importance of these issues for policy decisions, on this stream of literature it is focused the following paragraph.

1.4 Welfare analysis of the patent system: a normative outlook

The pioneering contribution in this respect is Nordhaus (Nordhaus 1969). He tries to determine the optimal patent length that maximises total welfare. Formally, he first finds the optimal level of research investment to be equal to:

$$\hat{R} = [(\frac{\alpha q_0 c_0 k(e^{-rt_1} - e^{-rt_2})}{r})]^{\frac{1}{1-\alpha}} \tag{1.6}$$

where:

k and α are constants

q_0 is the quantity sold at time zero

c_0 is the cost at time zero

r is the rate of interest

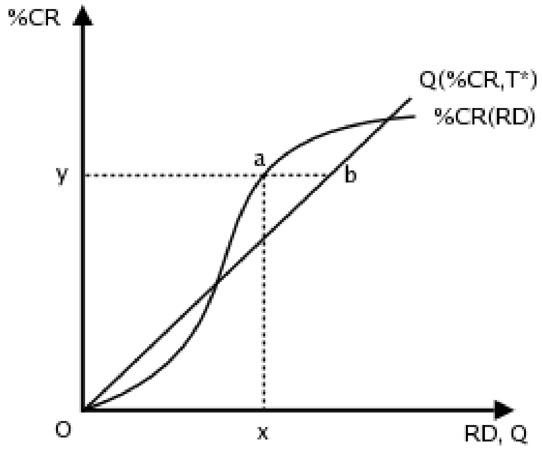
$[t_1, t_2]$ is the time interval in which IP protection is effective[14].

This result gives us the optimal response of the innovator to IP protection and it shows that the length of the protection must not be too short. Obviously, if patent length increases innovator's research investment will increase because it gains monopolistic profits for a longer period of time. On the other side, if patent length is too short the patentee is likely to do not recover from the investment made; this means that, in this case, the optimal amount of R&D spending does not exist. Then Nordhaus addresses the society point of view and tries to individuate the optimal patent length. He defines it as the patent length $\hat{L}$ that permits to the society to reach the higher level of welfare:

$$\hat{L} = -\frac{1}{r}\ln[1 - (\frac{c_0 k\hat{R}(\hat{L})^{\alpha} + aq_0}{c_0 k\hat{R}(\hat{L})^{\alpha}\frac{(\alpha+1)}{2\alpha} + aq_0})] \tag{1.7}$$

[14]He first finds the innovator total discounted value V derived from new product or process invention and then maximizes it with respect to investment in research

Figure 1.4: A graphical representation of Nordhaus result



To reach such a result Nordhaus assumes that during the period in which a firm holds a patent, it gains monopolistic profits and, then calculates the optimal length of the patent in order to maximise social welfare. In order to do that he first computes the net social surplus as the difference between the sum of producer surplus (in the period in which he/she gains from patent protection) plus consumer surplus (gained after monopolistic power is wiped out) and the cost in research and development incurred. He/she then maximizes it with respect to patent length. Nordhaus concludes that the optimal patent length is the one above which the gain of the innovator means a dead-weight loss for the society as a whole. In fact, there is a level of patent length which, if further increased, can bring to a general loss from the society point of view (the incentive of the innovator to see the patent prolongated is completely out-weighted by consumer loss due to the higher price). If we define, as Scherer does(Scherer 1972), the invention possibility function (IPF) as the relationship between the percentage unit production cost reduction derived from the invention and the expenditure in research and development assuming for low levels of R&D investments increasing returns and for high levels decreasing ones, then we can draw the graph (1.4) where %CR(RD) is the invention possibility function and Q(%CR,T*) is the monopolist rent function with patent length equals to T* and with no drastic innovation [15].

Hence we can obtain graphically the result obtained by 1.6 on the previous page. In fact the firm maximizes its profits investing the amount $\overline{oy}$ (and obtaining a cost reduction equals to $\overline{ox}$) where the distance between Q(%CR,T*) and %CR(RD) is max-

[15]The fact that it is a straight line is due to the fact that the quantity offered by the monopolist remains the same for any cost reduction derived from the introduction of new no drastic innovations.

imum (distance $\overline{ab}$). The second result of Nordhaus is quite more complicated to reach graphically[16], here suffices it to say that from this graphical interpretation one can draw important conclusions on factors affecting patent length:

1. Elasticity of demand. The higher the elasticity of demand, the shorter will be the optimal patent length;
2. The steeper IPF, the shorter the optimal patent life;
3. The sharper the curvature of the IPF, near the optimal R&D spending, the shorter the optimal patent life.

What has been learnt so far is that Nordhaus' work addresses the important issue of changing the focus of economic analysis of patents from pure single stage models of R&D competition (patent race models) to normative analysis of the patent system. It is recognised that the patent system, being a fundamental institutional tool in the hands of policy makers, can be studied from both a positive and a normative point of view and that it can be used in order to address some results for policy decisions. The model, however, has some drawbacks:

1. Even if patent length is important, other characteristics can be seen as very important for normative analysis, such as for instance patent breadth;
2. Most of the times a patent does not propagate its effect only in the current period but it is a fundamental tool for future innovation activities and the possibility of future innovations depends on the characteristics of a patent tha may have been issued long time before;
3. Patents affect innovation differently with regard to sectors. Hence the trade-off between firm incentive to innovate and society dead-weight loss is highly sector specific and the normative analysis must take this issue explicitly into account.

The fact that patent length is not the only factor affecting the reliability of patent protection can be well understood by looking at patent history. While the length of patent in all invention classes has remained similar during the last two centuries[17],

[16]The interested reader can find it in Scherer(Scherer 1972, p.424))

[17]In EU patent length has passed from 17 to 20 years following art. 33 of TRIPs agreement ((TRIPs 1994))

policy makers concentrated most of the times on patent breadth, i.e. on the possibilities allowed for re-invention around issued patent. Different authors define in different ways the concept of patent breadth but it is my opinion that a broad definition can be the one presented above(Panagopoulos 2004). Two models, introduced by Klemperer(Klemperer 1990) and Gilbert and Shapiro (Gilbert and Shapiro 1990), face the issue of patent breadth in economics of patent analysis. But while the former is interested on the quality advantage of the patent holder, the latter defines patent breadth as flow of profits that the patent holder gains while the patent is in force. Klemperer assumes that consumers can decide between products which are covered by the patent obtained by the producing firm and non-infringing substitute products which are less attractive. Then, for Klemperer, patent breadth is interpreted as the ability of a certain patent to cover a set of differentiated products; the larger is the range of products covered, the wider is patent breadth. In this way both patent length and patent breadth contribute to the determination of social welfare. In particular, welfare losses due to patent introduction can be of two kinds:

1. Consumption that switches to unpatented less-preferred products;
2. Consumption that is wiped out due to higher prices.

In addition, two limit cases are possible:

1. Infinitely wide patents, in which case only the second kind of dead-weight loss is possible (all possible products are patented, so no substitute products exist and hence society suffers only loss due to monopolistic prices);
2. Patent breadth nearly equals to zero, in which case only the first kind of dead-weight loss is possible. Given the highly competitive environment that it is formed, only small changes in prices are permitted, but even small changes in price bring a non negligible share of consumers to pass to substitute product.

Klemperer then demonstrates that, under the hypothesis that the value of consuming a preferred variety of products (which is provided by the patentee) is more than not consuming at all, short patents that are as wide as possible are optimal from a social point of view[18]. This conclusion is reached because the patent holder sets the price

[18]If all consumers value in the same way the substitution with a less preferred product, then a patent of infinite length and narrow breadth is optimal from a society point of view

at the level that minimizes monopolistic dead-weight loss and that disincentives consumers from buying substitute products. Klemperer model has been tested empirically by Lerner(Lerner 1994) who tried to give an assess of the relationship between patent scope and the ease with which consumers can switch to substitute products. He uses the number of subclasses in which USPTO assigns a patent as a proxy of its scope, computes the market value of the firm obtaining the patent[19], then following Klemperer model he asks if the marginal value of broader patents is higher when consumers find it easier to switch within the same product class which means that with an high number of substitutes inside the same patent class and with high costs in passing from one patent class to another, the value of the firm is more sensitive to patent breadth. This is empirically tested estimating a regression in which market value depends from breadth of patent claims and from a proxy representing the uniqueness of a patent[20] (a firm conducting unique research faces less substitution and thus its value is less sensitive to patent scope), the result indicates a negative and significant relationship between patent scope and uniqueness and hence the value of firms facing less substitution is found to be less sensitive to patent scope, which is consistent with Klemperer theoretical framework.

Contrary to Klemperer, Gilbert and Shapiro(Gilbert and Shapiro 1990) define patent breadth as the profits earned by patent holder during the patent life. Allowing for this definition of patent breadth, they reach quite different conclusions from Klemperer's ones. Patent of infinite length and narrow breadth are in fact socially optimal. Hence, from a patent policy point of view, the margin on which it is necessary to operate is patent breadth and not patent length (given its socially optimal infinite length). In order to find the optimal patent policy, that is the optimal mix between patent length and breadth, they maximize social welfare with respect to patent length and patent breadth subject to a suitable level of patentee reward. From this exercise of maximization they found that a narrow patent with infinite length is optimal from a social point of view. What it is important to stress here is that, when compared with Klemperer, Gilbert and Shapiro's model reaches opposite conclusions and hence opposite policy prescriptions. Indeed, infinite patent length is optimal and increasing patent breadth means more dead-weight loss due to substitution away from patented product.

The issue that innovation is a cumulative process and that patenting an innovation can hinder following discoveries has been a central concern in recent economic literature. Contrary to Nordhaus' provisions (Nordhaus 1969), it may be the case that increasing

[19] The market value of young biotechnology firms from 1973 to 1992

[20] A unique patent is defined as a patent assigned to a subclass that have few other patent awards

patent length, even if we are in a situation in which loss from consumers is out-weighted by producer surplus (and hence social welfare is still positive), can hinder future developments. Hence another trade off exists between the incentive of the initial innovator to see his discovery patented and the threat of infringement for future innovators relying on the same discovery. It may be the case that future inventors will not contribute to the inventive process given the long live patent assured to the original invention. The central problem is then to reward considerably the first innovator for the seminal contribution provided and little subsequent inventions which are useful improvements made to the startup invention. Allowing a firm to collect all the social surplus permitting it to patent an invention presents three main problems:

1. It leads to inefficient monopoly pricing for consumers(Nordhaus 1969);
2. Firms tend to over-invest in research in order to achieve monopoly position for first (see 1.3 on page 8);
3. When an innovation facilitates the following ones (as is the case in basic research), assuring patent protection on it can hinder future developments (Scotchmer 1991).

The key issue is that joint profits of the first and second generation innovators must be divided between them in an efficient way in order to keep their incentive to innovate. This topic has been put forward by the literature, modelling this issue via two-stage models. Where first stage refers to the seminal innovation to be created then, in second stage, other actors can decide to make improvements. Naturally patent breadth and length decide the distribution of incentives between the two types of innovators, in addition policy instruments may induce different effects (Green and Scotchmer 1995). Patenting-licensing structure is not a proper tool in order to incentivate firms to develop new products. In particular it may take a long time for subsequent inventors to reach sufficiently high contracting power in order to sign a contract with first generation inventor, costs in the transaction can hinder the conclusion of the agreement, actors can have different expectations about the usefulness and value of the invention(Gallini 2002). Prior agreements before each firm reaches fixed position (before any patent on second generation products has been obtained) is seen as a suitable solution to this problem(Scotchmer 1991). In particular a second generation innovator might propose to a first generation innovator possessing a patent to share costs and profits on a future invention. In this way, it is argued, providing first generation innovators with strong forward protection do not hinder the development of following improvements. However, this presents some drawbacks too, in particular its feasibility. In fact in order to resolve the incentive problem all negotiations must take place before all sunk costs have been borne by all firms. Hence it can not be applied in situation in which original invention and following improvements are quite distant in time, or in sectors where uncertainty is high. Finally, prior agreements can be easily mislead with collusive licensing and hence be opposed by Antitrust law.

While the above mentioned models are two-stage (only first and second generation innovators are taken into account), more recent ones consider continuous sequence of innovations with the presence of different actors which can be both first and second generation innovators(Sena 2004). O'Donoghue *et al*(O'Donoghue, Scotchmer, and Thisse 1998) study the relationship between the rate of innovation and patent breadth allowing for infinite sequence of improved products where market turnover depends on the contribution of firms to improved products. They define "effective patent life" as "the expected time until a patented product is replaced in the market" (O'Donoghue, Scotchmer, and Thisse 1998, p.2) and make it depending on statutory patent life (actual protection accorded by the patent) and patent breadth. Hence there is a strict relationship between the rate of replacement of different innovations (given different effective life of patents covering them) and patent breadth. Patent breadth can be decomposed into two main types: lagging breadth (breadth of patents which permits to be protected against lower quality products and hence from imitation) and leading breadth (protects from products of higher quality). Within this framework O'Donoghue *et al.* investigate the optimal patent life measured, as in previous models, from the trade-off between rate of innovation and monopoly distortions. They reach two main conclusions: leading breadth affects effective patent life and hence the rate of innovation in a positive way, a patent of infinite length and narrow leading breadth or a patent of narrow length and infinite leading breadth can both lead to a certain rate of innovation but, while the former minimizes efficiently R&D costs, the latter minimizes market distortions.

On the contrary, Denicolò(Denicolò 2000) integrates the patent race literature with the inter-temporal externality problem. In particular, he assumes the possibility for both first and second innovators to engage in patent races, in the sense that only after first innovation is achieved patent race for second innovation can start. Depending on the extent of the novelty requirement and leading breadth, the patent system can give rise to four different situations for the second innovation: it is un-patentable and infringing (UI), unpatentable and not infringing (UN), patentable and infringing (PI), patentable and not infringing (PN). After discarding the UN regime, no one has incentive to invest in second innovation given that it will be freely available to all, one can note that other regimes are in decreasing order of forward protection (first innovator has following preferences: $UI \succ PI \succ PN$ given that moving from UI to PN decreases its innovation returns, increasing the second ones). Clearly in such a model of patent race the sources of inefficiency are mainly three: inter temporal externality (due to the sequential nature of innovations); inefficient competitive externality; low level of private return due, respectively, to over-investment and under-investment in research properly outlined by patent race literature (1.3.6 on page 22). Denicolò shows how in a regime where the second innovation is unpatentable and infringing (UI) there is a tendency to under-invest in its development. This happens mainly because inter temporal and inefficient competitive externalities elide each other leaving as final outcome a situation of under-investment. A second result is reached under the hypothesis of symmetric innovation[21], that is, social welfare is higher under the PN regime than under UI one. This means that broad forward patent protection (passing from a situation where second innovations are patentable and non infringing to a situation where they are unpatentable and infringing means extending the breadth of patent protection for first innovation) may be welfare reducing due to the presence of R&D competition.

A slightly different contribution in welfare analysis of the patent system is provided by Mazzoleni and Nelson(Mazzoleni and Nelson 1998) and Merges and Nelson(Merges and Nelson 1990). Their contribution tends to highlight difficulty in applying the patent system homogeneously to all sectors. The fact is that both influence and consequences of patent application differ widely among technologies and, in a certain way, sectors. A sector is a multidimensional, integrated and dynamic structure that is devoted to the production of a particular set of products. Contributions in the branch of economics of innovation(Dosi 1988) have underlined the importance of the sector as a suitable environment for the creation of stable and specific ties among actors(Pavitt 1984). The notion of sectoral systems of innovation and production has thus been used to show that a sector is characterised by peculiar knowledge base, technologies, inputs and demand(Malerba 2002). These results are obtained on the basis of a quite radical shift from hortodox neoclassical theory towards a truly Schumpeterian vision of economic development by advocating to evolutionary principles (Nelson and Winter 1982)(Allen 1988)(Nelson 1995). Based on these premises Mazzoleni and Nelson present a different taxonomy of patent theory with respect to the one presented here. They group different contributions regarding incentives patent assures, in particular:

[21] a symmetric innovation is an innovation where the private returns, costs and non appropriable values of both first and second innovations are the same.

1. Patents motivate invention. Monopoly profits that are gained by the inventor after obtaining a patent induce the inventor to invest part of the profits in further research;

2. Patents are likely to foster the development and commercialization of inventions. If it is allowed to patent an invention in the early stage of its development, then the inventor has the economic and financial incentive to invest for the development and commercialization of the protected invention;

3. Patents incentivate the disclosure of inventions. In order to obtain a patent an inventor must present a detailed description of invention technical characteristics and fields of application. In this way, even if the invention is protected for the patent life period, technical information underlying the invention can diffuse widely;

4. Patents permit the development of broad prospects. Society as a whole can gain from the disclosure of a new field of research toward which investments can be directed.

To each of this four topics Mazzoleni and Nelson conduct a part of the economic literature concerning patents analysis and present some relevant drawbacks. Finally, they conclude asking if it is the case for a stronger and broader patent protection. They noted as the recent legislation in all developed countries seems to confirm the trend towards an enforcement of IPRs, in general, and patents, in particular, both in the field of application (business methods, software, living organisms) and in the instrument through which it is achieved (WIPO, CAFC) (see Section 1.1 on page 6). Their conclusion is that this generalised broadening and strengthening in patent rights must be avoided mainly because of effects that this may have on different industries. They argue that empirical literature has demonstrated that patents, with the exception of some peculiar sectors as pharmaceutical, are not a useful appropriability instrument(Levin, Klevorick, and Nelson 1987)(Cohen, Nelson, and Walsh 2000) and that particular technologies, defined as "cumulative system technologies"[22], given their complex nature, are not suitable of patent protection. In particular assuring the exclusive right on a basic invention via patent protection in a cumulative system contest is likely to produce under-investment by the patent holder and to hinder most part of future improvements(Merges and Nelson 1990).

[22]Namely a technology in which the possibility to innovate depends on the accessibility to the set of past discoveries made, in this sense relying on past innovations brings to the emergence of a cumulative system of innovation.

So for the analysis concentrated on the theoretical aspects of patenting outlining the contributions to patent race literature and the consequent welfare analysis. However, as a large part of patent literature is devoted to the empirical study of patents effects, to this argument the analysis will now turn.

1.5 Empirical Research

As far as empirical research is concerned, patents can be seen as both a useful instrument a topic of analysis. Since Schmookler's (Schmookler 1966) seminal contribution patents have been used as a proxy of innovative activity. In fact, he showed that the rate of investment and the output of some relevant industries (railroad, paper-making, petroleum refining, building construction) had an effect on inventive activity, as measured by patents. This finding gave rise to an important debate on the nature and the drivers of innovative activity. In particular, two opposite stream of view contrasted different interpretations: one, relying on the work of Schmookler, advocated that innovative activity is principally a "demand pull" phenomenon (investment and output of principal economic sectors influence the direction and the intensity of innovative decisions), an other one underlined the importance of "technology push" factors (basic and applied research together with techno-economic phenomena push innovative activity)(Rosenberg 1976). The debate found an important point of synthesis in the work of Dosi (Giovanni 1982) who suggested to overcome this contraposition using the technological trajectory/paradigm as a framework which summarized the contributions of the two schools of thought. Both demand and technological factors are fundamental to explain the rate and direction of innovative activity which plays such an important role for modern economic systems.

There are three main characteristics that makes patents a useful research tool for empirical research:

1. They are easily obtainable: data from the three main patent offices around the world are available on digital support. Moreover, these offices have drammatically increased the reliableness and the classification of patents issued during last decades.

2. Patents are usually measures related to the output of inventive effort: a patent is accorded once inventive activity has produced a result for the firm, then it can file an application for obtaining a period of patent protection on the invention. However patent can also be used as a proxy of input activity: this is a conclusion reached my Schmookler (Schmookler 1966) in his pioneering study, a patent indicate the technological and economic direction in which the inventive efforts of the firm applicant are live.

3. Patent is a well defined standard: its main characteristics are unchanged since

several years[23].

Many interesting informations are contained into patent documents which can be very useful for both quantitative and qualitative assessments: names of inventors, their addresses, name of the applicant if it is different from the inventor, patent classes to which it has been assigned, description of the invention, citation of previous patents and of scientific articles. Even if relevant informations can be deduced, two main problems characterize the use of patent statistics: intrinsic variability and classification. The first problem refers to the fact that not all innovations are patented and that not all patents reflect an equal innovative result: patent is not the only instrument used to appropriate innovative effort, there are many others such as secret, learning curve, complementary goods and services, and so on. In addition patents may protect both radical and minor innovations. The second problem is patent classification. In addition to the United States Patent Classification (USPC), the International Patent Classification (IPC) has been introduced since 1954. The latter is a classification that has been managed by the World Intellectual Property Organization (WIPO) and, from this point of view, is characterised by a widely shared international agreement IPC is surely more reliable than USPC, mainly because IPC is reviewed periodically and more frequently than USPC, then IPC is more useful to economists given its industrial and professional nature while USPC is more technical in nature; finally the classification in IPC is nested (for example we are absolutely sure that 435/15 is a subset of 435/14) while USPC is not[24].

In addition to these global classifications other ones have been created, usually it happened as a consequence of empirical studies conducted by researchers; economists wanting to use patents to study particular phenomena created their own classification on selected patents in order to accomplish more easily their task. Three main classifications of this type are worth noting: the Office of Technology Assessment and Forecast (OTAF) Classification, the Scherer Classification and the National Bureau of Economic Research (NBER) Classification. The first one was made in the mid-70s by creating a concordance between patent classes and the Standard Industrial Classification (SIC), in this way patents were allocated to industries that produce the new processes and products or to industries that use the new processes in the manufacture of their prod-

[23]The situation is rapidly changing in the recent years. In particular, as far as the progressive broadening of patent scope and the increasing low quality of issued patents, which is mainly due to the lowering of the novelty requirement are concerned.

[24]In addition to USPC and IPC, European Patent Classification (EPC) has been defined: it is an improved classification made by European Patent Office (EPO) which has further refined IPC, namely adding subgroups.

ucts. Scherer, on the contrary, grouped patents by different firms and then aggregated them into industries, referring to firms' primary activity. Hence he constructed a patent classification according to patent origin (they attached the patent to the industry to which the firm obtaining it belongs). The last classification contained patents data of all organizations from 1969 to 1982 with balanced sheet and stock market value data.

In addition to classification studies, other important empirical works have tried to shade light on the relationship between patents and R&D, such as the Organisation for Economic Co-operation and Development (OECD) and the Advisory Committee to the OECD (BIAC), which submitted a questionnaire to firms which are members of BIAC in several OECD countries(Sheehan, Martínez, and Guellec 2004). The results of the survey, together with OECD patent database, give an account of the increase and diffusion of patenting among OECD countries from 1989 to 2003 (OECD 2004). The two main findings are that all the major three patent offices (EPO, USPTO and JPO) have experienced in the last decade an increase in patent applications and that this overall surge has to be attributed to Biotechnology and Information and Communication Technologies (ICT) sectors.

The impressive growth of patenting has been a central concern in the discussion among empirical research of recent years. Three main reasons can be advocated to give account of it[25]:

1. Increase in R&D productivity. An increase in the productivity of R&D, usually measured as the ratio between R&D and sales, means a more efficient way of producing innovations and, hence, an increased number of patents applications and grants per firm. This is the main reason underlined by Kortum and Lerner in their recent work in which, excluding less reliable hypothesis, they indicate that increase in patenting is mainly due to improvements in the management and automation of the innovation process (Kortum and Lerner 1999).

2. Changes in the level of competition. There are important studies indicating the growing importance of strategic patenting in particular sectors. Strategic patenting is a phenomenon through which firms look at patents not only as a tool of appropriation of the returns from R&D spending, but also as a resource to be accumulated in order to prevent dangerous entries into the market and to eventually reach agreements with competitors.

[25]A rather similar taxonomy has been put forward by Lerner(Lerner 2002), where patent protection depends on relative economic strength, political conditions and legal traditions.

3. Changes in the legal framework and in particular in the patent regimes. A number of legal decisions, at the beginning of the 90s, had the effect of broadening the patent scope, extending patentability to new areas. Moreover, the formation in the mid-80s of new legal structures (such as CAFC) lowered standards of patentability allowing the rights of patent holders to be more easily enforced in courts. A test for structural break has been put forward in order to give an account of the existence and consistence of the above change (Hall 2004). The break has been tested in the aggregate, by region and by technology class. The results show how a growth rate jump has been experienced in patent applications in 1984 (from 0,3% to 6,9%), how in the same year U.S. witnessed a structural break and how in chemical and pharmaceutical no break occured contrary to electrical, computers, communications and mechanical technological classes.

The above mentioned phenomena stress the relationships between number of patents and R&D spending. It has been a central concern in the empirical literature of patents, and it has been studied for a long time, but conclusive results have not been reached yet. For example, Pakes and Griliches (Pakes 1986) found a strong relationship between R&D and patents at the cross-sectional level (both at firm and industry level), while Hall *et al* (Hall, Griliches, and Hausman 1986) found that in the time-series dimension the same relationship is weak both at firm and industry level (with the exception of drugs and industrial chemicals). The same conclusions can be found looking at the ratio of patents over R&D spending: time series analysis conducted in this field found a declining ratio and concluded for a diminishing returns to R&D (Hall, Griliches, and Hausman 1986). However, at the cross-sectional level the ratio is increasing for small and medium firms (Bound 1986) while it is declining for large firms (Scherer 1983).

Even if not conclusive, these studies shade some light on the influence of patent as a mean of value creation inside the economic system, but which is the value of the patent *per se'*? An important stream of empirical literature has concentrated on this topic, trying to compute the average value of patent rights, which is the value associated with the different legal situation created by the possession of the patent. Three main sources of data have been used in order to give account of such a phenomenon:

1. Direct surveys with patent owners. It has been asked the amount the returns from patent possession and the market value attached to it. The principal contribution using this kind of data was the one from Schmookler who conducted a mail survey in 1957 on a 2% random sample of patents issued in 1938, 1948 and 1952. He

reached two main results: first, he found that a large fraction of patents contained in his sample were commercially used, hence concluding that it was not true the statement that most patents were never used and that they were not associated with an economic event. Second, he noted that the economic value associated with the patenting of the innovation was highly dispersed (Schmookler 1966).

2. Renewal data. All around the world someone who wants to keep a patent has to pay an annual renewal fee to the patent office which issued the patent. If this fee is not paid the patent is permanently cancelled. Hence, informations on renewal decisions by firms can be used as an indicator of the value firms attach to the patent wheteher they decide to renew it or not. Using European renewal data Pakes (Pakes 1986) finds that uncertainty surrounding an invention (firms file patent applications for new inventions but are not aware of the real value of the invention yet) is resolved during the first three/four years of its life. Starting from this conclusion Schankerman and Pakes (Schankerman and Pakes 1986) estimate the distribution of the underlying patent right value and analyse the changes in its distribution finding a rather dispersed and skewed pattern (in France and UK the average patent values is found equal to \$ 7.000 while in Germany the value is \$17.000) mainly due to different patent quality, mainly descending from different rigorousness in examination procedures (Foray 2000).

3. Stock market value and profits of firms possessing patents. Authors using these data tried to relate the number of patents held by a particular firm with its stock market valuation controlling for other effects affecting it (tangible and intangible capital accumulated). Cockburn and Griliches (Cockburn and Griliches 1987), using this procedure, found that the estimated value of a recent patent is equal to \$500.000, while Pakes (Pakes 1985) conclude that 5% of the variance affecting the market value of a firm is caused by changes in both R&D and patent applications.

A third interesting use of patent data for empirical research was devoted to the study of spillovers and citations. Jaffe (Jaffe 1986) clustered American firms into 21 technological clusters using patent class data by firm and into 20 industry clusters using distribution of sales by SIC classification, in this way he was able to analyze spillovers taking place among firms inside the same cluster. In fact, he constructed, using informations on technological clusters, a measure of the common pool of R&D available to all firms in a cluster. Relating this measure to three firm level variables (R&D investment, number of patents, output growth) he found that: R&D investment by single firm is positively related with R&D pool variable, number of patents by single firm is positively related with R&D investment by other firms inside the same cluster and, finally, firm productivity depends positively both from average R&D investment by single firms and size of the R&D pool. These results suggest that, not surprisingly, inside the same clusters firms take advantage by R&D spillovers from other firms. For what concerns citations, they have been increasingly used recently in order to reap important informations regarding backward and forward citation lags, self-citations, indices of generality and originality (Hall, Jaffe, and Trajtenberg 2001). At the same time a correlation between patent citations and value of innovations has been put forward (M. 1990).

I am concentrating now on some works that i repute very interesting due to the different approach that they present. I am referring to empirical works that demonstrate the sector specificity of the patent system and, hence, the idiosyncratic nature of the effects that the patent system produce on the economic activity (see 1.4 on page 23)[26]. One of the first contribution to this respect is the one by Mansfield (Mansfield 1986) who analysed which could have been the rate of development and commercialization of inventions in the absence of a patent system in USA. In this way he was able to find how firms belonging to different sectors rate differently the importance of patent as an appropriability measure. On a random sample of 100 firms taken from 12 industries, patent protection was judged as an important appropriability measure for 30% of inventions in only two industries: pharmaceuticals and chemicals. In other three industries (petroleum, machinery and fabricated metal products) only 10-20% of inventions are likely to be patented and, finally, the remaining industries (electrical equipment, office equipment, motor vehicles, instruments, primary metals, rubber, textiles) rate patent protection of no importance in assuring protection into the development and commercialization of inventions. This inter-industry variation is accompanied by an intra-industry variation due to the fact that larger firms are more likely to patent inventions which are rated as patentable. In addition to inter-industry and intra-industry variations in the propensity to patent, Mansfield gives an account of the variation in the propensity to patent over time. He does not find any conclusive result concerning the supposed decline of the propensity to patent over time[27]. In fact he found that half of the firms

[26]A firm level analysis on appropriability strategy conducted by Laursen and Salter (Laursen and Salter 2005) on UK firms reaches approximately the same conclusions of the literature which concentrates on sector level analysis: fast mover strategies (patents, trademarks) are seen as more important than legal strategies (lead time, secrecy, complexity of design) in assuring appropriability of innovative results, industry with a low level of technological opportunities use less appropriability mechanisms. The only difference is that, at the firm level, legal appropriability strategies are found to be substitute, rather than complementary, of fast mover appropriability strategies.

[27]The number of patents granted to US inventors declined steadily during the 70s and the 80s. The

contained in his sample reported an increase in the percentage of inventions that were patented. Hence, he asked to these firms the reason for this increase and he found that the most cited answer referred to the change in the product mix (more sophisticated products entered into firm's domain of production causing an increase into the propensity to patent). He then argued that the decrease in US patent grants can be caused by a real decrease in the number of inventions, and not necessarily by a decrease in the rate of technological change.

A more comprehensive and representative work regarding patent protection was put forward by Levin *et al* (Levin, Klevorick, and Nelson 1987). They submitted a questionnaire to high-level R&D managers asking them how they rate the appropriability assured by a patent. Levin *et al* analysed answers of these 650 R&D attorneys and gathered important informations about:

1. <u>The effectiveness of different appropriability mechanisms</u>. Managers were asked to rate the effectiveness of different appropriability measures. For new processes the ranking was: lead time[28], learning curve advantage[29], secrecy and patents; while for new products: lead time, learning curve, sales and service efforts[30], patents and secrecy. The difference in the desirability of keeping secrecy for processes rather than for products (customers prefer to get in touch with the product they are likely to buy and so, in this case, secrecy is not well indicated as appropriability measure) must explain the different rating of secrecy between the two classifications.

2. <u>Inter-industry differences regarding the effectiveness of the protection measure</u>. Disaggregating answers in order to get a picture of 18 different industries shows that only 4 chemical based industries and petroleum rate patent at a high level of appropriation; but looking at process innovations none rates patent as more effective than other measures, while for product innovations only drugs rate patents as the most effective measure. Hence a clear picture on importance of patent as appro-

most cited reason was that the propensity to patent had fallen during the same period.

[28]Lead time refers to the competitive advantage that a firm possesses with respect to competitors during the time in which no imitation has been effective yet.

[29]Learning curve advantage refers to the advantage a firm has if it is able to descend more rapidly along the learning curve, the latter is the group of point which put in relation cumulated production with production costs. Obviously the increase in production may affect costs through different mechanisms: economy of scale, learning economies, process innovations, re-organization of production process(Grant 1999).

[30]These are the efforts devoted to complement final product with accessories favoring the selling procedure.

priability measure is put forward from this study: only for chemical industries patents are effective, this is probably due to clear standard setting used to assess patent validity and to defend against infringement, while firms from other industries do not rate patents as effective but they still use them to some respect, this happens mainly because they need an instrument to measure the performance of R&D employees and to gain access to foreign markets.

3. Reasons of weak protection in some industries. The most important factors affecting the low level of protection accorded by patents in a wide number of sectors are found to be the ability of competitors of inventing around and the lack of ready patentability for new processes. To this respect it is important to stress the fact that, being the patent system an institutional tool, the choice that a firm faces between deciding for patenting or keeping secret its invention depends, in a considerable way, on the disclosure that the patent system permits via the legal framework governing it.

4. Effectiveness of alternative methods of learning. Disclosure of information, and of a part of the related knowledge contained in it, has three different effects on the economic environment a firm is facing. First, incentive to R&D spending by the single firm is lowered by the easiness of knowledge spillover, but, at the same time, wasteful R&D duplications are avoided and R&D productivity may be enhanced due to complementarity of related projects. Coherently with such a theoretical framework, Levin *et al* find that independent R&D and licensing are seen as the most effective methods of learning.

5. Cost and time required for imitation. At this regard Levin *et al* ask respondents about perceived time and cost afforded to duplicate a number of innovations developed by competitors. Answers show that duplicating major innovations costs more and takes more time than for typical ones, innovation in products and processes do not differ with respect to time and cost of imitation, finally the presence of patents hinder imitation increasing time and cost of the process.

Even if very important the work from Levin *et al* has the relevant drawback of being currently outdated, since 1987 relevant changes have taken place both for firms' strategies and for institutional content of the patent system. Such changes could have lead to different behaviours of firms regarding instruments needed in order to foster appropriability of resulting innovation. Cohen *et al* (Cohen, Nelson, and Walsh 2000), through their recent contribution, decided to investigate if some changes have taken place or if the results from Levin *et al* study has remained unchanged. They presented results from Carnegie Mellon Survey (CMS) on Industrial R&D in the US manufacturing sector administered in 1994. Their results in some cases enforce Levin *et al* ones and, in some other cases, underline changes that have taken place in a 10 years period. First of all they found that there are three main factors affecting the link among different mechanisms of appropriability, and they are:

1. The complementary capabilities: lead time, learning curve, etc
2. Legal measures: patents, trademarks, etc
3. Process and product secrecy

All these strategies which a firm is able to use in order to enforce its appropriability over the result of the innovative process might be used together in some circumstances, mainly when the innovation is composed of separable defendable components.

As in Levin *et al* work, patents are rated as important appropriability mechanisms only in drugs and medical equipment sector. However, contrary to it, the ranking sees an increase of importance in secrecy both in process and product innovations and an increase in patent effectiveness as rated by large firms. The former result is outstanding for product innovations, hence meaning that the role of secrecy has quite improved. The latter result suggests that during the 80s and the 90s large firms begun to value more patent as mean of appropriation for product innovation.

The final result achieved by Cohen *et al* is the outcome of an investigation on the link between the propensity to patent and patent effectiveness. They estimated a model which put in relation propensity to patent both product and process innovations with scores assessing the effectiveness of patent at the industry level. They found a strong correlation between the two variables even though with a low explanatory power (low R^2). Once firms are asked to indicate their main reasons for patenting, principal reasons are found to be: prevention from copying and blocking rival patents on related innovations. The next step was to understand if factors inducing firms to patent affect in different way firms belonging to different sectors and technologies. From a technological point of view they introduce an important distinction between complex technologies and discrete technologies. The former refers to a product or a process that is composed by numerous separately patentable elements that can be thought of as complements (electronics, instruments, transportation, etc). The latter is constituted by a process or a product with few patentable elements and, hence, substitutes (drug, steel, metal products, etc).

In complex product industries patents are found to be used mainly in order to strengthen firms in cross-licensing positions. This is mainly due to the complementary character of elements constituting the final product. Patents are amassed not for their appropriability content but for their strategic meaning: they assure firms the possibility to continue their inventive activity avoiding to be blocked by competitors.

In discrete product industries, where patents are effective (where more than 50% of firms reported patents to be used in negotiations), they are mainly used as a way of obtaining a stream of monopoly profits via licensing revenues or for the commercialization of an innovation. In discrete product industries, where patents are less effective (where more than 50% of firms reported patents to be used for blocking rivals), they are mainly utilized to reduce competition via blocking rival firms.

Some other important insights on empirical research conducted on patents can be drawn by the work of Hall and Ziedonis (Hall and Ziedonis 2001) on semiconductor industries. They conducted both a qualitative (interviews with intellectual property managers and executives of US semiconductor firms) and a quantitative analysis (a database containing 100 publicly traded US semiconductor firms). The central hypothesis underlying their work is that the overall increase in semiconductor industry is mainly due to pro-patent shift in the 80s legislation. The creation, in 1982, of CAFC brought to a broadening of the interpretation in the patent scope, to the raise of evidentiary standards, to the easier concession of preliminary injunctions during infringement suits, to sustain large damage awards. All these changes created an incentive for semiconductor firms to increase their patent portfolios. Hall and Ziedonis tested two main hypothesis both using data and comparing their hypothesis with contrasting ones from Kortum and Lerner (Kortum and Lerner 1999). They believe that both of them contribute to explain the fact that institutional changes affected the patenting behaviour of semiconductor industry:

1. <u>Strategic response Hypothesis</u>. Firms that have higher sunk costs, and hence more sensible to hold-up by rivals, increased their patent portfolios after the institutional change.

2. <u>Specialization Hypothesis</u>. Firms tended to vertically specialize within the industry after the institutional change.

Field interviews showed that important court decisions, such as *Kodak vs Polaroid* and *Texas Instrument*, had a fundamental demonstrative effect regarding the changing institutional environment after CAFC creation. From then on, large damage awards and aggressive stance against infringement spur firms to collect patents as bargaining chips. In addition, from interviews with design firms' R&D managers, it is evident that these firms used patents to improve their competitive position in niche markets, mainly to gain market shares from rival firms, and to secure capital from private investors in the start up phase.

Empirical analysis was conducted in order to test empirically if the change in firm level patenting behaviour is primarily due to change in the enforcement of patent rights (strategic hypothesis) and if there are some differences in firms' behaviour (specialization hypothesis). For the former this was done by looking at the changing relationship between capital intensity and patenting by firms, while for the latter it has been investigated the changing pattern of firm entry and patent protection by design firms after 1982. Results show that capital intensity has an important effect over the propensity to patent, more than R&D investment. In fact Hall and Ziedonis (Hall and Ziedonis 2001) found that, in passing from the pre-1982 to the post-1982 period, three important features are worth noting as determinants of patenting: (I) patenting by semiconductor firms is less responsive to investment in R&D; (II) other incumbents are catching up *Texas Instrument* and (III) firm size is not a significant explanatory variable of the changing patent behaviour. Hence, the strategic response hypothesis can be valid given that firms with a higher level of capital intensity decide to patent more not because of an hypothetical positive effect on R&D investment but because of new strategic necessities against rivals. Differentiating between manufacturing and design firms brings the result that capital intensity is more important for the former, while post-1982 entry by design firms explains more of the propensity to patent. In particular patents are seen as necessary in securing venture capital for new entrants in the semiconductor industry. The idea that patent is an instrument useful to financing the start of a new venture has been empirically tested by Hall (Hall 2004) via a comparative market evaluation of entrants and incumbents. He hypothesises that in complex product industries, where cross-licensing is very important, patents are valued as much as R&D. Hence, controlling for R&D in a market value specification[31] will not bring additional effect on patenting; at the same time if patents are important assets for entry, entrants will have a port-

[31]The market value of a firm (the market value over the book value of tangible assets) is related to the proportion of the stock of R&D assets over the book value of tangible assets and to the proportion of the number of patents over the stock of R&D assets.

folio more valuable than incumbents. The equation is estimated for different periods (1980-1984 and 1985-1989) and for different technology classes (electrical, chemical and mechanical) and it is found that, after the mid-80s, patents held by entrants are valued more than the incumbents one and that in complex product industries entrants are valued more.

Hence, coming back to the work by Hall and Ziedonis (Hall and Ziedonis 2001), stronger patent rights facilitate the entry by design firms and lead to a more vertically specialized sector which is consistent with the Specialization Hypothesis. In the last part of their work Hall and Ziedonis deal with the contrasting work by Kortum and Lerner (Kortum and Lerner 1999). The latter suggests that the increase in patenting is mainly due to a shift in R&D investment from basic to applied research and to improvements in management or automation of the innovation process, in this way increase in propensity to patent (patents over R&D) is explained mainly through an increase in research productivity and not through institutional changes. Hall and Ziedonis (Hall and Ziedonis 2001) argue that this increase in managerial capacities may refer primarily, rather than to R&D input, to R&D output and so a tendency to harvesting patents of low quality could arise. They try to give an account of this trend measuring patent quality by means of two imperfect measures: forward citations and number of claims. Since 1984 a declining patent quality is found for US manufacturers as a whole.

1.6 Strategic Patenting

One of the major outcome from the previous section is the statement that firms regard patents as having a limited power of appropriability on the results of R&D activity. But if patent protection is not seen as a suitable and useful appropriability mechanism, then why did the number of patent filings increase during the last 20 years? In order to answer to this question a recent stream of the empirical literature has concentrated on patenting due to reasons other than appropriation of research spending, mainly on factors and results of patenting strategies put forward in order to avoid competitors entrance, gaining licensing revenues and obtaining relevant patents in a standard setting procedure. A firm amassing a huge amount of patents gains an impressive competitive advantage against new entrants. In fact, the latter may not have the financial resources necessary to rapidly collect the same number of patents. And even if financial resources could be available to them, they might be wiped out by long patent litigation. In addition to strategic competitive advantage firms that patent for strategic reasons gain advantages in negotiations with other incumbents, in cross-licensing and in preventing probable suits. Even if strategic patenting is growing in importance across different sectors, it is in complex technologies that it is particularly relevant. In these technologies the cumulative character of the innovation process allows a firm, which obtains a few patents, to avoid easily imitation, to take advantage in commercial negotiations, to fix the price in the final market, to avoid infringement and to collude with other large firms. In this respect economic literature talks about the formation of a patent thicket (Shapiro 2001): IPRs are so interwoven that an actor willing to use a particular good in its production process must ask for a huge number of licenses to different actors. In addition to monetary costs for the payment of royalty fees on licences, other sources of cost are even higher and dangerous: transactional ones. In the strategic patenting framework transaction costs derive from two order of problems:

1. **Hold-up**. A firm deciding to invent around a patented product may infringe IPR of a competitor. This means that the development of the new product may be blocked. Hold-up problem may arise because a high number of royalties must be paid to develop a new product, given that it relies heavily on past improvements[32]. On the other hand firms may face a hold-up problem deriving from the

[32] Patent offices all over the world have recently lowered requirements requested to patent an invention, causing the acceptance of a growing number of low quality patents, firms are thus paying royalties for mantaining patents which are completely useless to the innovation process.

fact that a new invention, that has been already commercialized, is found to infringe a patented product. This mismatch between the number of licenses needed to avoid infringement actions and number of licenses actually applied for has its main drivers in the difficulty by a single firm to analyze the growing number of issued patents and in the delay of patent examination by patent offices.

2. **Complementary inputs**. In this case transaction costs arise from the fact that the production of a new invention needs inputs which belong to two different firms. Of course production of the invention can not take place if one of the two does not allow the other to use its input. In addition, even if the two inputs are provided in exchange of a royalty fee the problem can be modelled as the classical complements problem introduced by Cournot (Cournot 1838). In fact, the resulting price of the invention will be higher than in the case of inputs belonging to a single firm, and the resulting combined profits lower (Shapiro 2001). A large number of instruments has been put forward to avoid such negative outcomes, among which acquisition, cash payment in exchange of exit, cross-licensing, patent pool, package license and standard setting.

    - Acquisition. A firm acquires the other one, thus resolving the complements problem through the internalization of the other's input of production.
    - Cash payment. A firm pays an amount of money to the other one in exchange for exit from the market, avoiding in this way any infringement procedure.
    - Cross-licensing. It is the usual instrument used to avoid the underproduction of inventions in presence of inputs distributed among different actors. It consists in an agreement between the two firms which grants each firm the right to practice other's patents. In this way the invention process can take place. But the problem remains that only firms having bargaining chips are allowed to cross-license, while new firms without patents are completely out of the market. Hence monopolistic positions are likely to arise in these situations.
    - Patent pool. It is often used if the manufacturers of the invention are more than two. Firms decide to create a patent pool. In this case an entire group of patents is licensed in the pool to anyone willing to pay the association fee. The problem may arise if in addition to complementary/blocking/essential patents, which foster a pro-competitive environment given that it allows competitors to use blocking patents, substitute/rival patents are inserted into the

pool. In this case firms forming the pool have anti-competitive goals, namely to obtain revenues each time one of the input is used.

- Package license. Two or more patent holders agree to the terms on which they will jointly license their complementary patents and divide up the proceeds.
- Standard setting. Participants license any essential patent before entering the standard. Three main types of standard can be individuated. The first one is a standard *de facto* which is defined by a single firm; otherwise a coalition of firms, both private and public, may form a standard (a *coalition* standard) [33]; finally a *de iure* standard may be created by government intervention [34]. Benefits associated with the formation of a standard are well known in the economic literature and they refer mainly to the positive implications of network effects [35]: higher competition within the standard, production of the good which in absence of the standard would not be provided, bandwagon effects [36]. On the other side, real costs on consumers are imposed by the creation of a standard: constraints on variety and innovation, proprietary control over a closed standard, lock-in in a inferior technology. All these factors are dangerous to competition, mainly because of two reasons: the nature of the standard and the strategies of management of the standard. The former depends on the rate of collusion of the standard members, on the exclusions taking place with respect to new entrants and on the types of licenses accorded to external utilizers of the standardized technology. The latter is influenced by the utilization of IPRs in the formation of the standard.

So far we have seen which are the costs, both monetary and transactional, deriving from the formation of a patent thicket, and the instruments used to resolve the complementary inputs problem. But once the thicket is present and patent infringements are more likely to occur, which are the incentives single firms are facing in dispute resolutions? Do they prefer to go to trial or to settle down? With regard to this aspect empirical works in the strategic use of patents have mainly concentrated on the process of dispute resolution through both court (going to trial) and settlement (parties reach

[33]These first two standards are widely diffused in United States where the formation of a standard setting is decentralized to the market.

[34]This type of standard is the most used in European Union where the central authority rates positevely the formation of a standard and decides for its creation.

[35]Network effects are the positive effects on demand and supply deriving from the use of the same product by a growing number of utilizers.

[36]The positive side of the bandwagon effect derives from the fact that producers, which are surrounded by the uncertainty of the result, are spurred to participate to the standard and to produce.

an agreement). The theoretical model underlying most of the empirical works, as presented by Lanjouw and Lerner (Lanjouw and Lerner 1997), states that: the probability of going to the court to litigate an infringed patent (P_l) depends on the size (A) and the asymmetries (Y_w) in the returns from litigation (stakes), on the uncertainty regarding the case quality (P_w) and on the cost of litigation and settlement (C):

$$[(A, Y_w); P_w; C] \Longrightarrow P_l \tag{1.8}$$

Hence, major drivers in the litigation decision can be divided into two main groups. Expected benefits deriving from litigation is the first one and refers to the award that the court decides to assign to the winner (J), in addition to different views in the returns to win the trial (Y). The second group refers to expected costs of litigation that are all those monetary and transactional costs necessary to end up the litigation via trial or settlement (C). All these factors are influenced by the subjective chances of winning the litigation (P_w).

A first empirical result in the strategic patenting literature is attributed to Siegelman and Waldfogel (Siegelman and Waldfogel 1996) who estimated a model using data on New York District litigations. They tried to find factors that, accordingly to the actors, affect the perceived quality of their cases (our W). A first result is that litigating IPRs have the lower value of the error term, which means that parties engaging in IPRs litigation have a precise assessment of the quality of their cases. Even if IPRs, and patents in particular, are found to be characterized by a low level of uncertainty, other studies have shown that there is high variation in this uncertainty among technologies. Lerner (Lerner 1995) and Lanjouw and Schankerman (Lanjouw and Schankerman 1997), in fact, found that litigation rate in biotechnology is substantially higher than in other technologies.

A second result obtained from Siegelman and Waldfogel, in line with results from a part of the empirical research, states that the decision standard for IPRs cases is the second lowest one and that it has decreased during the last decade meaning that a higher volume of litigation cases are going to trial and that plaintiffs are more likely to win.

Finally IPR cases are found to be characterized by a substantial degree of stake asymmetries[37], which means that parties value more litigating IPRs than others (such as contracts, civil rights, labor, etc). This last result may be due to a greater importance

[37] Asymmetric stake or strategic stake can be defined as the stakes associated with a litigated patent.

of reputational effects deriving from winning in court; in order to test this hypothesis Siegelman and Waldfogel analysed two indicators of the extent to which reputation might be important to the plaintiff: the first is the ratio between the percentage of cases with an institutional plaintiff and the percentage with an institutional defendant, while the second is the average number of previous cases that the plaintiff has faced relative to the average number of cases for the defendant. For both indices IPRs rank at the top meaning that stake asymmetries are important for reputational reasons.

Also Lerner (Lerner 1994) and Lanjouw and Schankerman (Lanjouw and Schankerman 1997) investigated the stakes influencing litigation decision with particular attention to patent value and scope. The former found that patent scope has a significant impact on the valuation of biotechnological firms and that an increase in patent scope increases the probability of litigation by 41%. The latter found out a correlation between the number of forward citations, and hence of patent value (M. 1990), and the probability of an infringement suit being filed.

Similar results are found by Somaya (Somaya 2003) who measured stake asymmetries in Pharmaceutical and Medical Biotechnology using the self-citation of a litigated patent as proxy. The hypothesis is that the more a patent is self-cited the higher is company's stake and hence the more likely is non settlement in a suit regarding it. Similarly the number of citations of a litigated patent made by another firm in the same technological area must be interpreted as a measure of its strategic stake for the patent, suggesting that it is more likely to be litigated in the court. Somaya conducted an estimation from patent litigation data from U.S federal district courts for suits filed between 1983 and 1993 in computer and research medicine industries (Pharmaceutical and Biotechnology). The results support the hypothesis that strategic stakes have an important role in determining the decision to settle or not. A Patentee with high strategic stakes, individuated as the one self-citing many times the litigated patent, is found to go preferably to court instead of settling down. Avoiding the trial could mean saving procedure costs but patentee stakes are so high on this patent that he/she is spurred to arrive to court decision. At the same time, non patentee with high stakes on the litigated patent, measured as the number of citations on it, are more likely to fight for the patent right until later stages of the suit.

For what concerns expected costs deriving from litigation, a study by Lanjouw and Lerner (Lanjouw and Lerner 1996) on preliminary injunctions shows how this instrument is used primarily by large firms with cases filed against smaller firms and that plaintiff size is positively correlated with the probability of asking for a preliminary injunction procedure. In agreement with the first result Lanjouw and Schankerman (Lanjouw and Schankerman 2001), who analysed patent suits and settlements during the 1978-1999 period, found that litigation risk is much higher for individuals and small firms but that post-suits outcomes do not depend on the size of the firm.

In addition to strategic stakes in litigated patents, another important reason that has been put forward to explain reasons for patent litigation is the state of mutual blocking among rivals. In fact, the presence of mutually blocking patent rights among firms seems to be a valid reason for settlement. The danger of counter-suits spurs firms to find an agreement, avoiding reliance on court decision. The work from Somaya (Somaya 2003) shows how in computer industry this is an important reason not to go to trial, in particular the greater the number of in-citations [38] by the patentee to patents in its rivals' portfolio the more likely is the settlement of an undergoing patent suit. In addition, in the same study, it is found that when the number of counter-suits increases, firms are more likely to settle instead of continuing patent litigation in the court. This means that in complex product industries, where innovation is sequential, where it depends heavily on rivals' improvements and where patent portfolios are tightly interwoven, mutual blocking is more likely to occur. Hence making firms, which are engaged in patent litigation, to opt for settlement.

The results presented so far rely mainly on USA data. An interesting study for the European Union has been put forward by Calderini and Scellato (Calderini and Scellato 2004) in which they examine patents filed at the European Patent Office (EPO) during the years 1980-2002 in the European telecommunication industry. Contrary to the American patent system the European one allows any third party to attack a granted patent within nine months from the grant date [39], hence the study of the dynamics of patent oppositions can be used to understand the strategic behaviour which characterize firms belonging to a particular sector. Calderini and Scellato found that, in the telecommunication industry, patent oppositions declined steadily during the period taken into consideration. They interpreted it as the proof of a collusive behaviour taking place among large firms in a concentrated market. Namely, large firms having monopolistic power in the telecomunication market behave collusively avoiding to oppose each other patents, and concentrate on contrasting new entrants. In fact, they found

[38] In-citations are citations that firms make to their own patents. A single patent which is highly in-cited might be treated as a real important patent to the firm.

[39] Actually in USA a re-examination procedure is allowed too, but the meaningless role played by third parties and the importance of the patent holder in the process makes it underused and incentivates agents to rely on litigation trials.

that the ratio of withdrawn oppositions against total oppositions is higher when the opposed patents belong to major innovators. Hence a threat effect may be active. In addition, 20% of oppositions are found to be filed against new innovators (innovators without any patent before opposition).

From this section it is clear that the adoption of patents as an IPR tool by a large number of firms has not been the mean to increase the investment on innovation, as highlighted by the Incentive Theory (1.3 on page 8). Instead, given their low appropriability content (1.5 on page 33), patents are requested for strategic purposes as much licensing revenues, gaining advantage positions in a standard setting creation, blocking dangerous competitors.

1.7 Conclusions

Till now we have concentrated our attention on patents in general, which means that we focused on the role of patents as both appropriability and strategic means for the economic system as a whole. This level of generalization is interesting if we want to analyze the role that patents have in the economy as a whole, but it leaves out from the analysis several factors. First, patents are likely to have different effects depending on the technology under consideration. For example, patenting a chemical compound is an extremely important mean of appropriation that firms belonging to chemical sector have in order to yield from the investment made. On the contrary, the possibility of patenting software is not often seen as a suitable appropriability instrument. In well documented cases software patents have been found to hinder the rate of inonvation. Second, patent system is not the only way available to enforce Intellectual Property Rights (IPRs). Other regimes like Copyright and trademark are available and widely used. It is straightforward that the different nature of the protection accorded by different means of appropriation allows an inventor to protect more efficiently the invention. Third, being the patent system an institution, it changes over time. New invention's types are added to the one already protected through time, while others remain out. Furthermore, the enforceability of the patent system is strengthened or weakened according to legislative decisions.

All these characteristics certainly raise the level of complexity and idiosyncrasy of the analysis. This means that the theoretical approach which focused mainly on the identification of optimal characteristics of a unique IPR system, is not able to tackle above mentioned idiosyncrasies. moreover, this approach did not manage to expplain results coming from recent empirical literature.

Chapter 2

Software patents

In the last chapter we have argued that theoretical literature has considered only ways of maximising the efficiency of a single patent system without taking into consideration idiosincrasies present in different sectors. In this chapter we deal with a specific sector of economy, namely software. But why do we confine our analysis about the effect of the patent system to the software sector?

First of all, the relevance of software cannot be analyzed separated from the more general area of Information and Communication Technologies (ICTs). As it will be shown in the first paragraph of this chapter, the latter has experienced an outstanding growth in recent years. The increase has been pronounced both in US and Europe, but while the former is still in a leading position from this point of view the latter is radiply catching up, at least in well defined branches. The fact that ICT contributes increasingly to worldwide economic growth has also some drawbacks due to its particular nature. At the base of ICTs, and software in particular, there is its similarity with knowledge. Hence, the well known appropriability problem appears once again. This has detrimental effects on firms' decisions of producing inventions in this area of technology. The emblematic nature of software technology can be be fully understood if reference is made to the diffusion of piracy. This has become a highly debated issue in recent years due to its wide diffusion. This has been raising given the possibility to copy a new software in a rather easy way. The main answer to this problem has been the tendency, experienced in the last decade, to IPRs' strengthening. In this way, it has been thought, the market failure will be restored through the allowance of temporary monopoly over the invention.

Second, software is a very important topic of analysis because of its pervasiveness. The impact on the worldwide economic growth is due to its ability to raise the productivity of a range of different economic sectors. This happens, thanks to the tight links software has with other sectors of economic activity.

Third, IPRs in the software domain have been a highly debated issue during recent years but comprehensive studies are missing. In US, the patentability of software has been present since the mid 1980s but it is still a debated topic among the scholars. In EU, the Directive on the patentability of computer implemented inventions has been at the center of public attention for several months. This has actually been only the final step of a long debate concerning the practice carried on by the EPO for a long time. Namely, the possibility for applicants to obtain software patents even if it is contrary to EPC provisions (Beresford 2001).

Obviously, given the complexity and pervasiveness of software technology this is likely to be protected with other IPRs other than patents. Indeed, copyright and trademark were quite used tools to protect software before the general upsurge in patent applications. Actually, copyright is still diffused in the software realm and used together with patent to achieve a better protection. But together with patent and, to a less extent, copyright a *sui generis* kind of protection has been developing for the last 10 years, namely Open Source licenses.

The present chapter is organised as follows: in section 2 we give an account of the performance of the software sector, taking into consideration branches that performed better in recent years. In section 3 we present the dynamics of the different IP regimes protecting software since its first appearance. Particular attention will be devoted to the legislation of software patents in US and EU. Moreover, the upsurge of open source licenses as an alternative mathod of IP protection will be discussed in detail. Finally, in section 4, recent developments in both theoretical and empirical economic literature concerning software patents will be presented and discussed.

2.1 The software sector: a brief overview

The software sector has been one of the fastest area of the economy during the last decade. Starting from 1995 the nominal value added has increased regularly in all OECD countries, in USA the share of total business sector value added has passed from

1.6% to 3%; the sector accounted for 1% of total business sector employment in 1993 to become 2.6% in 2000(OECD 2002). Computer software prices experienced a decline during the period 1987-96 with the annual average growth rate in North America being -2.7(OECD 1998). The heavy reliance on Research and Development (R&D) is shown by the fact that Computer and related activities account for 9% of total gross business expenditure on R&D (BERD) across OECD countries(OECD 2002). Packaged software remains the most important category of the software sector with an increase of 5% from 1985 to 1995, even if custom software and services remain stable (services grew of 1% in the same period) and embedded software is increasing its weight(OECD 1998). Looking at packaged software statistics disaggregated by country it is remarkable the role played by USA with its 97% in the internal market coverage, opposed to the 34.9% of Europe(OECD 1998). Even if USA leadership in packaged software is undisputed, the European Union has acquired importance in custom software and services, mainly in branches such as integrated software(D'Adderio 2000), multimedia software and open source software(OECD 2002). In 1996 the European Union (EU) exported computer services for 8.4 billion dollars, while United States ones were 4.1 (OECD 1998).

USA leadership in packaged software is mainly due to first mover advantage and heavy public investments in personal computer construction during the 1980s. These investments had the effect, in a second moment, of fostering demand for software. USA hardware producers constituted high value partnerships for the creation of a competitive software sector both inside the domestic market and foreign one; the role played by public funded universities and research centers was also central in the production of spin-offs(Malerba and Torrisi 1996).

The European information technology sector was as advanced as the American one in the late 1950s, but the highly fragmented internal market did not allow for the exploitation of economies of scale and scope. In addition the absence of "bridging institutions" (such as university departments or research institutes devoted to software research), and the lack of a well coordinated European policy brought to the acquisition of established European firms by American ones(Malerba and Torrisi 1996). Given this lag with respect to USA, EU relied mainly on customers satisfaction and on Small and Medium Firms (SMEs) and independent software vendors type of production(Malerba and Torrisi 1996). Indeed, where the localised interaction with users played a major role EU firms has managed to reach the world leadership(Malerba and Torrisi 1996).

One market segment which has experienced an outstanding growth during the 90s is integrated software applications. This segment is based on the need for enterprises to integrate different functions and activities, not only inside the firm, but also with regard to both customers and suppliers. USA still contribute for a high share of the sales in world-wide PDM market but this share is increasing at a slower pace than the European one(D'Adderio 2000).

Another market segment of increasing significance is Open Source. The basic idea is that, contrary to proprietary software, the source code [1] is freely provided with the software. The Open Source phenomena has also attracted the interest of business organisations which have found it convenient to enter into the new market segment. This has created sort of "hybrid organisations": private enterprises (such as, for example, Red Hat, HP, VA Linux, Collab.net) which, relying on the broad pool of freely developed open source code, use their knowledge in order to provide final users with reliable open source solutions. The most striking stylised facts which give account of the diffusion of this phenomena are among the many: the huge market share of software packages such as sendmail and Linux operating system (now at 5% of total PC market) and Apache web server (e.g., the 55% of market share)(OECD 2002), the rapid increase in the market share of Open source projects (Sourceforge database counts as many as 95000 projects and 1000000 registered users), and the increasing interest that international public administrations are devoting to the phenomenon [2].

Another way to give account of software sector growth is by means of patenting activity. For instance, if we consider the number of patents, classified in a selection of software-related classes, that has been granted by the United States Patent and Trademark Office (USPTO), they almost tripled during the 90s, while the number of patents that include the word "software" in their description quadrupled during the same period(OECD 2002).

[1] Code which, in a first moment, is written by the programmer using a defined programming language and that, in a second instance, is decrypted via a compiler which transforms the identifiable code in a string of 0 and 1 understandable by the machine.

[2] On the 1st of October 2004 Munich municipality announced the migration of 14000 PC desktops to the Linux operating system (the so called LiMux plan); this strategy was put forward in order to improve the quality of the IT organization and to reach further strategic goals. Before that, another successful process took place in Spain. There, Extremadura region, one of the poorest area of Spain, supported the LinEx project which is a localized, Spanish-language version of the Linux operating system. The software was installed on 40000 computers in schools and 150000 installation disks were provided to everyone who was interested. In this way a relatively poor region managed to spur accessibility to the internet by all the population and to increase their technological literacy. In addition, through the creation of a business incubator (Vivernet), local government managed to foster the creation of small and medium software firms providing ICT services to different municipalities.

2.2 Evolving Regimes of IPR Protection: copyright, patent and open source license

Table 2.1 presents the different stages in the development of software industry organised by type of protection and user profile. A first interesting pattern in the evolution of IPR protection is surely the change of users' type. In the 1950s and 1960s the only users of software were universities, where software was firstly developed. At that time, free/libre use was the practice meaning that software was developed through a collaborative effort made by developers scattered among different locations. Each developer contributed to a part of the source code and then sent it to another user in order to receive modifications and improvements. The definition of 'hackerdom' was born in this period to indicate these programmers. An interesting feature to this respect is the presence of 'hackerdom' at both the birth of software technology and its contemporary rediscovery through Free/Libre Open Source Software (FLOSS) (Raymond 1999c). Even if some features are in common, main differences exist between the first appearance of the phenomenon and its contemporary counterpart. Indeed, while the former was based on openness and free availability of the source code and, hence, of the program itself, the latter has to rely on a codified institutional arrangement to allow its survival, namely a license. Without this, FLOSS would not have appeared as an alternative organization of software production to the canonical 'Cathedral' one (Raymond 1999a). This is the lesson learnt by 'hackers' that saw most of their code being privatized during the 1970s (Raymond 1999b).

During the following decades other users started to get involved in software. In the 1960s early private markets appeared. Software was mainly developed by US hardware producers and sold bundled to it. Trade secrecy was the main mean of protection used to protect it. Sometimes specific licensing agreements were signed with specialized users.

When software started to become a more widespread phenomenon from which profits could be ripped, industrial and businesses necessities called for a proper protection. First copyright and then patent protection were extended to the software domain. Before that, in the 1970s, courts and patent offices made a feeble attempt in order to reject both copyright and patents as valid means of IP protection for software.

But during the 1980s this trend was completely reversed. Many regulations, both in US and EU, came out which tried to regulate the matter at both the national and international level. This change in the direction of software protection was mainly due to the birth and diffusion of Personal Computers (PCs). The increasing widespread use of the latter brought to an increase in the profits of firms which were producing both hardware and the software bundled to it. Indeed, the necessity to defend these profits brought powerful lobbies to ask for more enforceable means of protection. This is exactly what happened during these years in US, where both law cases and regulations led to a strengthening of copyright and patent as means of IPR protection for software technology.

Finally in the last two decades a contrasting phenomenon has arisen. From one side, the widespread possibility to protect software by means of patents, suffragated by new law cases and regulations in both US and EU, resulted in a spectacularly increase in the number of software patents granted at the main Patent offices around the world (Kortum and Lerner 1999). On the other side, alternative form of protection arose, namely open source licenses. The rational is that, given the nature of the technology involved, it is better to provide the source code when the software is released. Indeed, the production of software has the characteristics of a problem-solving activity: new software is developed once a suitable solution to a complex problem is addressed. Furthermore, in order to reach this solution the developers must take into consideration the high number of interdependencies characterizing different code parts. Hence, the high level of complexity and interdependency calls for a suitable protection. This protection is paradoxically addressed through code openness and, most of the time, through its free utilization. In fact, freeing the code and allowing other developers using it means that they are able to address more properly complexity issues and interdependency problems. This last development is possible not only when a high number of users and developers are available (more people can find bugs and fix them) but also when they can interact frequently and contemporaneously. This is exactly what happened thanks to the widespread diffusion of the internet that permitted a fast increase in the number of net users.

Before continuing and going deep into the different types of IPR regimes it is worth drawing the distinction between copyright and patent as means of software's IP protection. In general. while patent protects invention's idea as such, copyright covers the original expression of the idea. In the case of software, what is copyrighted is the actual code of the computer program and, at most, the way in which instructions have been drawn up, but not the idea behind it.

In recent years a longstanding debate has been put forward, mainly in the EU, with at the center the term computer-implemented invention. Given that its definition is strictly related to the software domain, we deem as important to stress its meaning here. In particular, computer-implemented invention is a broader concept than software and it incorporates it as a special case. Computer-implemented inventions can be divided in four main categories:

1. Computer systems. These are compositions of hardware components that perform a given task. Examples of this are database, printing and scanning systems. System components are essentially hardware products and, for this reason, they do not present any problem concerning their patentability. Every patent system allows patentability of such products.

2. Computer program products. In this case we face a situation where a pure software component interacts with a hardware medium. Examples are printer controller or database maintaining. Here the issue of patentability is more controversial. In US the possibility to patent software had been allowed since the mid-1980s and this does not pose any problem on patenting products of this type. On the contrary, the rejection of the European directive on patentability of computer implemented inventions in 2005 hasn't introduced these kind of patents, at least formally. Nevertheless, the EPO has a long practice in according these patents provided that the encoded software is characterised by a 'technical effect'. Hence, the rejection of the proposal had the effect of making the EPO practice to perpetuate.

3. Data structures and Graphical User Interfaces (GUIs). Data structure is the structure of a database model used to organize and represent some sort of informations. An example can be represented by the different fields in a database containing the characteristics of buyers in a stock exchange. GUI, e.g. menu entries representing the characteristics of buyers in a stock exchange, can be considered a specific case of data structure. While in US these kind of patents are permitted, in the EU the situation is not so clear.

4. Business methods. Business methods are mechanisms to perform data processing or calculation operations in the practice or management of an enterprise. An example is constituted by a computerized method to identify the matches between characteristics of buyers in a stock exchange. In US business methods are patentable since the 1998. In Europe this practice is not allowed.

2.2.1 Copyright Protection

Copyright protection has been usually accorded to literary and artistic work and it protects a particular ‘expression’ of an idea while leaving the ‘idea’ itself not eligible for protection. This means that the program source code is copyrighted against literal copy but the idea surrounding the ultimate function is not covered by copyright protection.

While copyright protection has a long story, the extension to software is more recent and controversial. The first attempt into this direction has been put forward in the US system. In 1979, the National Commission on New Technological Uses of Copyrighted Works (CONTU) recommended to the US Congress copyright as the most suitable mean of protection for software, and the Congress adopted this vision in 1980 when computer programs were inserted into the Copyright Act.

At the international level, the Berne Convention, the Agreement on Trade Related aspects of International Property Rights (henceforth TRIPs) and the World Intellectual Property Organization (WIPO) Copyright Treaty are the main documents regulating copyright protection[3]. The former is an agreement first adopted in Berne in 1886, but it increased in importance only once US decided to join it in 1989[4]. It regulates copyright protection internationally requiring convention's signatories to protect the copyright on works of authors from other signatory countries in the same way they protect own national authors. In addition, strong minimum standards for copyright law are required to member countries (i.e., copyright protection must be accorded for, at least, 50 years after author's death). No express mention is made to protection of software under Berne Convention but, if interpreted as literacy works, then they fall under article 2 of the convention. This is exactly what it is stated under article 10 of TRIPs: "Computer programs, whether in source or object code, shall be protected as literacy works under the Berne Convention (1971)". This means that all countries adhering to the World Trade Organization (WTO) and, hence, subject to TRIPs must apply the provisions of the Berne Convention to software as well. In this way an international general framework of copyright protection surrounds software expression. Contrary to TRIPs, the WIPO Copyright Treaty (WCT) is not binding on all WTO members that have not ratified it. This is a more defined source of international protection for ICT products. In addition to

[3] Universal Copyright Convention (UCC) regulates copyright at the international level as well. For the sake of clarity, we present only Berne Convention because it is a more far reaching regulation of copyright than UCC. In particular, in Berne Convention, copyright protection is accorded even if no formalities are fulfilled.

[4] As of 2006, there are more than 150 countries which are parties of the Berne Convention.

software, which is protected under the provision of article 4, also databases are indicated as suitable for protection under art. 5. In addition, special provisions against the circumvention of technical measures created to protect the work are inserted into the document. Finally, unauthorized modification of the rights management information is forbidden as well. US joined the treaty the 14 May of 1998 when the Senate approved the Digital Millennium Copyright Act. Instead, EU first extended copyright protection to software through the directive 91/250/EC and then implemented the WCT on 22 May 2001 through the Directive 2001/29/EC, also known as EU copyright directive. The former is quite important because it contains de-compilation exception for purposes to develop interoperable programs. This means that de-compilation of a program is allowed only if it done to acquire information necessary to make an independently developed program to interoperate with the de-compiled one (Marengo and Pasquali 2006). The latter is a directive aimed to harmonize member states' laws on copyright and, in this way, to increase certainty of protection[5].

2.2.2 Software patents

Contrary to copyright, patents are deemed to protect the idea itself. This means that the very conceptual idea at the base of the invention is protected until the patent protection expires. Furthermore, no shared agreement has been reached on patent protection of software at the international level. Indeed, while the extension of copyright to software is regulated by more than 3 international agreements, only TRIPs agreement mentions software patents, and its interpretation is a bit controversial. Art. 27 par. 1 of TRIPs states:

> ...patents shall be available for any inventions ... provided that they are new, involve an inventive step and are capable of industrial application. ...patents shall be available and patent rights enjoyable without discrimination as to the place of invention, the field of technology and whether products are imported or locally produced.

Even if the statement can look like quite clear and favorable to patentability of pure software, many caveats apply. For example, many countries do not consider pure software to be an invention, in this way not meeting the requirements of inventiveness in order

[5]Despite this, EU members still have much freedom in the implementation of the last directive. This means that relevant differences can be found among similar countries (Harison 2006)

to get a patent. Furthermore, other requirements may not be fulfilled if pure software is taken into consideration: namely industrial applicability and the technological content.

The lack of clear interpretation of the TRIPs agreement concerning the patentability of software is one of the reasons that have led many countries to produce their own legislation on the subject.

The path breaking country was the US, with Japan and the EU acting as followers. Here we concentrate on the changes occurred in the US system given their influence on changes that came about in the EU. After that we will present changes undergoing in the EU.

Patenting software in the US: law cases and USPTO guidelines

As far as patent protection in the US is concerned, case law plays a prominent role. In particular, in 1981 the *Diamond v. Diehr* dispute was solved allowing for the first time the patentability of software[6]. Here, an algorithm used to cure rubber in a mold was deemed patentable. This was the first important case in US that allowed patentability of software. Since then, many other cases concerning the domains of computer science and software information technologies were discussed and software patents started becoming more and more diffused. In 1994 also data structures were allowed to be protected by patents[7] and, in 1998, patentability of business methods was decided too[8].

An important role in shaping and directing the case law towards patentability of software was played by the Court of Appeal for the Federal Circuit (CAFC). This was created in 1982 to provide US with a unified court where patent cases were appealed and discussed. Before that, the cases were discussed in courts at the national level. Soon the CAFC become a place where many appeals were made and important decisions were taken, like the ones regarding the patentability of software. Many authors state that CAFC was an institutional arrangement that led to an increase of the number of patents in general and of software patents in particular. Indeed, the continuous broadening in the interpretation of patent scope, together with the tendency to sustain large damage awards and to accord preliminary injunctions, acted as an incentive for companies to rely on patent protection of their technologies.

[6] *Diamond v. Diehr*, 450 U.S. 175 (1981).

[7] *In re Lowry*, 32 F.3d 1579 (Federal Circuit 1994).

[8] *State Street Bank and Trust v. Signature Financial Group, Inc.* 149 F. 3d 1389 (Federal Circuit 1998).

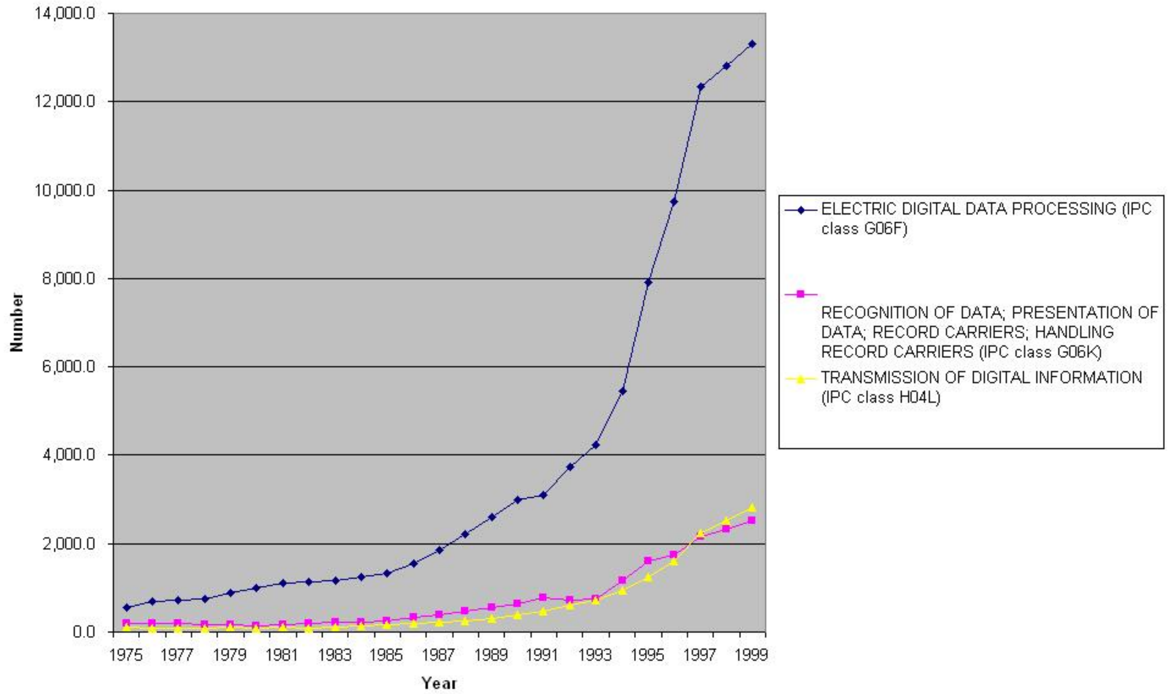


Figure 2.1: Number of Software Patents accorded by the USPTO: Applicants from OECD countries

The progressive increase in the number of software patents accorded by USPTO from the 1980s (see figure 2.1) led the patent office to publish guidelines for the examination process of computer implemented inventions (USPTO 1996). An outline of the guidelines adopted to grant software patents is presented (see figure 2.2). The decision was taken to regulate a situation that was more and more a matter of fact. Furthermore, in the mind of the regulator there was the idea that copyright protection for software was not enough. The main point was that software is not only an expression of an idea, as literary work can be, but it can also be interpreted purely as an idea and hence susceptible of patent protection. Therefore, the issuance of the guidelines was an attempt to protect the hybrid nature of software products, as both idea and expression. To this respect, overlapping protection, through copyright and patent, was deemed essential.

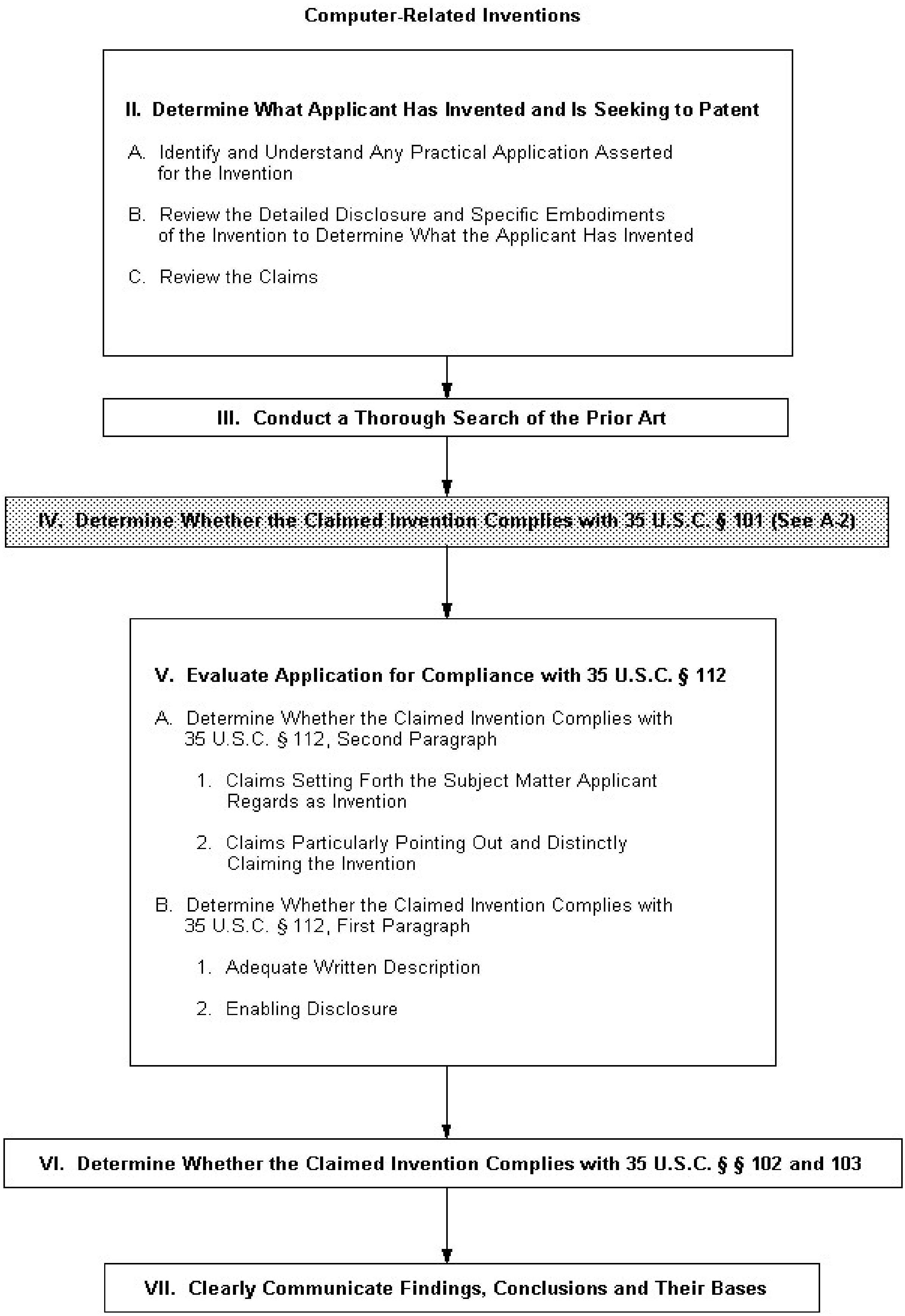


Figure 2.2: USPTO Guidelines for Computer-Related Inventions: basic structure

Patenting software in the EU: European Patent Convention and EPO rules of practice

In the EU, the legal protection by means of patents is regulated by the European Patent Convention (henceforth EPC) signed in 1973 and by the rules of practice of the EPO, mainly through the interpretation of the EPO Boards of Appeal (Office 2005). Article 52 of the European Patent Convention (EPC) defines what inventions are and when they are patentable under the EPC. Article 52(1) states:

> European patents shall be granted for any inventions which are susceptible of industrial application, which are new and which involve an inventive step.

Even if the convention does not indicate what is patentable and what is not, article 52(2) provides a list of things that shall not be regarded as inventions:

1. Discoveries, scientific theories and mathematical methods;
2. Aesthetic creations;
3. Schemes, rules and methods for performing mental acts, playing games or doing business, and programs for computers;
4. Presentations of information.

Thus, it expressively states that software is not patentable under European legislation. The scope of this list is reduced by article 52(3) which states that the provisions of paragraph 2 shall exclude patentability of the subject-matter or activities referred to therein only to the extent that an application or a patent relates to such subject-matter or activities as such. This last statement has been recently used to put forward the idea that inventions having a technical character, and hence that are or may be implemented by computer programs, may well be patentable. The Directive on the patentability of computer-implemented inventions (2002/0047/COD) was such an attempt. Its aim was two-fold: first to harmonize national patents law of member countries about software programs, second to stop a situation where software, even if not eligible for patentability, were patented as well[9].

[9] While presenting the Directive, European commissioner Charlie Mc Creevy stated that it would have been important to approve it because European need for certainty in a topic which had not been yet regulated and where more than 7000 software patents had been already granted.

The directive, first initiated by the European Commission in 2002, had a long and difficult *iter*, ending in 2005 with the definite withdrawal of the proposal via parliament rejection on the second reading[10]. Thus, despite the rejection of the directive by the European Parliament, the EPO continues to provide a plurality of actors with patents on software. This was possible before the refusal of the directive and it is still possible given that no certain and clear legislation has been put forward to fill the gap. EPO is allowed to continue this practice becasue it relies on the case law of the EPO Boards of Appeal which, starting from the 1980s, interpreted Art 2(3) of the EPC in a way which favors software patentability. The mentioned article states that:

> The provisions of paragraph 2 shall exclude patentability of the subject-matter or activities referred to in that provision only to the extent to which a European patent application or European patent relates to such subject-matter or activities as such.

The practice by the Board of Appeals was to allow for patents on computer programs whether they are consistent with a further technical effect that goes beyond the technical effect normally present between the software and the machine[11]. This rule of practice has been also codified through the publication of guidelines which help evaluate whether an invention falls under a statutory subject matter (Office 2005). The idea is that if a further technical character is present in the invention, then patent protection can be asked for. The link between the pure abstract characters of the software as such and the more technical feature of the machine on which the software is implemented in is resolved completely in favor of the latter one. Thus, the algorithm on which a software is developed is not patentable as such but it can be part of a patented invention if it produces an improvement of a technical character.

[10] Here there is a timeline of the events regarding the proposal:

- 2002: European Commission proposes the directive on the patentability of computer implemented inventions. According to European legislation, the directive must be approved through co-decision procedure.
- 2003: European Parliament accepts the directive in an amended form.
- 2004: European Council reaches an agreement on the directive as it was presented by the Commission.
- 2005: European Parliament votes the directive on the second reading and it withdraws it.

[11] An example of such a further technical effect, according to the Board of Appeals practice, could be a reduced communication time between two computers or a better reception of audio/video signals.

2.2.3 Open Source Licenses

As shown in table 2.1, Open Source is a relatively recent and controversial mean of IPR protection. In fact, only in 1998 the term Open Source started to be known from an international audience. Before that, free software was more diffused. The idea behind free software dates back to the early days of software programming, when software was a research tool in the hands of Academia. After that enterprises entered into the business, the freedom of software faded away little by little. This happened because IPR protection of software was put forward, first through trade secrets and copyright and, finally, via patent protection. But in 1984, with the creation of the Free Software Foundation and the launch of the GNU Project by Richard Stallman, free software regained importance, even if mainly among practitioners. It was only with the coinage of the term Open Source by Eric Raymond and Bruce Perens that a new way of thinking to the development of software gained in importance at both public and private level (Raymond 1999a, Benussi 2005).

The three main factors that allow the perpetuation of this alternative method of software production are:

- *The presence of non-monetary incentives for the community of developers.* A large amount of the literature has concentrated on this aspect so far. In particular, it has put forward that both intrinsic and extrinsic motivations are important in explaining motives bringing developers to contribute freely. This distinction is drawn from Psychological literature and it refers to the fact that motivations can be distinguished on behalf of the way needs are fulfilled. Motivations are extrinsic if needs are satisfied indirectly, usually by means of money. Alternatively, intrinsic motivations come from the pleasure of carrying on an activity. Hence, in the first case, developers contribute to OSS projects in exchange of a future monetary reward (in particular they invest in signalling and reputation which will be paid back through future remunerative jobs) (Lerner and Tirole 2002). In the second case, the mere altruism and generalised reciprocity are main motivations (Rossi and Bonaccorsi 2005) (Rossi 2004).

- *The ability to coordinate the Open Source project or the 'governance' of FLOSS projects.* The main issues here are the way in which the project is organized and which factors are essential to allow the sustainability of a FLOSS project. The 'cathedral' mode of production, traditionally adopted by producers of proprietary software, has been substituted by the 'bazaar' model where community's participants contribute freely at different levels. A graphical idea of the differences in the two production processes can be desumed from figure 2.3 and 2.4. From the picture a comparison between standard software life cycle and FLOSS one is put forward. In the closed source software case the production process is linear and feedbacks must necessarily go through each phase. Instead in the FLOSS case, which is typically more non linear, a higher degree of modularization is permitted to single blocks. Moreover, feedbacks among different phases are mediated by FLOSS developers. Another important issue, strictly related to the latter one, is surely coordination. This is essential to avoid problems that are commonly encountered in the FLOSS project realm, namely project's 'sudden death', low number of contributions and 'forking'. This is strongly based on the presence of a well recognised authority inside the project, authority that has always the last word to say on the code to be incorporated into the new release of a software.

- *The presence of Open Source license as an instrument to assure the reproducibility of the production process.*

Here our main interest concerns to the last of the three factors. Indeed, the main institutional tool that ensures the persistence of this alternative model of organization of software production is certainly the presence of an Open Source License (O'Mahony 2003). Many different types of licenses exist even if only four are the most diffused ones, with the GPL being absolutely the most used[12]. The main idea is that the software is not free[13], it is instead copyrighted and covered by a license, but of particular kind. In fact, instead of preventing the use of some rights on the computer program developed, the developers assure to the user more rights than they previously had. This does not mean that the computer program is free of charge, on the contrary the possibility remains that a version of the same program can be sold via a non-commercial, non Open Source

[12] Lerner and Tirole(Lerner and Tirole 2005) found that in May 2002 over a sample of 39,000 OS projects the 79% use a GPL license. Other licenses are ranked far below: second position is achieved by LGPL (with 10% of the projects) and third from BSD license (7%).

[13] The creation of the Open Source Definition in 1998 by B. Perens and E. Raymond was also deemed to change the perception of free software as something free of charge, and hence not appealing for the private sector. The main misunderstanding comes from the meaning that the word free has in English. In fact, this can mean both free of charge and free from any kind of constriction (liberty). The term Open Source was deemed to stress this last aspect. Providing the source code with the software is a way to provide the user, either it is a normal user or a firm, with the ability to improve the program and to adapt it to its own needs. In this way, open source software (or Free/Libre Open Source Software (FLOSS)) becomes a definition which can be better understood by users that want to make profits out of that (Ghosh 2002).

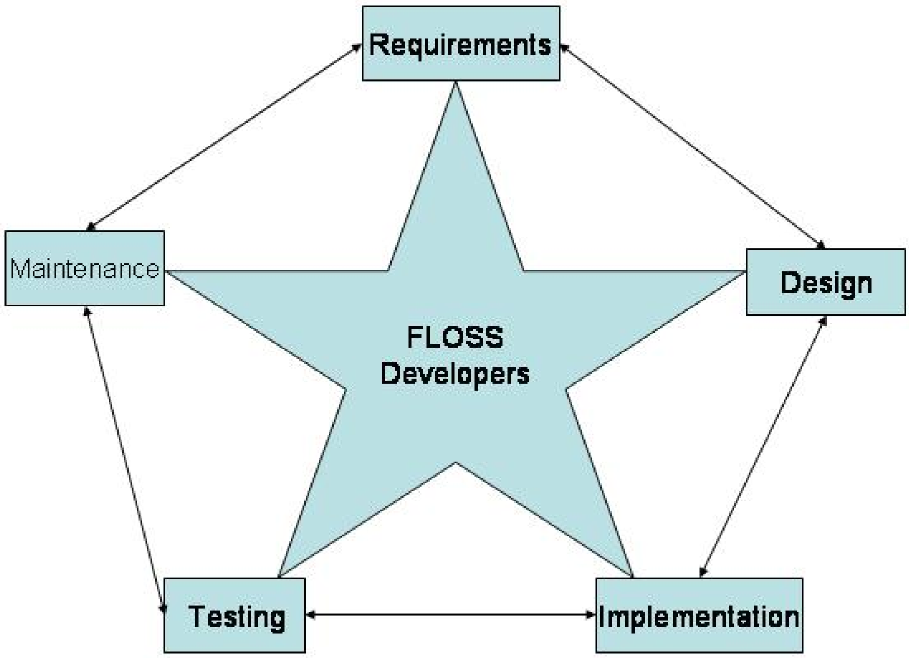


Figure 2.3: FLOSS production process

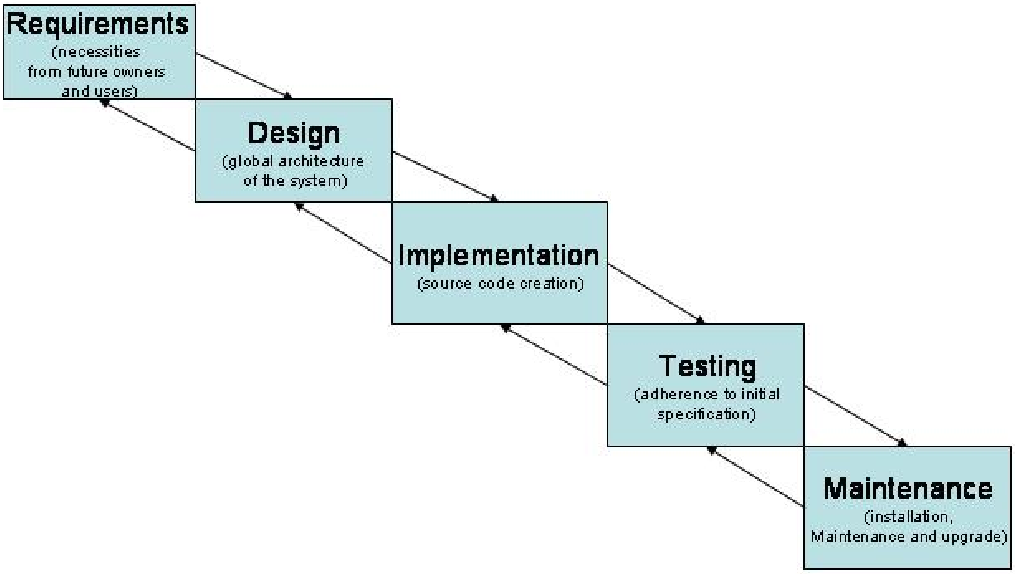


Figure 2.4: Proprietary software production process

license. An Open Source license instead must satisfy these compelling requirements:

1. The source code must be available at no cost or at little fee;
2. Redistribution of the program must be allowed;
3. Distribution of the modifications of the computer program must be allowed too.

Frequency distribution of the main OSS licenses is presented in figure 2.5. General Public License (GPL) is surely the most diffused one. It's birth dates back to the creation of the Free Software Foundation by Richard Stallman when GPL was assembled with the help of law professors. The main idea behind this was to create an institutional tool that permitted the perpetuation of software development by free sharing. The main feature is that everyone is permitted to copy and distribute copies of the license but noone can change it. Here it comes its viral nature. Once decided that a particular software is protected through GPL, no way to go back is allowed. No possibility to mix it with no-free software is allowed and all subsequent modifications must be distributed under the GPL as well. Many other licenses, other than the GPL, exist and, among them, some are less restrictive than the latter one, especially the BSD-type licenses. For a taxonomy of the different type of licenses with related main characteristics see figure 2.2.

The choice of the type of license by single developer or community

Traditionally the licensor is identified as the single developer or, at most, the whole community. Factors affecting the decision to adopt or not can be summarized in this way:

- Intrinsic motivations. Intrinsic motivations, such as altruism and gift-giving attitude, contribute to explain why, for example, GPL is still the most diffused type of license chosen by single developer/community. In fact, this is still deemed as a safeguard against private appropriation of the collective efforts put forward by the community members and as a way to spur participation to the development of the code (Kasper 2001).
- Extrinsic motivations. Extrinsic motivations have been extensively surveyed by the literature and consist of signalling effects, reputation building, solving concrete

problems and material benefits (future creation of a business on the project)(Lerner and Tirole 2002, Rossi 2004). Here it suffices to say that a recent empirical work has shown how self-esteem and reputation building are important factors explaining the amount of contribution of developers. The work is from Fershtman and Garndal, and it is based on an analysis of 71 Open Source projects hosted on SourceForge that have been studies for a 18 months long period. They find that output per contributor (number of lines of code produced per contributor) is higher when licenses are less restrictive (Fershtman and Gandal 2004). This result is probably due to the high number of contributors per project that adopt restrictive licenses. From that, the authors desume that, in projects with more restrictive licenses, developers contribute up to the minimum threshold to be included into the official list of contributors. After that, their rate of contribution decreases noticeably.

- Dynamic network complementarities and standard setting. The main problem with a very restrictive license is, in fact, that it limits the degree of interoperability among software. Given its viral nature, adopting a GPL license means making a strong commitment toward the same type of license for future modifications. Furthermore, the interaction with proprietary software is prohibited which means that some opportunities cannot be exploited. Hence if the developer/community operates in an environment where most of the projects are licensed under a GPL license he will license its new project under a GPL as well. On the contrary, if less restrictive licenses protect programs he is likely to cooperate with, then he will license the software under a less restrictive license (Lerner and Tirole 2005). Finally, if the single developer/community carrying on the project wants it to set as a strong standard, then a less restrictive license is probably the best solution. In a market still dominated by proprietary solutions a less restrictive license is surely the best option in order to increase the likelihood of standardisation.

- Risk of hijacking by private enterprises. The more unrestrictive is a license the higher is the probability of the project to be hijacked by commercial vendors. Bezroukov (Bezroukov 2005) asserts that the risk of hijacking depends primarily on the nature of the project and on the size of the code itself. The former condition derives from the idea that conservative re-implementations of existing projects are less prone to be hijacked than highly innovative ones. The rational behind this is straightforward, the more innovative a project is the higher the profits a firm can obtain from it. The latter condition refers instead to the fact that large projects are costly to re-write. Re-writing many source code's lines ia a time consuming task that it is likely to be avoided by private firms. In this sense, the likelihood of hijacking by private enterprises is lower for large projects.

In an empirical testing of the above mentioned factors Lerner and Tirole analysed nearly 40,000 projects, hosted on SourceForge on May 2002, and found out that projects designed to run on commercial operating systems and the ones more geared toward developers are less likely to have restrictive licenses . On the contrary, projects that develop applications for end-users/system administrators and whose natural language is not English are more likely to be covered by restrictive licenses(Lerner and Tirole 2005). Behind this empirical result there is the theoretical assumption that extrinsic motivations are absent (benefits deriving from tailoring the code are weak or career concerns do not act as incentives), as in the case of end-user applications or unknown projects (namely the ones in languages other than English). If this is the case, then a more restrictive license is put forward when the developer starting the project wants to attract as many developers as possible. When, instead, extrinsic motivations are prominent the licensor chooses the less restrictive license to be able to 'profit' directly from this.

Recent developments: private enterprises as licensors

More permissive licenses have acquired in importance recently, mainly because of the entrance of businesses partners in the FLOSS development. These enterprises were looking for a way to decrease costs of development of some of their products and found very interesting the way in which FLOSS could help. With the increase in the number of these, licensors begun to be identified in firms desiring to increase their profits or innovativeness. In both cases, one of the main constraints that the licensor faces is the need to make the community to participate, and the choice of the license is surely important to reach that goal. Indeed, a more restrictive license, as GPL, would foster many contributors to participate. Given the viral nature of the license, they will be sure that their contributions won't be appropriated by a private firm and that modifications will continue to be of public domain. On the contrary, a loose license will be appealing for the private firm that can privitaze the modifications but it will weaken the contribution by the community. But, at the same time, a private corporation might want to adopt a viral license. In this way it increases the rate of participation, and hence contributions, by the community of developers and it may profit from services or software that complements the open source software freely distributed. This is the case for Red Hat Linux business model where a viral license is adopted.

Also strategic issues are at stake here. The choice of a particular license affects the rate of competition faced by the firm. Indeed, if a GPL license is adopted, its viral nature will provide all the firms, both the licensor and its competitors, with a common knowledge base. The firms will then compete either on the base of their ability to offer complements to the open source code freely produced or depending on code protected through other type of licenses. On the contrary, when less stringent license is adopted the firm is able to retain private some of the modifications made even if knowledge spillover is still present.

The main idea behind new business models appeared in recent years is that enterprises participate to the community of developers for profit reasons rather than pure altruism. Software production is a high cost activity. Main costs faced by enterprises are surely the production costs of the first unit and the cost for maintainance and upgrade. The Open Source Software mode of production is an intelligent way in order to reduce most of these costs (Kuan 2001). Under this new framework, the principal cost is the ability to create a well working community of developers. But, in the case the community is already exists and the project is ongoing, the initial cost for the Open source business model is reduced consistently. In this way the firm is able to reduce heavily the costs connected to maintainance and upgrade by releasing the code and making it being part of the mantained code base (Hawkins 2004).

Hence, the choice of the license by private firms starting an OS project depends on two main factors:

- The type of business model that the firm decides to adopt. Different business models with their different characteristics are presented in table 2.3. The license type has a striking role in shaping the adopted model. A viral license, e.g. the GPL, allows the enterprise to profit from providing complementary services to the software developed in the community. Alternatively, as in the Apple's case, the main source of revenues derive from the increased sales of its hardware. Indeed, being its 'core business' the sale of its PCs, Apple decided to open kernel's code running on all of its machines. In this way, Apple managed to reduce the development costs of the operating system, i.e. Darwin[14], and to increase its reliability[15]. Another type of business model is what we have called 'client-server model'. The main idea is to

[14]The release of Darwin's code permitted the automization of the process through which it was produced. As a result, development costs were sensibly reduced.

[15]In 2006 Apple decided to close the source code of Darwin for which pertains the version running on Intel Microprocessors. This decision is in line with its 'core business' strategy and discussed here. Indeed, given that its main source of revenues derives from the sale of its PCs, providing the code of a

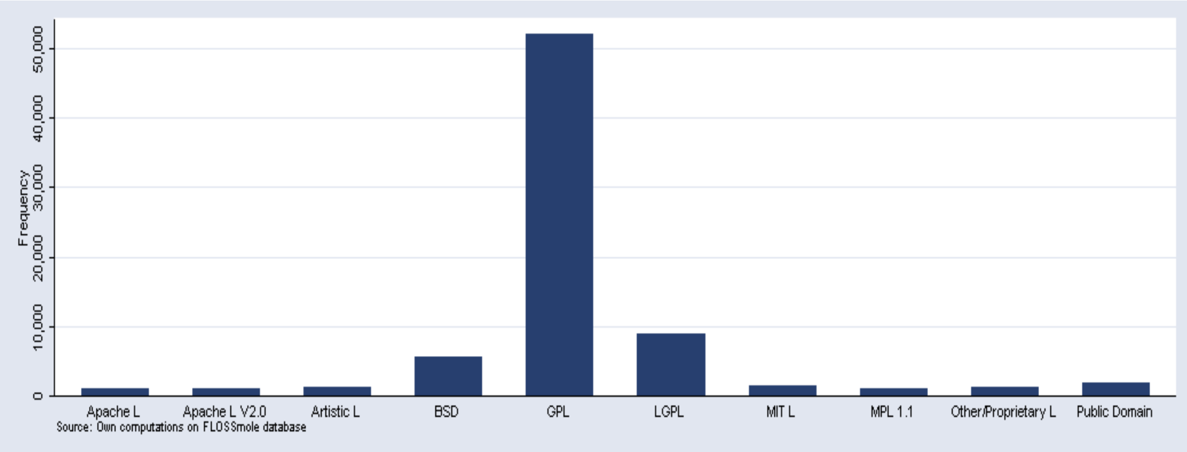


Figure 2.5: Frequency of the 10 most diffused OSS licenses: Sourceforge Projects at 1st June 2006

decrease the development costs of software by opening the code of some products (OpenOffice, Mozilla Firefox and Apache). In some cases, alternative/proprietary products are either sold in the market (StarOffice) or they are given for free and fees are charged only for support. In other cases, the main goal of the enterprise is to foster the sale of hardware products, mainly web servers (IBM and Sun Microsystems). Indeed, the market for server's hardware and for server's software are not separated. This means that the firm can reduce the development costs of the software and, at the same time, exploit indirect network effects by increasing hardware sales.

- The type of product that they offer to the market. This is a result coming from one of the few empirical studies conducted on this topic, i.e. a survey of 146 Italian firms that do business with OSS and that it has been conducted in 2003. In particular, it seems that firms adopting restrictive licenses supply less proprietary products than firms adopting non-restrictive ones. This is mainly due to the importance attached to social motivations and the involvement that these firms show in the OS community. From the same study, evidence in favor of use of mixed licensing is also put forward (Rossi and Bonaccorsi 2005).

kernel able to run on Intel processors would mean allowing the creation of non official version of Mac OS X that runs on generic PCs (not only Apple's ones) and, in this way, allowing for fierce competition.

2.3 Economic Literature Addressing Software patents

In the following section it will be our concern to present the contributions made in the economic literature on software patents. From a theoretical standpoint the papers written on this topic are much more than the one presented here. But, we will concentrate on few of them that we deem very promising and able to shade light on controversial findings reached by the empirical literature. The latter is composed, as far as we know, from no more than 10 contributions. Most of them analyze the United States while few (2 or 3) take into consideration the European Union. But which is the rational behind this short survey? First of all, it is important to stress that these recent developments in the economic literature challenge the application of 'incentive theory' to the software realm. In both mainstream economics and evolutionary thinking arguments have been put forward to question the necessity of monopoly, even if for a delimitated period of time, in order to reward software developer of its innovative effort. Empirical literature finds that strategic patenting is a phenomenon increasing of importance in recent years, and this happens predominantely in software. Second, these contributions are strong arguments in favor of the adoption of Open Source software which is increasingly gaining importance as a feasible alternative method to standard method of software production. The magnitude of the phenomenon is extremely high in the EU, also thanks to the big commitment by Public Administrations. Finally, new techniques in the collection of patent data are present inside these contributions and they will be useful for application in both similart and different studies.

2.3.1 Theoretical Literature

The first set of three contributions presented here go in the direction of challenging common arguments in favor of 'incentive theory' (for a discussion on the latter see 1.3 on page 8). Boldrin and Levine's main aim is to challenge the common economic arguments in favor of strong intellectual property protection (Boldrin and Levine 2002). According to the 'incentive theory' a strong intellectual property protection is essential if the economic system wants producers of ideas, namely inventors, to continue their productive effort. Production of inventions is likely to be not carried on if appropriability of the results of this process is not sure. And if inventions are at the heart of the innovative process, as they are, then the decreased rate of innovation will hinder economic growth. If this last outcome is to be avoided strong intellectual property rights must be accorded.

Thus, the grant of a temporary monopoly on the invention is seen as the optimal solution to the problem. In the case of software, the cost of innovation is a fixed cost, while marginal costs are nearly zero. But, given that a perfectly competitive market sets the price equal to marginal cost, the price will be zero as well. In this way fixed costs will not be recouped and innovation is not taking place.

Boldrine and Levine challenge this interpretation starting from the nature of intellectual property itself. They define the cost of innovation as a sunk cost rather than a fixed one. They assert that the only difference that exists between knowledge and normal commodities is the feature of indivisibility that characterizes knowledge. Moreover, they distinguish between the right of the first sale and dowstream licensing. The former is the right to own and sell ideas, a right that should be protected and assured to the inventor. The latter, instead, consists in the possibility for the inventor to control the use of ideas after sale. According to the authors, this last feauture can be removed without necessarily incurring in market failure. Furthermore, this last feature of IPRs is getting more and more costly in recent years. In particular, two types of costs can be detected: direct costs, like writing laws and bringing legal actions, and collateral costs, like the suppression of ideas and strategic patenting[16] and copy-protection technologies.

Boldrin and Levine shows that in a competition regime, even in the absence of dowstream licensing, the innovator can earn competitive rents and hence keep on producing the innovation. In fact, they derive a condition under which an increase in the rate of increase of numer of copies made (β) may increase, rather than decrease, competitive rents (q_0). The effect of the numbe rof copies over rents is exemplified by following equation:

$$\frac{dq_0}{d\beta} = (\frac{1}{\beta}) \sum_{t=0}^{\infty} t(\beta\delta)^t u'(\beta^t)[1 + \frac{\beta^t u''(\beta^t)}{u'(\beta^t)}] \tag{2.1}$$

where:

- δ is a discount factor that takes into account the time for copying innovation. It ranges from 0 to 1 and it equals 1 when additional copies are istantaneously made;

[16] To this respect, an interesting empirical study shows how stronger IPR protection is associated with higher cooperation between incumbents and start-up innovator entrants. Here, returns on innovation of start-up entrants are found to be obtained mainly through cooperation with established firms (i.e. licensing, alliances and aquisitions) (Gans, Hsu, and Stern 2000)

- β^t is the number of copies available at time t;
- $u(.)$ is the consumer utility drawn by the consumption of copies;
- $u'(.)$ and $u''(.)$ are the first and second order derivatives of $u(t)$.

Hence, the marginal return on competitive rents due to the rate of innovation's copying can be either positive or negative depending on the sign of demand elasticity, i.e. $-\frac{u''(\beta^t)\beta^t}{u'(\beta^t)}$. If demand is elastic an increase of the reproduction rate pushes rents toward infinity. This is the simplest formulation presented but, even if more complications are inserted[17], the main result does not change.

The model presented so far shows how monopoly is not always the best way to solve market failure in the production of innovation. Following this line of reasoning, Hunt challenges another idea at the heart of the 'incentive theory', i.e. that patents and R&D are complementary inputs in the production of inventions. According to the 'incentive theory' reducing the cost of obtaining patents will lead to more patents at the firm level, and thereby to more R&D spending. This happens because a higher number of patents leads to more profits at the firm level and to more R&D. In addition, the firm has a strong incentive to patent an invention, given that it is now cheaper to obtain a patent on it. What the author contend is that while an increase in the R&D spending is likely to increase patents applied for, the opposite does not always applies. It is likely that an increasing number of patents is not accompanied by a movement in the R&D spending in the same direction. Following this reasoning, Hunt draws sufficient conditions for patents and R&D to be substitute inputs in the production of firm profits. These conditions emphasize the fact that firms increase patenting in order to tax rents of rivals' inventions, e.g. collecting rents from their infringements, and to conuteract the same behaviour by rivals. In this way, they are likely to increase their profits through strategic patenting and, at the same time, to reduce their R&D investment. More precisely, the conditions to have patents and R&D as substitutes are:

1. There must be an overlap between firms' patented inventions. This depends on both the nature of the technology (complex ones) and on the characteristics of the

[17] Boldrin and Levine present a refinement of the model where a general reproduction technology is introduced. In this case, inputs other than initial innovation copies are used and the trade-off between consuming and making copies is not present. At the same time, spillover externalities are taken into consideration allowing copies of innovation to wind up in the hands of lucky competitors. Finally, complementary sales are analysed. All these modifications of the basic setup do not change the basic picture that can be drawned from the model, namely that under specific conditions market failure in the production of innovation does not take place.

granting procedure (overlapping claims);

2. Firms must be R&D intensive;

3. Patents must be cheap relative to both cost of R&D and the value of final output.

If these conditions are fulfilled, then the relationship between patent and R&D at the firm level is no longer a positive one, but it turns to be negative (Hunt 2006).

At the industry level, Hunt develops another theoretical model of sequential innovation in which industry structure is endogenous. The industry rate of innovation depends on different factors: industry structure (number of firms spending in R&D), fixed R&D costs, R&D productivity and firms' profits. In this case, the rate of innovation at the industry level affects directly industry structure. A higher rate of innovation inside the sector is likely to increase the number of firms that spend in R&D. The procedure taken by Hunt is that of finding the patentability standard, namely the inventive step, that maximizes the industry rate of innovation. The final result is that a higher inventive step is needed in highly innovative industries if the rate of innovation of the industry wants to be fostered. This means that, from a policy perspective, a weaker patent standards (lower inventive step) decreases the R&D in industries that innovate rapidly (e..g. high tech industries). Thus, in this situation a less stringent patent standard has to be preferred (Hunt 2004). For a graphical representation of the model see Figure 2.6.

Marengo and Pasquali, basing their analysis on the work of Simon (Simon 1969), contend to the standard economic theory that digital goods have not the characteristics of public goods. In fact, characteristics of non-rivarily and non-excludibility are blurred in the digital good case. In order to be non-rival a good must be both non-measurable and characterized by high cross-externalities. Indeed, these features are likely to miss in digital goods. Their distinctive feauture is the pattern in the marginal cost of reproduction, which is very low, and the easiness of accessability of the technology for duplication. Thus, what really matters when analysing digital goods is the technology of production together with the cost structure. But while the former is important in the production of the first unit, the latter is crucial in the production of additional units. In fact, the production of further units other than the first one is characterised by high expansibility and perfect codification which lead to rapidly decreasing diffusion costs. Instead, the production of the first unit of digital goods has the typical feature of a problem solving activities. These are: the high degree of interdependencies, cumulativeness, sequentiality, path dependence and, finally, the sub-optimality arising from imperfect

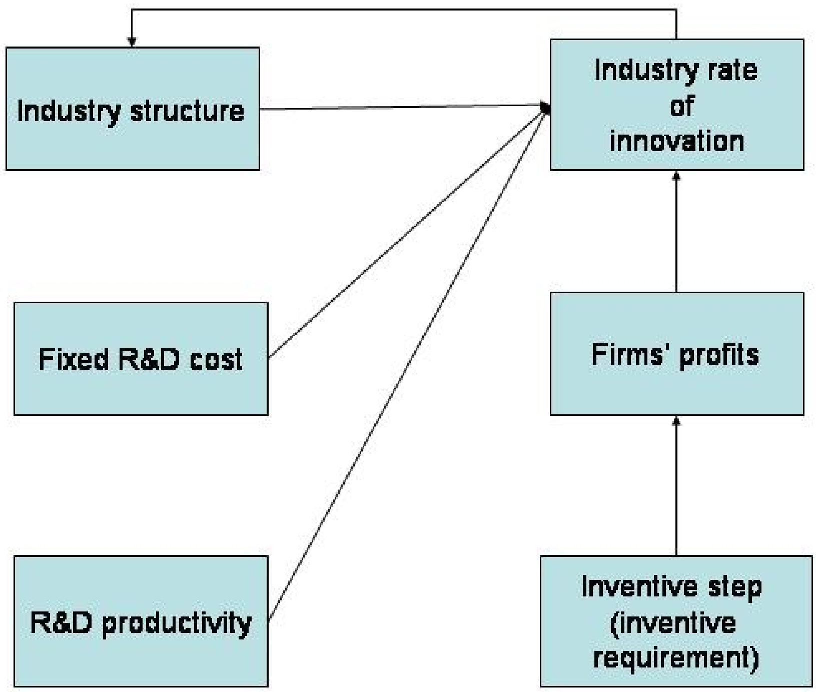


Figure 2.6: Sequential innovation with endogenous industry structure

problem decomposition.

In this sense, producing a digital good is a process of finding suitable solutions in a huge combinatorial problem space, characterised by numerous interdependencies. Hence, a finer decomposition of sub-problems through a tight patent system presents a trade-off: from one part decentralised local adaptation fosters higher adaptation speed while, from the other side, the probability for interdependent problems to be separated increases. The latter can lead to lock-in the technology in sub-optimal solutions. The conclusion reached by the authors via simulation analysis is that in domains of high interdependence optimal dynamic search path is usually not generated by highly fragmanted structures (Marengo and Pasquali 2006).

2.3.2 Empirical Literature

Empirical comtributions in the area of software have been increasing in recent years. This is mainly due to the increasing availability of related patent data. As it will be shown, the collection of this kind of data are more difficult in the European case. Empirical works can be divided into two main groups. First, studies that gather data mainly through surveys and interviews. Second, the ones that use different methodologies, i.e. individuating software patents in datasets containing patents in general. In the former case, the operation is highly time consuming and usually confined to a delimited geographical region. Normally no more than a single state or area within a nation is surveyed. For the latter, the results are more general because they cover broader areas, but at the price of being less precise. In this case, errors consist in the possibility to identify software patents that are actually more general patents (error of the second type) and to not identify true software patents (error of the first type).

Empirical Findings in the US

The study of patenting in the software sector has been more prominent relative to the US patent system rather than to the European one. Data availability, among all of patents and R&D spending, easened these studies at the micro level.

The first contribution presented here is a detailed analysis of more than 200 software patents. In this case, the definition of software patent is obtained by reading the description of every single patent. This time consuming operation is adopted in order to compare internet-related patents and general patents. The study is based on random sample of 230 patents issued by the USPTO between 1996 and 1998 (Allison and Tiller 2003). The dataset is composed by a database built in a previous work (Allison and Lemley 2000) and a new database constructed through a research conducted on some USPTO patent classes[18] for the words 'Internet' and 'www'. The main aim of the work is to test the general belief that internet business method patents have not been properly researched for relevant prior art. This means that they are likely to be of poor quality. The rational is that software development has been taking place for a long period before software was deemed patentable. But when USPTO begun to issue patents in this area, they did have neither examiners with the relevant training nor adequate database with software prior art. In order to test their main hypothesis, the authors use patent citations. Patent citations are a useful source of information other than simple patent count. They are of two different types: backward citation and forward citation. The former consist in citations made to other patents by the patent under examination. The latter is the number of citations received by a single patent. While forward citations can be treated as predictors of patent economic value, backward citations are more similar to prior art citations. Hence, a patent with a low number of backward citations is likely to lose if challenged in court given its lower quality. In addition, internet business method patents are expected to cite fewer patent references than patents in general. This is due to the shorter time in which software has been a matter of patentability compared to other types of invention. Finally, given their shorter life cycle, Internet Business Method Patents (IBMPs) are likely to rely more on citations to other software and to industry publications other than more general patents[19]. As a consequence, if the number of references for both total and non patent prior art is found to be lower for internet business method patents than for more general ones, then this is likely to point out the fact that they are granted without sufficient review by the USPTO. Conclusions of the study point out that there is little support for the main criticism. In fact, internet business method patents are found to be characterised by the same amount of prior art references as more general patents. The differences between the two type of patents, namely IBMPs and general ones, are found in the non patent prior art reference which is higher in the former case. Individuals and SMEs are the subjects applying most for IBMPs. Finally companies and inventors from the US apply more for these kind of patents (Allison and Tiller 2003).

[18] In particular patent classes number 705, 707 and 709.

[19] Industry publications are non patent prior art references. They are composed by publications in the area of academy, company and industry, university, government and software popular press.

On the line of the previous study, Chanchoub and Niosi show which factors affect the propensity to patent software analysing American and Canadian firms in the period 1986-2002. First, they present some theoretical arguments relative to factors determining software patenting. The nature of the industry is one of these, together with firm size and geographical location. Second, an empirical model is implemented to test the different hypothesis. Results show an increase in the likelihood of patenting software when larger firms are considered. Indeed, larger firms have larger resources that they can spend in both the R&D process and IPR department and this is likely to foster their ability to apply for, and obtain, software patents. Furthermore, firms with a higher share of revenues in products, rather than services, patent software more often. Given that product inventions are more likely to be patented than process inventions[20], a firm with a higher share of revenues deriving from services has less chances to patent a software than a more product oriented firm. Finally, firms belonging to a cluster of innovative firms are more likely to patent software. This happens because their level of innovativeness is higher thanks to positive externalities they are experiencing.

To our knowledge, the first contribution that tried to find a general rule in order to identify software patents is the one from Grahan and Mowery (Graham and Mowery 2003). They examined all the patents falling into identified IPC classes[21] and they defined them software patents. IPC classes were individuated by analysing overall patenting by the six largest US producers of personal computer software based on their 1997 calendar revenues[22] (Graham and Mowery 2003). Main findings obtained by the study can be summarized as follows:

- Largest and older firms tend to increase their patent propensities.
- Large electronic systems firms are more important than packaged software ones in software patenting. This result was obtained by the simple comparison of IBM with Microsoft. While the patent propensity gap is narrowing, IBM still patents more.
- The ratio between the number of citations of top 100 packaged software firms patents to the number of all software patent citations is increasing while it is decreasing for electronic firms.

[20]This is mainly due to the fact that for products the requirements of inventiveness, non-obviousness and industrial application are more likely to be achieved than for processes. It happens mainly because in processes the above mentioned requirements are easily individuated.

[21]These IPC classes are G06F 3/, 5/, 7/, 9/, 11/, 12/, 13/, 15/, G06K 9/, 15/, H04L 9/.

[22]Firms analysed were Microsoft, Novell, Adobe Systems, Autodesk, Intuit and Symantec.

- A decreasing propensity to copyright software is found. This points out that, in this case, a substitution effect is in action.

An alternative way to identify software patents has been put forward by Bessen and Hunt (Bessen and Hunt 2003). They develop a search algorithm in order to find the number and the characterisics of software patents accorded by the USPTO during the period 1976-2002. From a preliminary analysis it comes out that two software patents out of three are applied for by firms belonging to industries such as machinery, electronics and instruments[23]. This points out the fact that software patents are applied for by firms which primary activity is not software development. Indeed, companies in this group has a higher propensity to patent software than the group composed by software firms. Moreover, a sharp overall rise in software patenting has been witnessed starting from the 1984 at a rate that ranges from 7% to 11%. The interesting aspect of the story is that the sharp rise starts very close to the period when CAFC was formed. As mentioned in the previous chapter (see 1.5 on page 33), the creation of the court triggered a decrease in the standard of patentability and eased the enforceability of patents in court. This is likely to mean that the legislative decision incentivized companies to apply for software patents. The second step taken by the authors is to develop an econometric model and, through it, to show that in the 1990s companies belonging to the above mentioned industries have substituted patents for R&D. They actually conduct an empirical test of the theoretical model discussed in the previous paragraph (see 1.5 on page 33). The main idea is that patents can substitute for R&D for two different order of reasons. One is that mature firms with diminished technological competitive advantage can choose to harvest patent royalties from past research instead of conducting further R&D. Second, other firms facing increased payment of royalties choose to reduce R&D, in this way diverting resources in favor of defensive patent portfolios. This empirical finding is obviously inconsistent with the view that software patents increase R&D incentives. The so called 'incentive theory' does not fit properly to the software sector.

To identify software patents, Hall and MacGarvie adopt a methodology that is a composition of the one previously presented (Hall and MacGarvie 2006). First, they identify all the US patent class-subclasses combinations where 15 software firms patent[24]. In this way they find 2886 unique class-subclasses. After that, in order to minimize errors of both first and second type they merge their database with the one built by

[23]Standard Industrial Classification (SIC) classes are 35, 36 and 38.

[24]The firms identified are Microsoft, Adobe, Novell, Autodesk, Symantec, Macromedia, Borland, Wall Data, Phoenix, Informix, Starfish, Oracle, Veritas, RSA security and Peoplesoft.

Graham and Mowery (Graham and Mowery 2003). In this way they obtain a database where approximately only 5% of patents are not software patents (they minimize error of the first type). After that, they intersect the resulting dataset with the one obtained by Bessen and Hunt, minimizing in this way error of the second type (Bessen and Hunt 2003).

In a second istance, they conduct an event study and, then, they test an econometric model relating the value of patents with some relevant variables at the firm level. Two main results are note worthing. First, the event study reveals that the expansion of patentability affected negatively firms without patents and firms in the downstream sectors[25]. This happens because firms had to ask for licenses to have applications to run on middleware and operating systems. Second, software patents resulted to be valued more by the market than ordinary patents. For hardware producers this is likely to reflect the strategic value of software patents rather than their technological value. In fact, only patents and not the citations of those patents are valued by the market. On the contrary, software patents are found to be technologically valuable for software firms. Indeed, their citation is valued positevely by the market.

What's going on in the EU

All the studies presented so far concentrate on the American patent system and deal with software patenting by American firms. An interest in the study of software patenting in the European patent system has been increasing during recent years. To our knowledge, the contributions in these field are few. This is mainly due to both difficulties in data collection and the absence of a clear legislation concerning software patents. Data problems have constrained the analysis to rely on surveys rather than trying to adopt more complex techniques as in the US case. Nevertheless, few attempts have been made towards this last direction.

For example, Mcqueen and Olsson introduce a useful bibliometric technique to individuate software patents among more general patents. This technique allows them to show the distribution of software patent applications across 118 IPC patent classes in the years 1988, 1993 and 1998. The authors present some descriptive statistics that indicate how, from 1988 to 1998, the number of software patents grew at an overall rate of 17%

[25] The downstream market segment is comprised by software that must interact with, or operate on top of, other software platforms. It is commonly composed by applications and services. On the contrary, the upstream market segment is made up of hardware, software systems and middleware.

and that the highest concentration of software patents is found in classes H04 and G06 where the 40% of the total numner of patents is found (McQueen and Olsson 2003).

In a following work McQueen refines the above bibliometric technique and computes the distribution of software patents accorded at the EPO in 15 EU countries, US and Japan for the years 1987, 1990, 1993, 1996 and 1999. The 49% of software patents are found to be assigned to European countries (with Germany as a top leader accounting for 50% of the amount), the 18% go to Japan and the 29% to US. From a dynamic point of view, there has been an overall increase of 60% of software patent applications in the last 12 years and the number of software patents classified in IPC class C is increasing compared to class H, while class G is maintaining its dominant position. Finally, the author computes the rate of diffusion of patents' applications assuming a logistic pattern. They find that the growth in software patent applications has already slowed for EU (the inflection point is set in year 1985) and US (1991) while it will grow exponentially until 2026 for Japan applications (McQueen 2005).

For what concerns survey studies, the main contributions have been made in the direction of individuating factors affecting software patenting for both large and small firms.

For example Blind and Edler study the idiosyncrasies on the software development process (Blind and Edler 2003). In particular, they are interested on how sequentiality, FLOSS and interoperability affect the number of patents software firms apply for. To do so, they rely on a survey conducted on the German software sector in the period May-June 2001. Of the 266 total responses, half of them belong to the primary sector, i.e. independent software developers (ISDs) and companies that develop and sell software. The other half is composed by the secondary sector, i.e. who develops and sells software but produces it also for its own hardware[26]. Using the gathered data, they try to test a set of five hypothesis:

1. *H1: Software development is an activity characterised by high sequentiality.* As a proof of this statement they show that the 2/3 of firms in their sample re-use more than 30% of the code. This high rate of code re-use is likely to point out a high sequentiality in software production.

2. *H2: External code and FLOSS are increasingly used in the activity of software development.* In the data gathered by the authors a greater share of code re-use

[26]In European industrial classification terms, primary sector refers to ISDs and companies belonging to NACE subclass 72.202. While secondary sector is composed by NACE classes 34, 30-32, 64 and 29

stems from own development, but new code is instead due to an external source. Furthermore, over 70% of the input of ISDs is composed by FLOSS. Finally, 60% of the firms in the primary sector and 70% in the secondary sector claim future importance of FLOSS in software development.

3. *H3: Interoperability is a crucial competitive factor*[27]. Dataset's descriptive statistics show that interoperability is a critical factor only with regard to customer products while it is not with products of competitors and suppliers.

4. *H4: Firms rating external code and interoperability as important factors think that IPRs have a bad effect on the software development process.* On the contrary, firms mainly relying on in-house code development of the code think that IPRs have noo effect on the development process. This hypotheis are tested through econometric modelling. First, it is shown that firms using FLOSS as an input in the production process are likely to be restrained by foreign IPRs, i.e. software patents. Second, firms developing internally and with a high share of code recycling are less affected by IPRs of third parties. Finally, interoperability explains an important fraction of the problems with foreign IPRs.

5. *H5: The choice of the regime of software patents depends on the importance of sequentiality, interoperability and FLOSS.* A different specification of the econometric model shows that open source users agree with a restriction of software patenting while firms already using patents ask for an extension of the software patenting similar to that present in the US.

Finally, Olsson and McQueen concentrate their analyis on factors affecting software patenting by Small and Medium Enterprises (SMEs). SMEs are likely to have reasons to patent that differ from larger firms' reasons. In markets characterised by an easy access to financial resources patents can be regarded as a crucial signal in order to obtain external financial resources. This is what it happens in US where venture capital is a diffused phenomenon (Hall 2004). The same it is likely to happen in the specific case of software patents asked for by SMEs. Software development process needs ingent resources, mainly devoted to the production of the first copy of the software and to update and maintaining. In order to attract these resouces venture capital is needed by SMEs. To do that, the venture capitalist needs a signal that hints toward success likelihood, i.e. a patented invention. The study is based on interviews carried on 13

[27]Interoperability is interpreted as both interaction between systems and applications and between applications themselves.

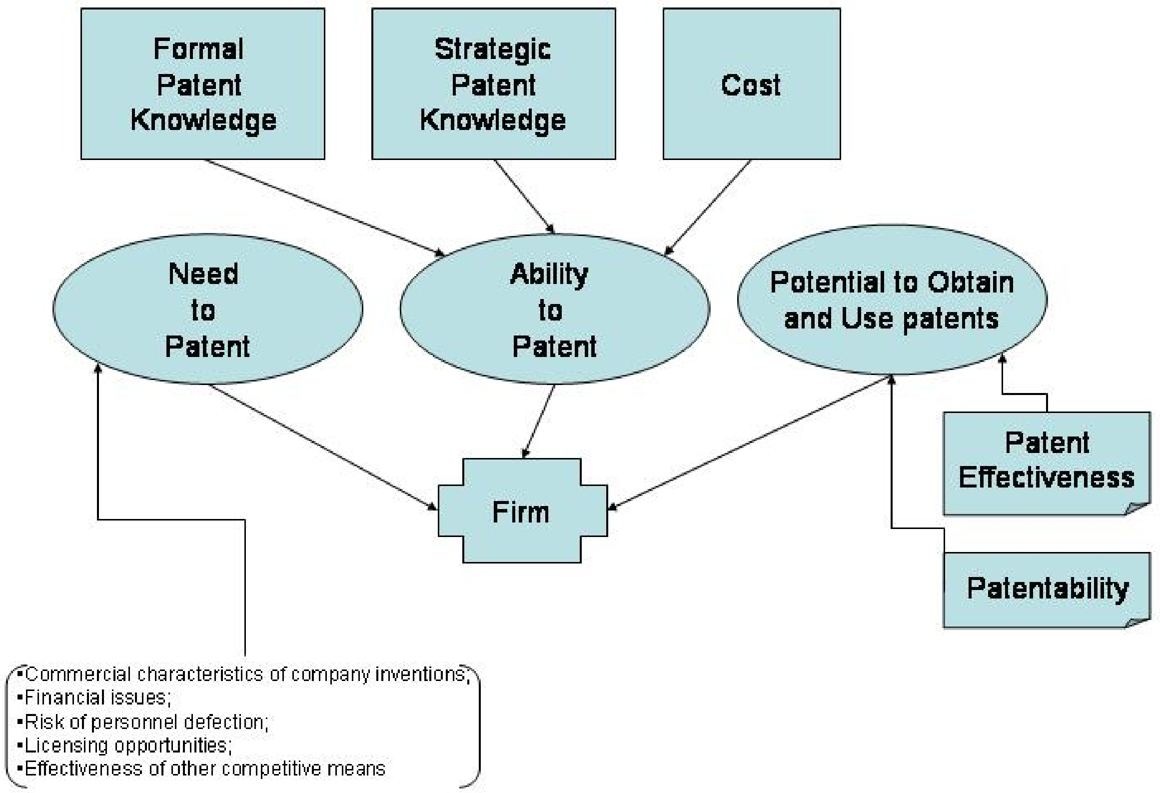


Figure 2.7: Factors affecting software patenting by SMEs

companies with 5-30 employees. The authors test a very general theoretical model, which is presented in fig 2.7, obtaining some useful results. The model is built around the set of factors affecting the decision to patent or not. Three main classes of factors are specified: the need to patent, the ability to patent and the potential to obtain and use patents[28]. The results of the study show that the lack of strategic patenting knowledge and the difficulty in detecting patent infringement are main factors hindering software patenting of SMEs. Contrary to expectations, the high costs do not deter patenting (Olsson and McQueen 2000).

[28]For details on main classes' sub-categories see fig 2.7

2.4 Free/Libre Open Source Software: a dedicated survey

The Free/Libre Open Source Software (FLOSS) is a phenomenon that has acquired of importance in recent years. Its diffusion and reliability has improved at an outstanding pace both at the public and private level. This upsurge has characterised both PAs and private enterprises. Indeed, they have started to rely heavily on the advantages characterising this alternative method of software production (Bonaccorsi and Rossi 2003).

Notably, public administrations have been at the forefront of the above mentioned dynamic. The predominance of the studies concerning public administrations can be explained via three main orders of reasons.

First of all, PA is seen as the ordinary place where FLOSS can be implemented. In fact, contrary to the private sector, public organisations respond to a set of different incentives and have different aims. Above all, they tend to provide citizens with services of high quality and, at this regard, FLOSS is likely to be a useful instrument to accomplish the task. The high technical quality and the saving on licence fees from private software vendors are factors affecting the productivity of services provided by the PAs (Lerner and Tirole 2002, Ghosh 2002).

Second, interesting case studies have shown that a structured adoption of FLOSS by local governments have fostered the rate of development of the relative local community. An emblematic example is surely Extremadura region in Spain where a concerted adoption of OSS has encouraged the entrepreneurial spirit in the Extremadura ICT sector and has spurred the creation of innovative business activities[29]

Third, the development of a bundle of high level competences is fostered by the adoption of FLOSS. Indeed, developing tailored solutions inside public administration is a way to invest on employees' competences (Varian and Shapiro 2003).

Many studies dealt with the state of the art of FLOSS in the PAs[30]These studies have

[29]For an exhaustive description of Extremadura case study see http://ec.europa.eu/idabc/en/document/1637/470.

[30]In addition to studies concerning the situation of government organisations in general, such as OSOSS (Ghosh and Glott 2003) and FLOSSPOLS, several studies dealt with more specific cases. An exhaustive list of European case studies is available at the Open Source Software Observatory website (see http://ec.europa.eu/idabc/en/chapter/470).

been mainly of a descriptive type while reasons concerning the adoption of the FLOSS by public bodies and the impact of such a decision have been systematically disregarded. To our knowledge, the only contribution in this direction is the Free/Libre Open Source Software – Policy Support (FLOSSPOLS) study. The latter is a government survey conducted on both local and regional government authorities of 13 European countries in year 2005. The main results from the study have shown that FLOSS is used in about half of the EU local government authorities, while almost 70% of FLOSS users and 38% of FLOSS non-users are greedy of increasing the future use of FLOSS. We can think to the former as the supply of FLOSS by government organisations, which seems to be still quite limited, while the latter can be interpreted as users demand, which is evidently stronger. In addition to this general statement, the study has tried to give a preliminary account of both important drivers and main barriers to the adoption of FLOSS in government bodies (Ghosh and Glott 2005).

In the area of FLOSS, Emilia-Romagna government has been quite active and has put forward two main initiatives relative to software and its applications with particular interest on FLOSS. These initiatives are the observatory for innovation and technological transfer on open source software (OITOS) and the Emilia-Romagna open source survey (EROSS).

The former is a newly constituted organization mainly concentrating on FLOSS by the point of view of private enterprises. Its main objective is to provide companies with useful information about tools and standards from the ICT world with a particular emphasis on FLOSS. The latter is seen as a strategically important instrument to support both innovation and economic growth into the region.

On the contrary, EROSS deals with PAs focusing mainly on the state of the art and practices on FLOSS adoption.

2.5 Conclusions

In this chapter we have concentrated on the analysis of a well defined sector of the economy, i.e. the software one. First, we have shown that this sector is growing at an increasing rate and that a clear international division of labor is present. Indeed, while the US is still the world leader in packaged sofware the EU is catching up for what regards the services and custom software. Moreover, a fast growing branch of the sector, i.e. open source software, sees the Eu as the undisputed leader[31].

After that, we have argued that software has been at the center of both academic and political disputes concerning the appropriate form of protection it should be accorded. Recent developments have brought patent protection at the forefront. Indeed, patent protection in the software domain is rapidly increasing of importance. Furthermore, in the US patent system defined legislative provisions and consolidated rule of practices point out that software is patentable. On the contrary, in the European patent system the situation is more complicated. A legislative attempt carried out by the European Commission to allow software patentability has resulted in a situation where software is not patentable from a legal point of view but, in the facts, the EPO grants these kinf of patents.

Together with the strengthening of IPRs in the software domain, an alternative form of intellectual protection has gained in importance in recent years, i.e. open source licenses. Among the different types of open source licenses, GPL is still the most diffused one even if less stringent licenses are catching up. At the same time, numerous types of OSS business models are appearing. In this contest, we have shown that the choice of the license is a crucial factor which shapes the adoption of a particular type of business model.

Finally, we have conducted a focused survey of the economic literature concerning software patents. From a theoretical standpoint, the new contributions usually challenge the traditional view of 'incentive theory'. Contributions from the empirical literature are few given the difficulty in collecting reliable data. Nevertheless, some specific contributions have tried to implement new techniques other than traditional surveys. From the survey of the literature, main issues concerning the rate of innovation in the software sector emerged. In particular, the software development process has been found to depend heavily on the following factors: sequentiality, cumulativeness, interoperability, network externalities and pervasiveness.

[31]For a quantitative assessment of the above proposition see Ghosh (2002)

	Type of main user	IPR protection	Regulations		Case Law	
			US	EU	US-Federal Circuit Court of Appeals	EU-EPO Boards of Appeal
1950s and 1960s	Academia	No protection: free/libre use	'free culture'/'hackerdom'	'free culture/'hackerdom'		
1960s	Academia and early markets	Trade secrecy and licensing	Fair use law, trade secrecy and contract law			
1970s	Academia and Industry	Rejection of Copyright and Patent protection	Fair use law, trade secrecy and contract law	European patent convention (EPC), rules of practice at the EPO	*Gottschalk v. Benson* (1972)	
1980s	Academia,Industry, Business, early home users	Copyrights and Patents	Copyright act, Berne Convention, patent law	Berne Convention, European Patent Convention (EPC), rules of practice at the EPO	*Apple Computer, Inc. v. Franklin Computer Corp.*(1983), *Diamond v. Diehr* (1981), *Diamond v. Bradley* (1981)	*In re Vicom Sys., Inc.*(1986), *In Siemens A.G. et al. v. Koch and Sterzel GmbH and Co.*(1988), .
1990s	Academia, Industry, Business, Home users, Net users	International Copyright, Patent laws, Open content	Copyright Act, Patent law, TRIPs agreement, Berne Convention, OSS licences	EU green paper, Berne Convention, TRIPs agreement, OSS licences, European Patent Convention (EPC), rules of practice at the EPO	*In re Alappat, In re Beauregard, State street bank and Trust co. v. Signature Financial Group, Inc.*	*In re Sohei*(1995), *In re Pension Benefit System Partnership*(2001).

Source: based on (Harison 2006, Samuelson 1993, Graham and Mowery 2003)

Table 2.1: IPRs regulation: 1950s-1990s

Table 2.2: Characteristics of main OSS licenses

	Distribution	Use	Code Openess	Copyleft
Proprietary	license payment	restrictions	close	no
Shareware	free	restrictions	close	no
Freeware	free	free	close	no
BSD/MIT/Apache/MPL	free	free	open	no
LGPL	free	free	open	standard*
GPL	free	free	open	strong**

*Modifications cannot be privatized

**A mixture of free and non-free software is not allowed

Source: Own adaptation of Perens (1999)

Table 2.3: Open Source Software business model by license type

License type	Business model	Revenues' source	Example	OSS
Public	Licensor	Sales and support	Microsoft	BSD (partially)
Viral	Provider of complementary services or software	support	Red Hat and Novell	Red Hat Enterprise Linux, Jboss, Suse Linux Enterprise
Apple Public Source License	Hardware seller	Additional hardware sales (PCs)	Apple	Darwin*
LGPL, MPL/NPL, Apache license	Client-server model	Software sales (StarOffice), Support fees (StarOffice and Netscape), Additional hardware (webservers)	Sun, Netscape and IBM	OpenOffice (StarOffice), Mozilla Firefox (Netscape) and Apache

*In the 2006 Apple decided to close Darwin's kernel source code.

Source: based on Hawkins (2004)

Chapter 3

Software Patenting in the European Union: Empirical Insights

During the last ten years the number of filed and granted patents at the main three Patent offices has increased spectacularly. This increase has been driven mainly by patent filings in high tech classes (Hall 2004, Kim and Marschke 2004). Among these, software patents attract particular interest mainly because of the nature of the technology and because software patentability has been, quite recently, at the center of a debate at the European level.

Since a long time, the economic literature has recognized the importance of the patent system in shaping and directing the rate of appropriation of the innovative effort of the firm (Arrow 1962, Nordhaus 1969). Besides "classical" contributions, the literature that has been developed to explain the recent trends in worldwide patenting has relied on Schumpeter's contributions to economic thought (Schumpeter 1942). More recently, evolutionary economics (Nelson and Winter 1982) has focused on the role of patents in enhancing or hindering innovation depending on sectors where firms compete. Therefore, a number of authors underlines that, depending on appropriability conditions of sectors in which they are used, patents might be, or not, a useful institutional mechanism in order to promote the variety of technological solutions and the selection by market forces via competition. Moreover, empirical contributions have shown that firms do not always rate patents as effective appropriability mechanisms (Cohen, Nelson, and Walsh 2000). Hence, on one side, empirical literature has shown how patents are not suitable appropriability mechanisms in a high number of sectors, but, on the other side, we have witnessed to an explosion in the number of patents filed in recent years. Why is there such a trade-off? Which factors contribute to explain it? One of the main reason refers to strategic patenting, which is a strategic behavior of firms aimed at hindering competition, obtain licensing revenues and to have stronger power in negotiations.

Our work wants to give an account of the patenting behavior of a complex technology such as software. While for the US some works have already been presented (Bessen and Hunt 2003, Graham and Mowery 2004), European Union has been disregarded, mainly because of art. 52 of the European Patent Convention, which regulates patenting activities inside the Union and expressively do not allow software and business methods patentability. This exception is not applied in the practice, in fact we show that more than 40,000 patents have been accorded by the European Patent Office in 1981-2004 period. It must be stressed that industries where the innovation process relies mainly on improvements made by others, namely cumulative system technologies (Mazzoleni and Nelson 1998), are more likely to be characterized by strategic patenting behaviors such as cross-licensing, blocking rivals or gaining licensing revenues. It is for this reason that our work is going to analyze the software patenting by European firms.

First, software patenting is shown to be a phenomenon common to European Union as well. Second, a theoretical model explaining factors affecting software patenting at the firm level is put forward. Third, an original dataset for the period 2000-03 is constructed which links the number of software patents filed at the European Patent Office with the R&D spending and other relevant variables of applicants. Fourth, econometric analysis via different types of count data models is performed to find out the most relevant factors affecting software patenting decisions for firms belonging to software and hardware sector. Finally, results are presented and briefly commented.

3.1 Patenting in the European Union

It is a well recognised fact that European Patent Office (EPO) faced increasing requests of inventions to be patented. Even if the rate of increase is not comparable with the one of the United States Patent and Trademark Office (USPTO), it is surely important and prominent in new technologies. The average annual growth of EPO applications for the period 1995-2001 is more than 8%, with a peak of 12% in both Biotechnology and ICT (see fig. 3.2); in addition, propensity to patent[1] rised spectacularly inside the EU with

[1]Propensity to patent is proxied by the number of patents applied for over the R&D expenditure (Scherer 1983).

an overall increase of nearly 50% in period 1995-2000 (see fig.3.3) (OECD 2004).

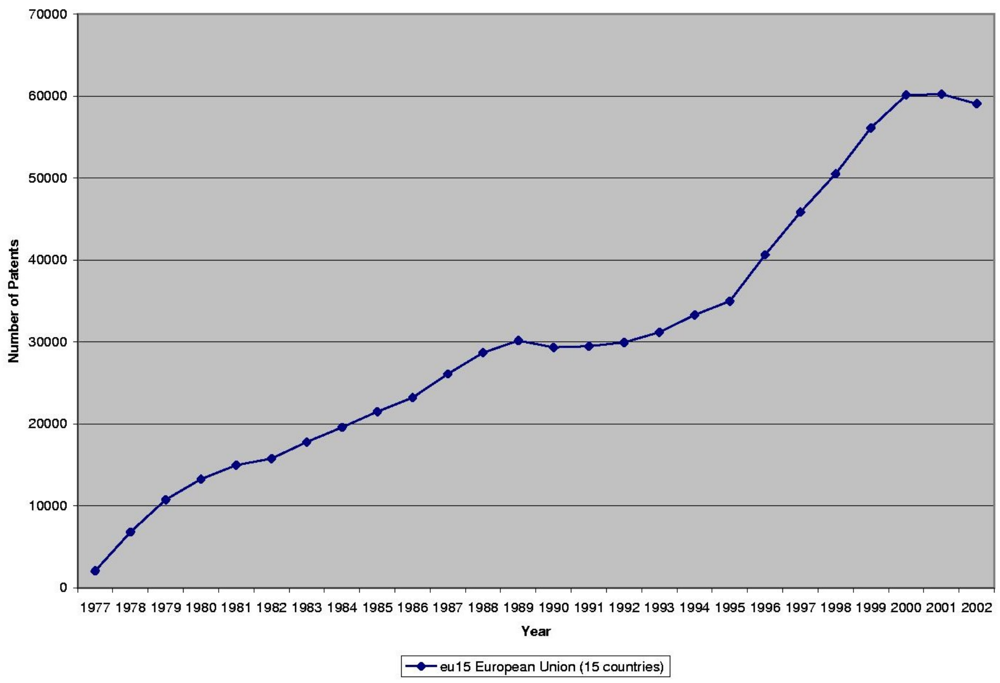


Figure 3.1: Patents accorded by EPO to EU15 countries (1977-2002) - Total number

This upward surge in patenting is due to the joint contribution of member and foreign countries. Moreover, other important changes have been taken place into the European patent system. First, increase in the length of granting procedure that has now reached the length of three years and a half[2] (Malerba and Montobbio 2002). Second, number of designated countries and number of designated countries over number of designable countries have increased in recent years, pointing out the increase in the number of countries where patent protection is asked for. This means that inventors are internationalizing more their competences and that they are probably trying to reach new

[2]This is mainly due to the decision by WIPO of assigning granting procedure of international patents to EPO Office, contributing to increase the average examination period. In fact, substantive examination of International patents are anteponed to European patent ones. What happens is that the procedure for European applications are deferred bringing, in this way, to an increase of the average granting procedure period.

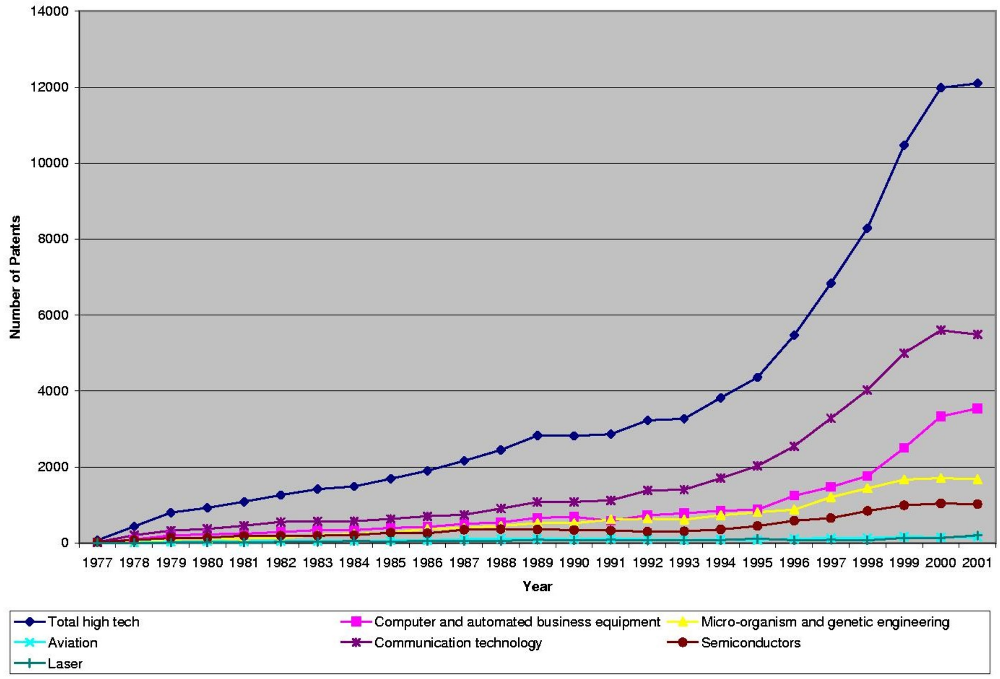


Figure 3.2: Patents accorded by EPO to EU15 countries (1977-2002) - High Tech application

markets using patents as competitive assets. Obviously, the increase in economic integration among member countries and the number of designable countries are important factors to this respect[3].

The strong increase in the number of patents filed to the EPO has an unusual character, though. It seems that the growth in the number of patents filed has not been accompanied by a comparable increase in research inputs. The explanation of this last fact is far from being totally agreed by the literature. Some authors underline the importance of the increase in the productivity of R&D inputs which yields more inventions and, as a consequence, more patents (Kortum and Lerner 1999). On the other side, someone has highlighted the importance of changes of worldwide patent systems which

[3]Another factor related to this issue is the role played by countries where production has been increasingly outsourced.

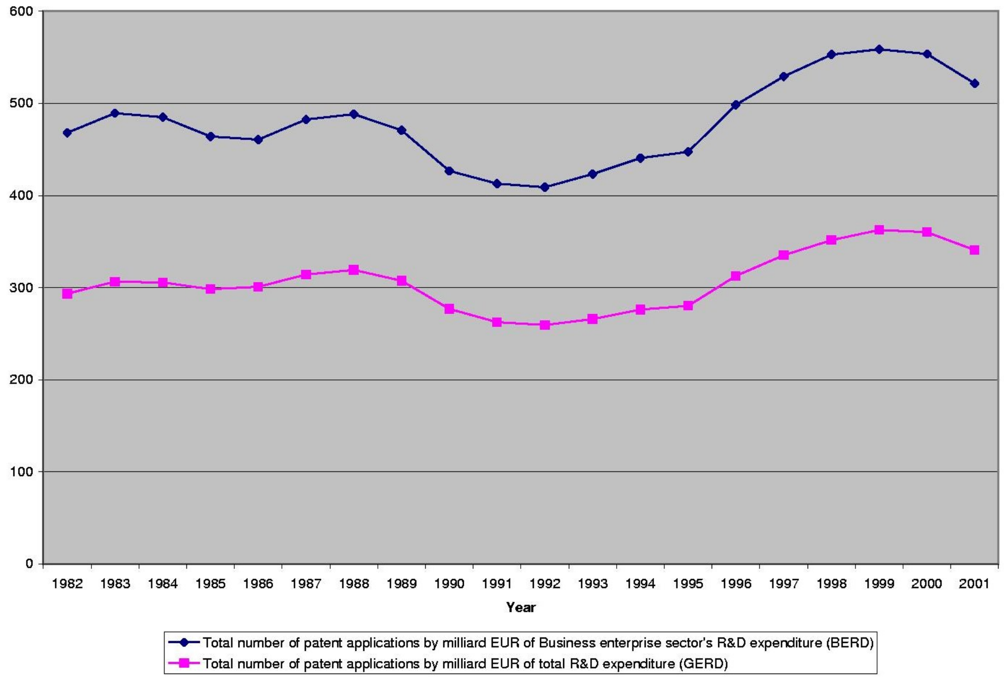


Figure 3.3: Patents accorded by EPO to EU15 countries - Propensity to patent

could have brought to a increase in patent propensity without a parallel rise of inventive activity (Hall and Ziedonis 2001).

This last explanation is in line with the increase of strategic patenting as a mean to appropriate monopolistic revenues. In fact, a growing number of large firms started relying on patenting strategies that allow them to ammass a huge amount of patents with the only aim of hindering competition or prevent hold-up by rivals. To this respect, an interesting study has been put forward by Calderini and Scellato (2004) who analyzed patenting behavior in the European telecommunication industry[4]. Analysing oppositions of patents filed at the EPO during 1980-2002 in the telecommunication industry, they show that large incumbents have mutual opposition rates lower than the ones involving

[4]This sector has recently witnessed to the implementation of two standard setting procedures (GSM and UMTS). The implementation of a standard setting can be quite problematic in the case in which firms participating to the standard hide relevant IPRs assets and decide to reveals these once other firms taking part to the procedure have already implemented complementary investments.

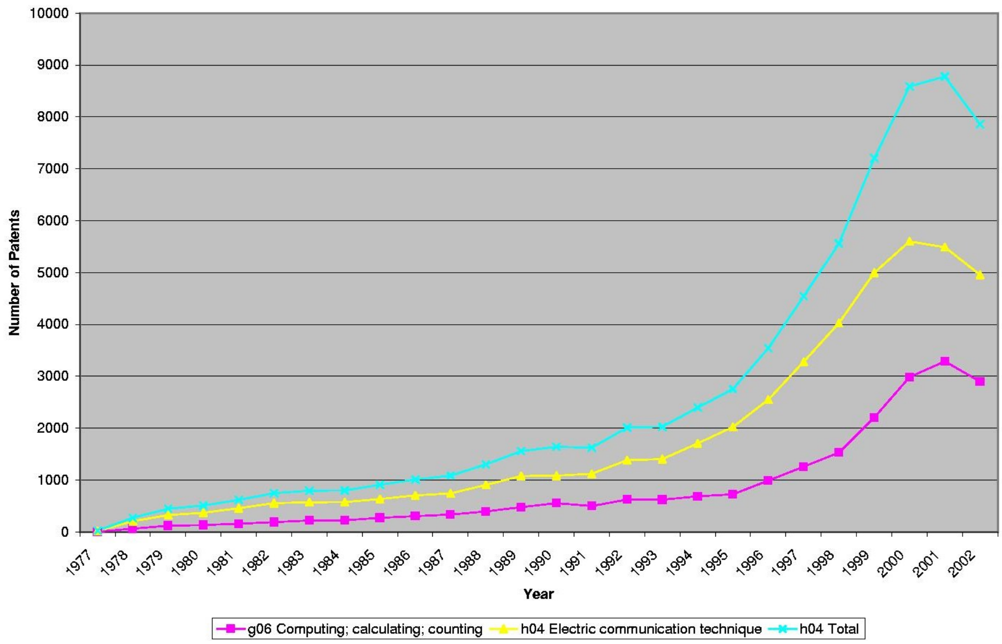


Figure 3.4: Patents accorded by EPO to EU15 countries - Software patents

one small and one large patentee. This result may indicate a threat effect of large patentees toward small ones, which are usually new and more innovative firms.

Thus in a ICT sector, such as the Telecommunication one, incumbents have been found to use patents for other reasons than appropriation of the results of research and development process. In this sense strategic patenting is devoted to avoid more innovative firms to erode their market shares. This poses relevant problems for the variety and selection processes inside the sector: it seems that competition is not fair in this case.

3.2 European Software Patent

The complex legislation concerning software patents, both at national and international level, has been treated extensively in the last chapter (section 2.2.2). Nevertheless, here it is important to remind the main points dealing with the previous discussion. First of all, we have shown that Article 52 of the European Patent Convention (EPC) defines what inventions are and when they are patentable under the EPC. Definition of what an invention is, or is not, is not provided by the EPC. However, article 52(2) provides a list of things that shall not be regarded as inventionsa and software is listed among them.

The scope of this list is reduced by article 52(3) which states that the provisions of paragraph 2 shall exclude patentability of the subject-matter or activities referred to therein only to the extent that an application or a patent relates to such subject-matter or activities as such. This means that, according to the EPC, what can be interpreted to be an invention must consist of a technical character. Whatever it is not technical and hence, according to the previous statement, not an invention cannot be suscetible of patenting. But whenever a technical character is found, then the topic that was previously not deemed as an invention becomes, all in a sudden, suscetible of patenting. The EPO rule of practice has put forward this interpretation for software. In case a technical effect or a technical contribution to the prior art is found, then software must be considered as an invention and, in this sense, can be patented. The technical effect term should be interpreted as a further technical effect that goes beyond the normal physical interaction between the program and the computer. At this regard, the situation is not completely clear and the interpretation of the technical effect proposition is not uniform. As an example, the controlling pension benefits system case of the 2000 reports that all programs when run in a computer are by definition technical mainly because a computer is a machine. In the line of this interpretation the European Commission proposed the Directive on the patentability of computer-implemented inventions (2002/0047/COD). Its aim was two-fold: first to harmonize national patents law of member countries about software programs, second to stop a situation where software, even if not eligible for patentability, were patented as well[5].

The directive, first initiated by the European Commission on February 20 2002, had a

[5]While presenting the Directive, European commissioner Charlie Mc Creevy states that it would be important to approve it cause EU needs certainty in a topic which is not yet regulated and where more than 7000 software patents have been already approved.

long and difficult *iter*, ending on 6 July 2005 with the definite withdrawal of the proposal via parliament rejection on the second reading. This means that for the moment, even if patenting of software and business methods patents are not permitted by EPC, EPO is going to provide a plurality of actors with patents on software. Obviously this is possible given that there are different interpretations on the definition of software, and hence of software patents [6].

At present, the situation in the Eu is that there is no effective prohibition of software patents. On the contrary, EPO rule of practice spurred a growing number of firms, both European and foreign ones, to apply for software patents.

3.3 The Model

3.3.1 Theoretical Background

The study of the effect of Research and Development spending, and other factors, on the number of patents filed has relied mainly on the Knowledge Production Function (henceforth KPF) approach . The main idea is that the R&D expenditure at the micro level could be interpreted like a correct proxy for the production of knowledge. Then, if we are able to calculate the stock of knowledge for a certain firm at a fixed point in time, this value might have a high validity to explain the output of the KPF.

Following figure 3.5 the R&D expenditure contributes directly to the formation of the knowledge capital of the firm. The relationship between R&D and Knowledge capital is straightforward: the amount of R&D expenditure contributes directly to firm's stock of knowledge[7]. Hence, knowledge capital is the factor that influences directly the output of the KPF.

In a simple form the innovation equation can be indicated as:

[6] One of the reasons that has prevented the directive to be implemented is certainly the discussion on the presence of a "technical" content for the invention to be patented.

[7] This relationship is even more true nowadays. In fact, the R&D process often takes place inside formally implemented R&D labs which is a sign of the direct link between the amount of resources invested by the firm and its knowledge competence.

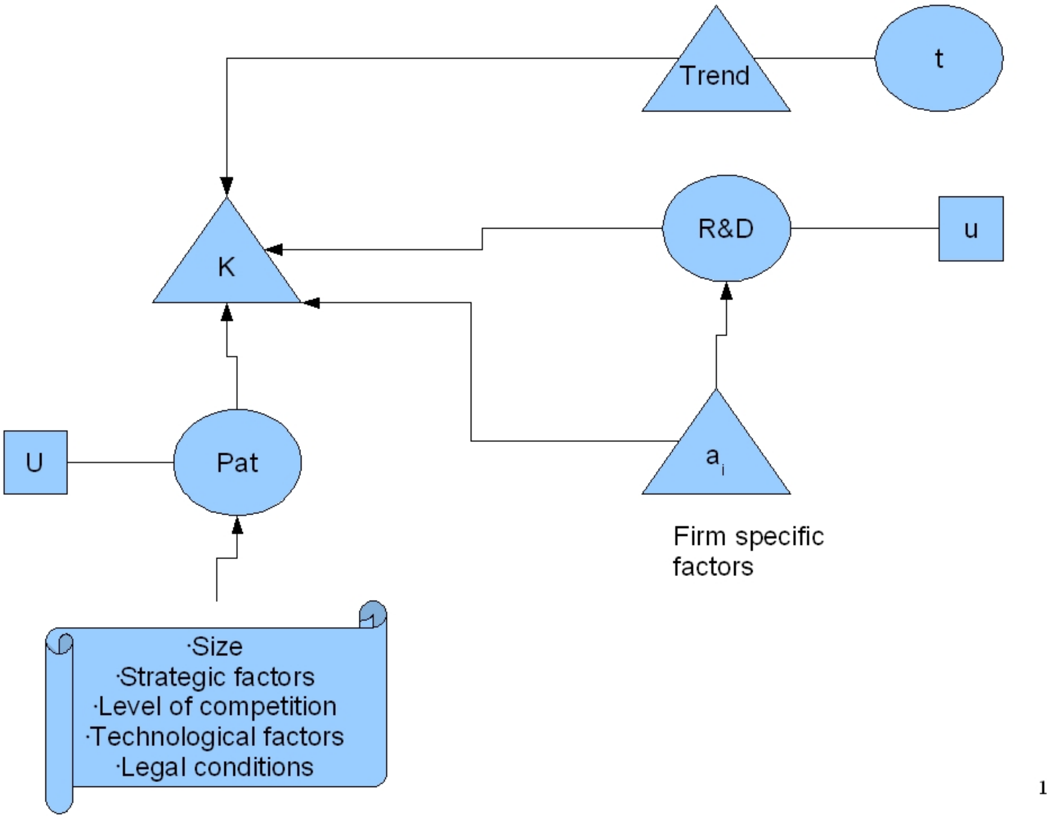


Figure 3.5: Theoretical Model

$$\dot{k}_{i,t} = a_i + bt + \sum_{\tau=1}^{3} \theta_t r_{i,t-\tau} + u_{i,t} \tag{3.1}$$

where:

$$a_i = \sum_{\tau=0}^{3} \psi_\tau r_{i,.-\tau} + u_i \tag{3.2}$$

with a_i proxing firm specific factors like managerial ability, opportunities, etc. As it is indicated in the figure (see figure 3.5), a_i affects both $\dot{k}$ and $r_{i,t-\tau}$. Indeed, managerial ability and other firm specific conditions may have an influence on both the amount of R&D spending of the firm as well as on the output of the innovation process and hence on the stock of knowledge produced by the firm.

The problem remains that what it is produced through the R&D effort of the firm is a rather unobservable quantity, namely technological knowledge. Hence, a good index of the output of this process is needed. At this regard, the economic literature has relied on the number of patents filed by a single firm in a fixed point in time[8]. Even if this index has relevant drawbacks, among which the fact that not all new innovations are patented and that patents differ in their economic impact, it has been widely adopted during last 20 years (Griliches 1990). This happened because patent statistics are easily accessible, which is even more true now after that worldwide patent offices (USPTO, JSPTO, EPO and WIPO) have computerized their data and have granted the public access to it through web access. Following this line of reasonment we can write:

$$p_{i,t} = \beta \dot{k}_{i,t} + dt + q_{i,t} \tag{3.3}$$

where $q_{i,t} = v_i + v_{i,t}$ and both $v_{i,t}$ and v_i are orthogonal to $\dot{k}_{i,t}$

[8]The seminal contribution to the KPF approach is from Pakes and Griliches (1984). They present a simplified path analysis of the overall KPF model. There, R&D expenditure contributes to the formation of an unobservable variable K, the technological knowledge of the firm, which could be proxied by the number of patents filed.

After some algebric manipulation (see Appendix A) we are able to disentagle the effect of R&D on $\dot{k}_{i,t}$ and the one of a_i on $\dot{k}_{i,t}$:

$$p_{i,t} = \alpha + \gamma t + \sum_{\tau=0}^{3} \omega_\tau r_{i,t-\tau} + \sum_{\tau=0}^{3} \phi_\tau r_{i,.-\tau} + \eta_i + \epsilon_{i,t} \qquad (3.4)$$

where $\omega_\tau = \beta\theta_\tau$

The present model is quite simple and contributed to the understanding of the relationship between the amount of R&D spent by the firm and the output of the innovation activity, namely the knowledge stock which is proxied by the number of patents filed at the firm level. Obviously, the amount of R&D cannot be thought to be a simple amount of spending that is done once per year and that its value is remaining costant over time. On the contrary, the R&D diminish its own value through time, hence it depreciates as time passes. This is why a sounder definition of R&D that takes into account this fact has to be implemented. The concept of R&D stock is taken into consideration at this regard (for a formal definition of the latter see Appendix B). Moreover, R&D stock takes into consideration also the fact that a certain amount of R&D at time t is affected by past quantities too.

The amount of R&D expenditure at the firm level is not the only factor affecting the output of the KPF. Other factors are crucial. We have classified them in three main groups: economic, technological and legal conditions. The first group, economic conditions, is composed by three main factors:

- Size. The fact that size influences the innovation process of the firm can be reconducted to four main order of reasons. First, large firms benefit from economies of scale and scope . In this way, they are more competitive than smaller ones (Cohen, Nelson, and Walsh 2000). Second, large firms benefit from complementarities and spillovers coming from other departments. Third, capital markets are more prone to finance risky innovation projects of larger firms other than small ones (Carine and Bruno van Pottelsberghe de la 2006). Finally, large firms are more likely to be endowned with a legal department which expressively handles IPRs matters (Lerner 1995).
- Level of competition. Two opposite effects are present in this case. First, a replacement effect which refers to the fact that firms with a high market power are

eager to invest less in R&D and, in this way, to innvate. This is due to the lack of incentive in doing so, given their dominant position in the market (Arrow 1962). Second, what has been called the efficiency effect. According to this effect firms with a high market power innovate more cause they do not face any kind of competition for the exploitation of the results of their innovation process (Gilbert and Newbery 1982) (for a better discussion concerning differences and peculiarities of the two effects see section 1.3.2 on page 14).

- Strategic factors. These are factors explaining recent trends in firm level patenting. In fact, while traditional "incentive theory" has advocated for a long time that the monopoly power, accorded to the patent holder, acts as an incentive to R&D expenditure[9], recent contributions assert that the high number of patents filed by companies, in particular larger ones, are instead a strategy aimed at hindering competition and increasing their monopolistic position (Merges and Nelson 1990, Hall and Ziedonis 2001). This is particularly true in what have been called "cumulative system technologies", that is technologies where innovation process is highly cumulative. Therefore software sector, for the essential cumulativeness of its embedded technology, is also prone to be threatened by strategic patenting activities; and this is what we think it is happening in EU too. These factors are of different nature and content. Among them, it is worth reminding cross-licensing, threat effects, patent thickets, and so on (for a better discussion of strategic patenting see section 1.6 on page 45).

The second group, legal conditions, can be proxied by geographical factors. Different opportunities may arise from being located in different regions having different legislations. Among them, four main macro-areas can be individuated: European Union, United States, Japan and other countries. Among them, EU and US legal regimes have been extensively discussed (see section 2.2.2 on page 61) while Japan and other countries deserve a mention. Japan has changed its patent system from a single-claim to a multiple-claim one in 1988. This reform induced two main effects in the japanese patent system: first the number of applications decreased and second overlapping claims have been used extensively in order to defend strategically acquired inventions.This major changing in the japanese patent system influenced both patenting by japanese firms and American ones, which were the ones patenting more in Japan before the reform. On

[9] An inventor, deprived of the exclusive right to exploit its invention for a definite period of time, would not had even started the inventive act if he was aware of it. This is obviously related to the public nature of knowledge (Arrow 1962).

the contrary, with other countries we indicate fast growing countries (such as India and China) the patent sytem of which is not as trustworthy as the one of more developed countries. It is well known fact that in countries such China the enforcement of some international regulations concerning Intellectual Property Rights is not always completely pursued.

The third group is constituted principally by technological opportunities that we proxy through the industrial sector of activity of the firm. Indeed, the effect of formal R&D spending on the innovation output, mediated by the rate of formation of the stock of knowledge capital, depends on the sector of activity of the firm (Mansfield 1986). To our concern, technological opportunity is of particular interest. In fact, we want to investigate the different behaviour taken by firms belonging to two separated sectors, namely hardware and software producers. It has been showed that, during the last 10 years, main patenters at the USPTO are likely to be part of electrical, computing and instrument industries (Hall 2004). Moreover, if only software patents are taken into account firms belonging to electrical, machinery and instruments account for more than the 60% of software patents accorded at the USPTO. While software publishers and firms from other software industries contribute only for the 7% to the overall share of software patents (Bessen and Hunt 2003). Hence, if firms not belonging to the software sectors are more likely to patent software inventions, then it seems reasonable to suppose that they are doing it for reasons intrinsically different from spurring innovation spending.

3.3.2 Method of Estimation

Following the reasonment done while presenting the theoretical model, we discover that the object of our interest is the number of patents a firm applies for. In particular, the number of software patents. Before continuing and going into the detail of how the database was built up, we'd like spending some time on the peculiarity of the estimation methods implemented. The main object of the analysis is to explain which factors influence the number of software patents a firm applies for at the EPO. Hence, our dependent variable is of a count data type. That is it can assume only positive integer values. Given this particular feature, together with the fact that we are facing micro-level data repeating through time, we rely on count-panel-data models. In particular, we adopt Hausman, Hall, and Griliches (1984) and Wooldridge (2005) specifications. While the former is usually advocated as the seminal contribution in these kind of models, the latter is a straightforward procedure which allows to take into account dynamics without using GMM estimation of the parameters of interest[10].

The first type of count-panel-data model is surely the Poisson one- Here, the dependent variable, being of a count data type, is assumed to be distributed as a Poisson. This means that the probability for fim i to obtain y patents at time t is equal to:

$$P(y_{i,t}) = \frac{e^{-\mu_{i,t}}\mu_{i,t}^{y_{i,t}}}{y_{i,t}!} \tag{3.5}$$

with $\mu_{i,t} = \alpha_i \lambda_{i,t}$, where:

α_i is the unobserved heterogeneity term which takes into account firm-specific effects arying among different firms but constant throug time. An example can be managerial ability, which is a factor specific to the firm but constant through time.

$\lambda_{i,t}$ is a function of a set of explanatory variables explaining the number of software patents filed. In particular, an exponential form is usually assumed:

$$\lambda_{i,t} = exp(X_{i,t}\beta) \tag{3.6}$$

Before continuing with the explanation of the estimation procedure it must be stressed that usual hypothesis concerning panel data model are assumed [11]. The estimation of the model presented so far can be done via two different methods: fixed effect and random effect models. These are two methods common to linera panel data models but the procedure through which they are implemented differs from the former. While in the linear case the fixed effect is cancelled through a first difference procedure, this is not the case in the non-linear case. Implementing a first difference will not allow us to cancel out the unobserved heterogeneity term. Moreover, while in the linear case the estimation procedes via OLS or GLS, in the non-linear one maximum likelihood estimation is the correct procedure to adopt. In particular, in order to drop out the heterogenity term, wer rely on a conditional maximum likelihood estimation (Andersen 1970, Andersen 1972). The inference is conducted conditional on sufficient statistics for the heterogeneity term

[10]Models using GMM estimation to analyze filed patents in a Count-Panel-Data setting are reviewed by Cameron and Trivedi (1998).

[11]In particular, for all the kind of models strict exogeneity is assumed while for the random effect model the expected value of the heterogeneity term is assumed to be zero.

α_i, that is $T\bar{y}_i = \sum_{t=1}^{T} y_{i,t}$. After some remarkable algebra the log-likelihood is obtained which can be maximized to find consistent and efficient estimates (Hausman, Hall, and Griliches 1984).

Contrary to the fixed effect procedure, random effects hypothesized a distribution of the heterogeneity term as in the linear case. The difference pertains to the kind of distribution assumed that, in this case, is gamma rather tha normally distributed.

The three main drawbacks of the Poisson panel data model are:

1. Conditional mean and conditional variance cannot vary independently. Formally:

$$E(y_{i,t}|x_{i,t}) = \mu_{i,t} = \alpha_i \lambda_{i,t} = Var(y_{i,t}|x_{i,t}) \tag{3.7}$$

2. The main assumption behind the model is that $y_{i,t} \sim Poisson(\mu_{i,t})$. This assumption does not hold in the case zero outcome originates from a separate decision process or when there are non-llinearities in the innovation process. In the first case, problems can arise because firms prefer a strategy of secrecy. The zero outcome can be due to the fact that either firms do not patent or firms prefer to keep innovation secret. In the second case, problems arise from the fact that the first innovation is more difficult to achieve than following ones and, for this reason, the innovation process in non-linear in nature.

3. In case autocorrelation is present, then it is impossible to introduce dynamic into the model in order to reduce it

All of these drawbacks are overcome through the implementation of several methodologies:

1. We adopt a Negative Binomial panel data model introduced by Hausman, Hall, and Griliches (1984) which allows conditional variance to vary with respect to conditional mean.

2. In order to overcome problems arising from the different processes yielding a zero outcome we tests our specification through a logit panel data model.In this way, we checked whether factors influencing software patenting are robust to different specification of the econometric model.

3. In order to introduce dynamic we relied on a specification of the Poisson panel data model introduced by Wooldridge (2005). There, one lag of the dependent variable is implemented which considerably lowers the extent of autocorrelation into the model.

We ran regressions using negative binomial specification, and this gave us results identical to poisson specification. Hence, given the possibility of incorporating dynamic into the model only through the poisson specification we decided to rely on the latter one.

3.4 Data

As discussed before, our main aim is to give an account of factors affecting software patenting by firms applying for patents at the EPO. To do that, we first need a reliable dataset of software patents accorded by the EPO. In order to build up the mentioned database it is extremely important to identify software patents among more general patents. As discussed in section 2.3.2, few methodologies have been implemented by the literature so far. Among them, only one has had Europe as field of application (Hall, Thoma, and Torrisi 2006). In this sense, this might be thought as a preliminary study. In fact, while there are several contributions that have analysed software patents in the United States (Graham and Mowery 2004, Bessen and Hunt 2003), our work wants to give an account of the same phenomenon for the EU.

The first step of the current section, section 3.4.1, is to propose a general description of the GAUSS database, with some relevant statistics concerning European software patents. But contrary to the study of Hall, Thoma, and Torrisi (2006) we relied on a database made available and mantained by a group of developers, i.e. GAUSS. The reliability of the latter one has been checked by several means, among which comparing it against another database built via a different methodology. Furthermore, a set of similar descriptive statistics have been drawn from both databases and are used to compare one against the other. Finally, relevant statistics are presented which give an account of the current situation of software patenting at the EPO.

After that, in section 3.4.2 we investigate the construction of our sample concerning both European and foreign firms patenting software at the EPO. In order to do that, first we will explain the procedure used to build the sample concerning firms' patenting strategies. Then, the biasdness of the sample is checked, comparing it with both ANBERD and EUROSTAT population statistics. Finally, the sample subset of data is presented, underlining certain characteristics that call for the use of defined econometric techniques and providing descriptive statistics for the sample itself.

Our last step (section 3.4.3) will be to discuss the ratio behind the adoption of particular variables in our analysis, together with the discussion of some technical issues concerning the econometric model adopted.

To do that, we have linked the number of patents applied for by a relevant subset of EU and foreign firms at the European Patent Office.

This section starts with the description of the dataset of software patents accorded to both European and Foreign firms by the EPO. European, American and Japanese firms are the relevant subset of firms applying, and obtaining, EPO's patents. In particular, firms belonging to the latter two countries own nearly absolute majority of software patents accorded at the EPO: this means that law regulations, as the one that has been rejected by the European Parliament regarding the "Patenting of computer implemented inventions" (see section 3.2), must take into account this fact. Indeed, a legal decision that, all in a sudden, allows patentability of software could threat the future of European sector. The fact that foreign firms already own large software patent portfolios could hinder competition. This first move advantage is something that must be stressed and it must be taken into consideration by economic politicians who wish to extend patentability to software domain.

3.4.1 GAUSS database and descriptive statistics

As mentioned, the present analysis of recent trends in software patenting inside the European Union relies on the Gauss.ffii database, which has been accessed through a Postgres Client allowing to perform SQL queries. The Gauss.ffii database has been created by a group of developers via multiple sources: it includes the FFIIs (Free Foundation for Information Infrastructure) database of software patents, as well as the Stefan Wagners database of 1,900 business method patents. In addition to those sources and in order to maintain it up to date, Gauss.ffii performs continuously searches of patent documents by applicants likely to produce software or business method patents. They also make searches for about 150 words occurring in software patents and, furthermore, searches in European Patent Classification (ECLA) classes with a high probability of containing software patents. The database is constructed as a wiki, meaning that users are not only allowed to add content, but also permitted to edit the content; this revealed to be a very effective way to take advantage of improvements through collaborative efforts. This means that a continuos strategy of checking over patents inserted in the dataset is performed meaning that the overall quality of the database is improved.

Nevertheless, a careful check over the reliability of the database is surely needed. In order to perform that, we decided to build another database to compare it with that. Obviously, the methodology chosen for this procedure is in line with the one presented while reviewing the literature in section 2.3.2. The procedure that has been adopted can be syntethized as follows:

1. We relied on a list of the most important software firms doing business inside the EU. The distribution of the firms is skewed towards foreign ones given their importance in this business area. The list has been compiled by Hall, Thoma, and Torrisi (2006) following the methodology first implemented by Graham and Mowery (2003) for the US software industry.

2. We accessed the EPO database via MIMOSA software checking for defined characteristics of the patents selected firms are applying for. So we individuated a number of unique IPC classes/subclasses where these firms patent.

3. We interpreted the nature of these classes/subclasses as the place where software patents are more likely to be found. Then, we retrieved from the EPO database relevant characteristics of the patents belonging to cited classification.

The database obtained can be thought to be a reliable proxy for the number of software patents accorded by the EPO. But then, why do we perform our analysis on a different type of database instead of using the one described above? There are two main order of reasons for this. First, it is debatable the assertion that all the patents found inside the unique classes/subclasses are software patents. It may be the case that in that class either few software patents are present or that software patents are actually falling under other classes. This phenomenon is caused by the fact that software patents have not a defined class in any patent system. They are usually classified under different classes according to the examiner choice. This fact implies that the most reliable way to individuate software patents is actually to read the description for every single item and classifying it accordingly (Allison and Lemley 2000). The second reason why we rely on GAUSS database is that, being it a collaborative environment, it is continously updated. This means that it is dynamically more efficient. At the end, the dataset constructed following the methodology described so far has been mainly adopted as a mean of comparison and benchmarking for GAUSS database.

The whole GAUSS database is composed by patents filed between 1978 and 2004. Many information have been extracted from the dataset. In particular, statistics concerning designated countries, yearly evolution in the number of filed and granted software patents, country of residence for both inventors and applicants and patents' software domain have been collected. As it can be seen from figure 3.6 the number of software patents filed at the EPO has increased steadily starting from 1984. During the second half of the 1990s the increase has been impressivejumping from 4500 patents in 1995 to almost 12000 for the year 2001. After 2001 the amount of software patents filed dropped consistently. One of the reasons for this fall can be reconducted to the burst of the dotcom bubble of the 2000. Indeed, the crisis of many firms making business in the ICT sector could have been conductive of diminishing patent applications.

On the contrary, the amount of software patents granted is increasing with respect to filed ones after 2000. This is due to the fact that we graphed the number of patents granted at the EPO in one particular year and not by application year. As it usually happens granting procedure lasts more than one year, meaning that a patent that was filed, for example, in year 1999 is granted in 2002 or later. This falsifies the graph as it has been presented.

In order to give a more realistic picture of the pattern of software patents granted at the EPO, we shift the graph concerning patents granted of five years back (see 3.7).

Indeed, this is the average length of the granting procedure of software patents at EPO computed by ourself [12]. In this way, we obtain more reliable information on the number of software patents filed at the EPO from 1978 to 1998 that were actually granted. From the figure we note that the pattern in the patents granted follows closely the one of patents filed, nevertheless the gap between the two is increasing. This is an indication of the increasing strictness of the EPO concerning this patent typology. A proof of this statement can be desumed also from figure 3.8 which graphs, for the top twenty applicants, the number of software patents granted as a percentage of filed patents. From this, we see that it never happened that more than the 50% of software

[12]The computation was done substracting the filing date from the granting one for every single patent in GAUSS database and, then, calculating the mean for all patents.

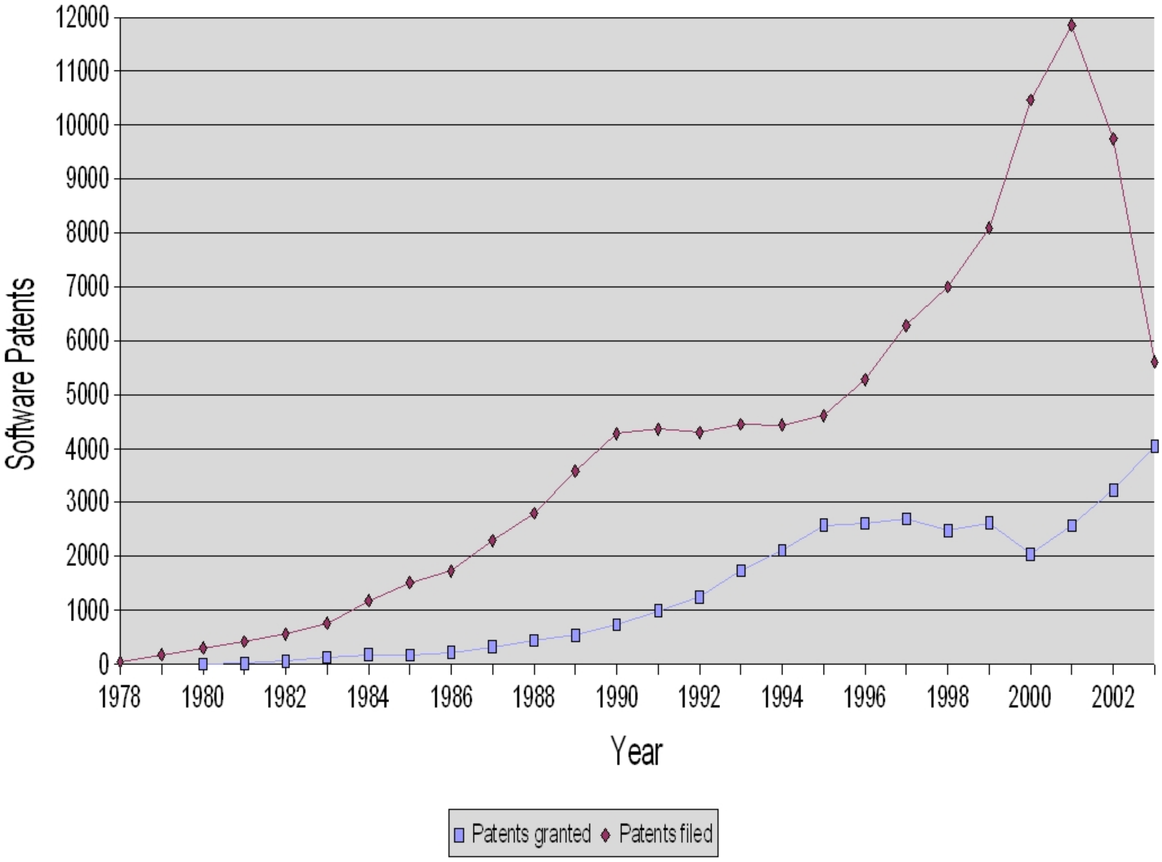


Figure 3.6: Yearly evolution of filed and granted software patents (1978-2003)

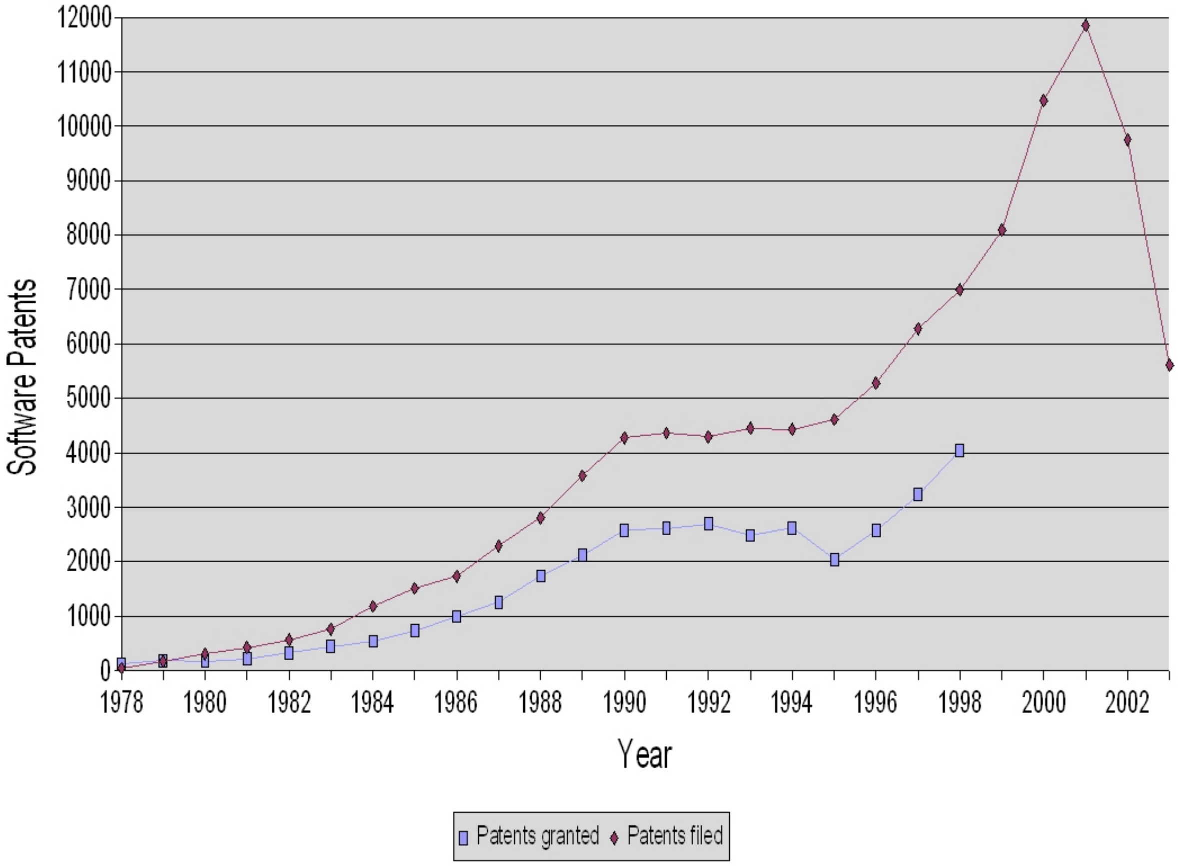


Figure 3.7: Yearly evolution of filed and lagged granted software patents (1978-2003)

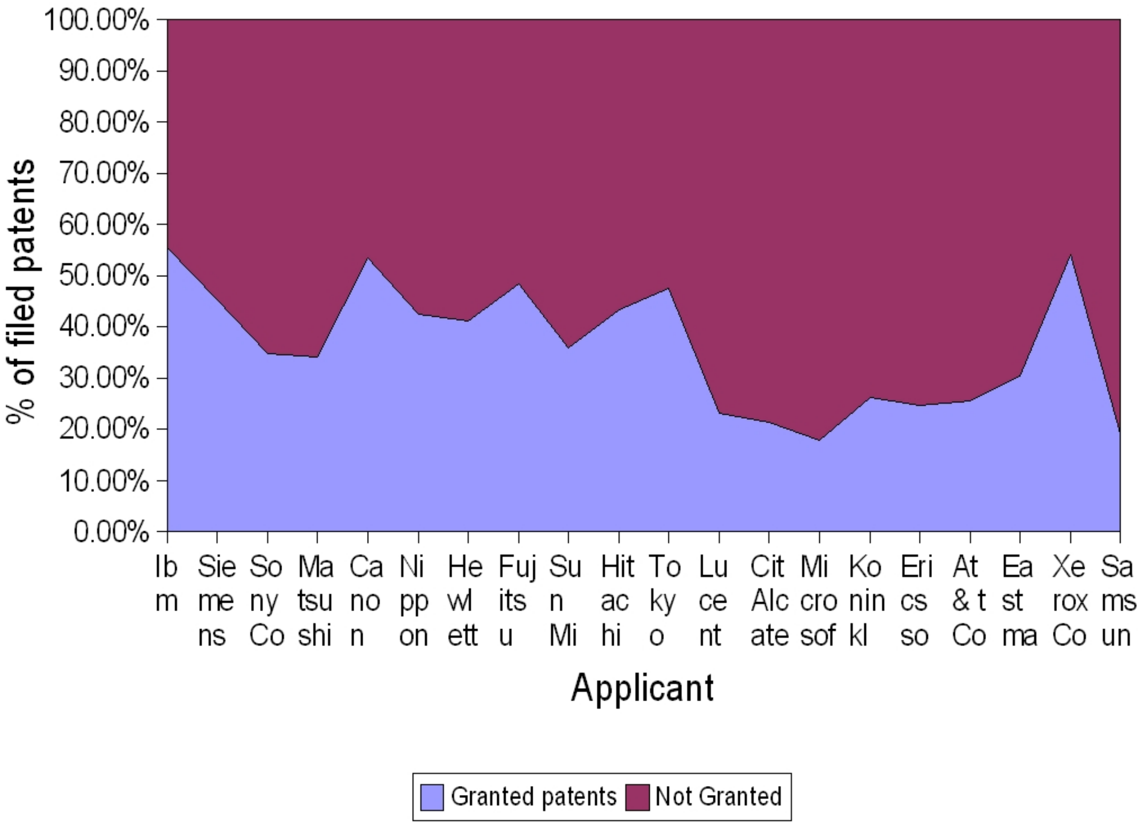


Figure 3.8: Granted versus not granted patents for top 20 applicants

patents filed have been granted from the EPO.

From figure 3.9 and 3.10 we can desume the increasing role that software patents are playing among more general patents and ICT ones. Indeed, software patents constitute a large share of patents (from 6% to 12%) and even a larger part in ICT related patents (from 22% to 32%). This points out the increasing role that software patenting in several OECD countries.

Other facts ca be desumed from figures ranging from 3.11 to 3.13. First the most designated countries, that are the countries inside the EU where patent applicant is asking expressively for protection, are Germany, UK, France, Italy and The Netherlands. But at the same time other countries, mainly European Union new entrants, are aquiring in importance meaning that either seeking protection or behaving strategically is an active strategy by software patents applicants. Second, both applicants and inventors applying for software patents are mainly from US (respectively 39% and 40%) and Japan

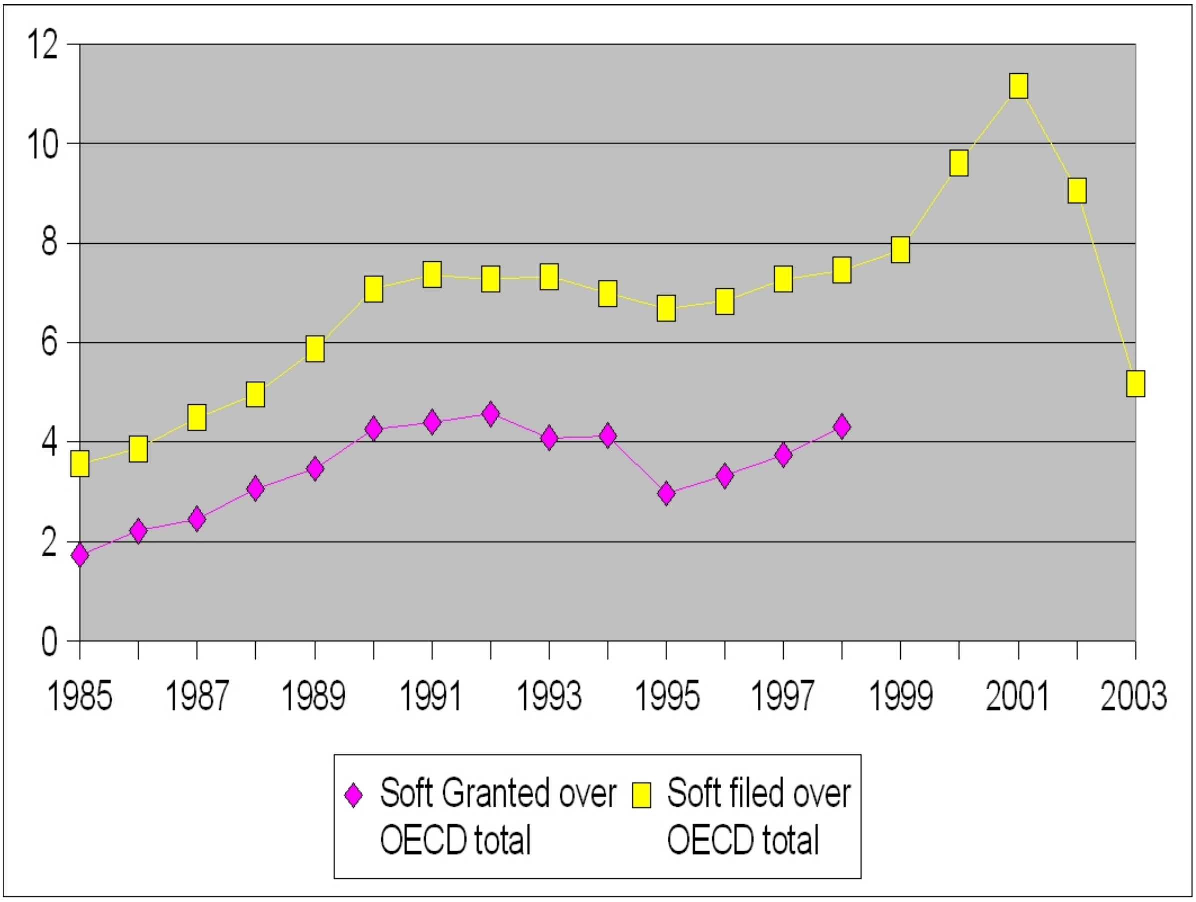


Figure 3.9: Yearly evolution of filed and lagged granted patents over OECD totals (1978-2003)

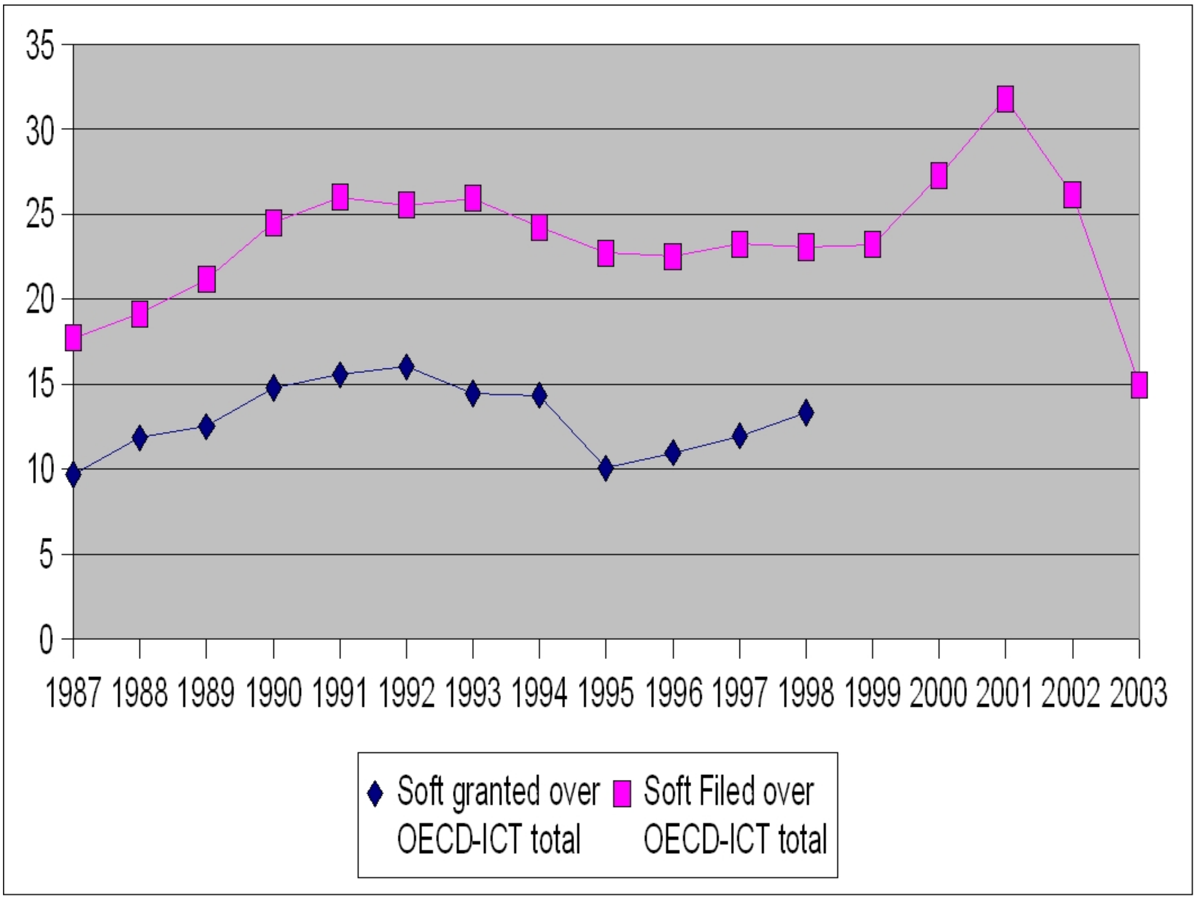


Figure 3.10: Yearly evolution of filed and lagged granted patents over ICT related totals (1978-2003)

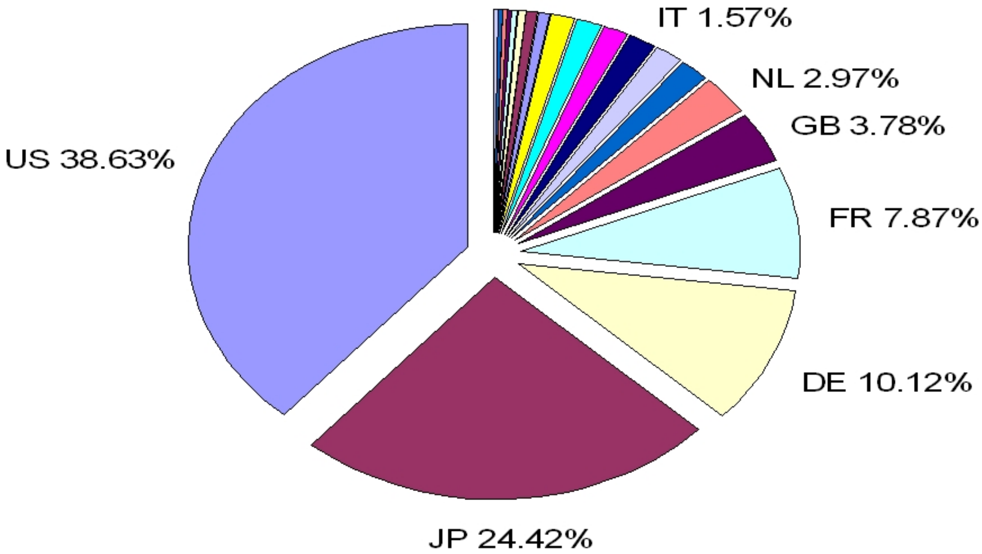


Figure 3.11: Country of residence for top 20 applicants

(respectively 25% and 26%) with a minor role played by European Union inventors and applicants. Germany, which is one of the best performing one accounts only for 10% and 9%. This is mainly due to the leading role in ICT-related products by the US and Japan and from the fact that, at least for the US, software is suscetible of patenting since the beginning of the 90s. This has allowed American firms to acquire expertise in both dealing with application procedures and identifying more valuable inventions to be patented.

If we focus our attention on software patent concentration, then a highly concentrated pattern is found out. According to figure 3.14 the top 50 applicants account for more than the 50% of patents accorded at the EPO.

Moreover, main software domains where patents concentrate are shown in figure 3.15. Program, data processing systems, content, security and server are the five main areas where software patents are asked for.

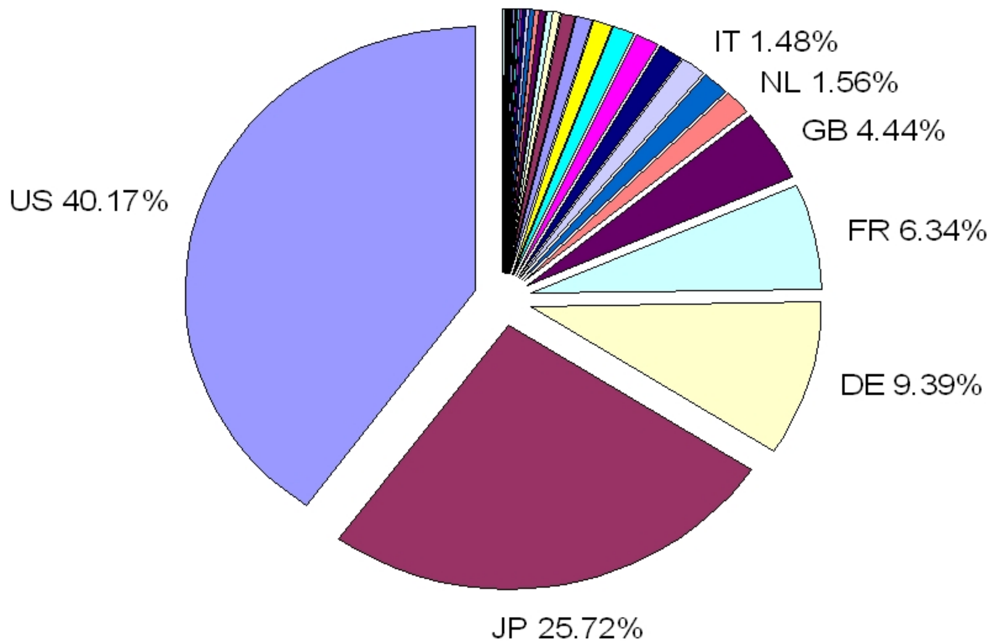


Figure 3.12: Country of residence for top 20 inventors

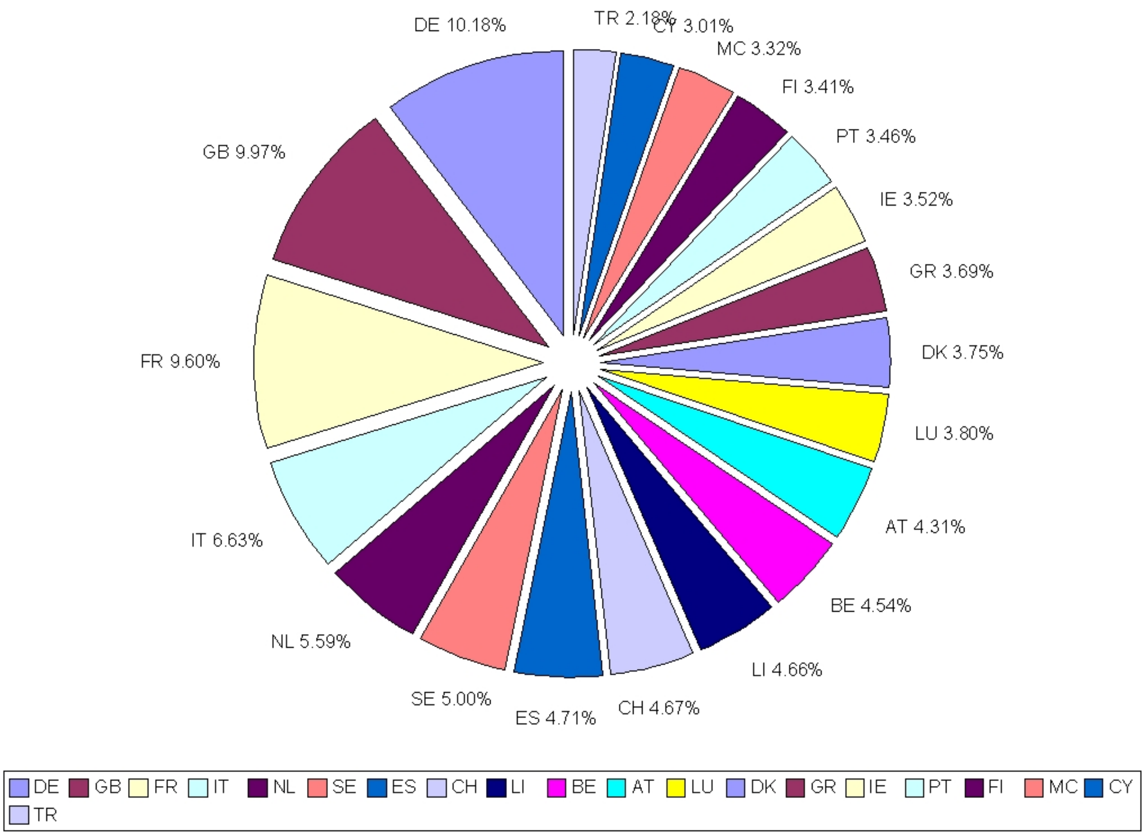


Figure 3.13: Top 20 designated countries

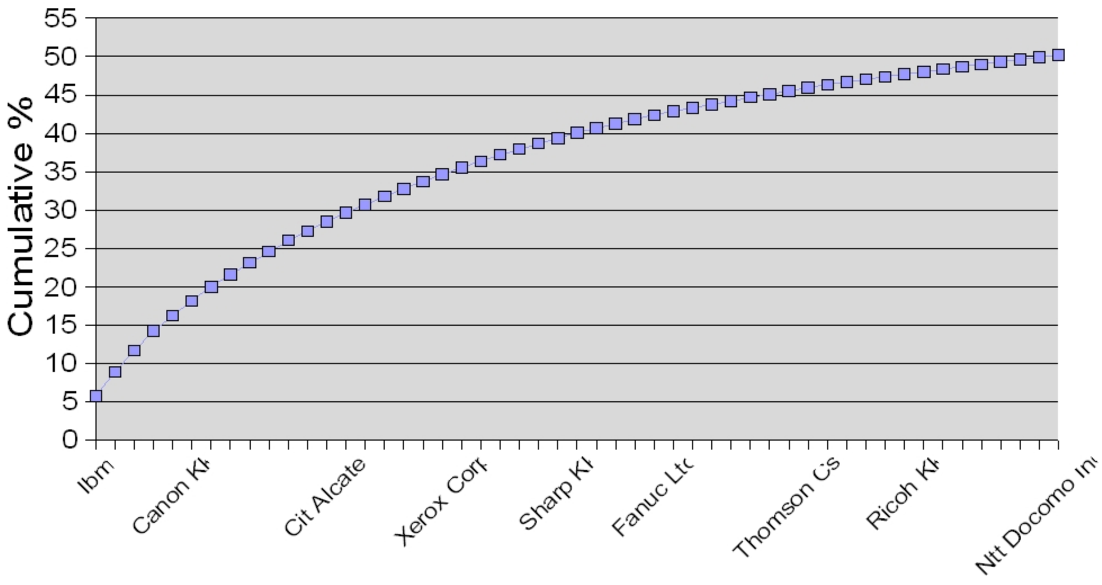


Figure 3.14: Cumulative percentage of software patent applications by top 50 applicants

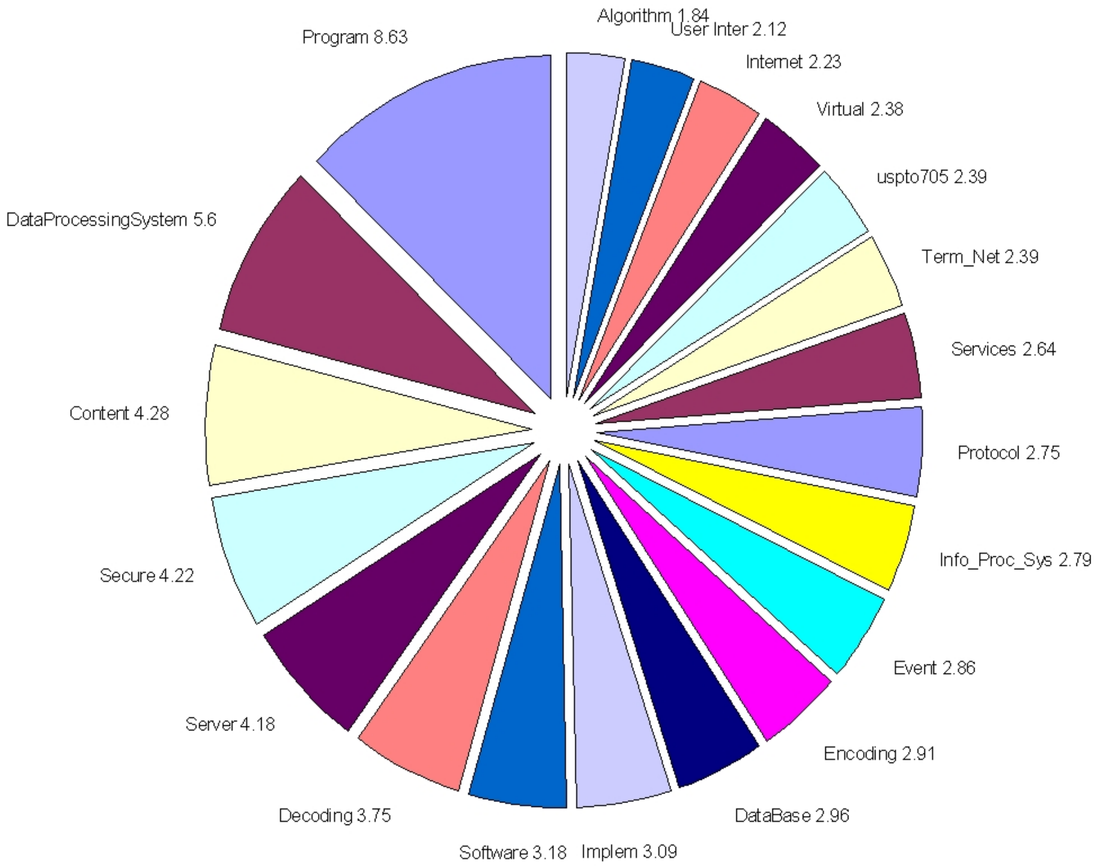


Figure 3.15: Percentage of software patents by software domain

In order to check the robustness of GAUSS database, namely its ability to include patents that are actually accorded on software, we adopted a three stage procedure:

1. We compared the main features of GAUSS with the database built following the methodology discussed earlier.
2. we compared descriptive statistics obtained by a recent work on European software patents by Hall, Thoma, and Torrisi (2006).
3. We checked the reliability of 100 patents randomly drawn by the GAUSS database, following the statement enounced by Allison and Tiller (2003) that '.......'[13].

In all the cases analysed a consistent robustness of the GAUSS database has always been found. In particular, from point 2 we have found that:

- Software patents as a share of all patents almost coincide;
- High concentration of software patents among applicants
- Absolute numbers are different but the upward and downward patterns coincides;
- Most diffused assignee's countries are the same;
- Software patents mainly concentrates in two sectors, i.e. ?????.

The subset of data relevant to the present work had been built by extracting all records of information regarding patents filed between January, 1st 1995 and December, 31st 2004, obtaining a total of 65,536 patent records out of the available 77,540 filed between 1982 and current date. This allowed to track 85% of filed patents, corresponding to 44% of the overall number of granted patents. Besides the filing date, date of publication and date of granting had been collected where present depending on the state of each patent. Other relevant information available are the list of designated countries to which each patent refers (see fig. 3.13), the list of the International Patent Classification (IPC) codes relevant to each patent, and the applicant name (or the list of applicants where necessary). Some interesting statistics can be drawn to describe the patenting process by EPO in general, and that of software related products or methods in particular, by analysing the number of designated countries where the patent must be enforced,

[13] In order to select a patent as software we used guidelines contained in the work from Campbell-Kelly and Valduriez (2005).

number of IPC subclasses, which can be thought as a proxy of patent scope, and average length of the granting procedure for software patents. The subset of software patents in the period between 1995 and 2004 shows an increasing number of filed patents which are not granted or not yet granted: while about 60% of patents filed in 1995 switched to the granted state before the end of 2004, 83% of patents filed in 2000 are not granted yet. This justifies the low share of granted patents included in the mentioned subset, and it is connected to an increase in the time required to complete the granting process, whose average length is of 3,5 years: while granted patents in 1997 had been filed about 1 year earlier, those granted in 2004 took, as an average, more than 5 years to complete the granting procedure. It must be mentioned that getting closer to 2004 the database updating procedure has a relevance in justifying a lower share of granted patents. It is possible to point out, anyway, that in the period 1995-2004 a lower number of patents had been granted against a fast increasing number of filed requests, and in general the granting procedure slowed. This finding can be explained by different means. First, the productivity of the EPO is decreasing. This is mainly due to two main order of reasons: the growing number of patents filed in general and an additional weeight constituted by international patent applications. The former factor is due to the rising importance of patents among other IPRs. All patent offices around the world are facing a huge number of patent applications. These are not counterbalanced by an adeguate investment in internal personnel. This means that the number of patents per employee is steadily increasing, leading the ranting procedure to slow down. At the same time, EPO has been selected as the more efficient patent office around. This has leaded international patent applications to be redirected there given the higher quality assured in the granting procedure. This fact has additionally increased the already huge number of patent applications to be processed.

All of these reasons can not fully explain the high difference in the average grant of the granting procedure between patents in general and software patents, i.e. 3,5 years against 5 years. The cause for this difference must be found in other factors such as the complexity of the patenting matter and the absence of clarity concerning decision procedures. Moreover, the lack of a well defined prior art contributes to the uncertainty surrounding the granting procedure.

By processing the collected data, it was possible to single out 4,992 different IPC codes in the 13,203 patents granted in the period 1995-2004, to which software related patents referred. About 45% of patents declared multiple IPC codes, with an average of 1,65 IPC code per patent which could be used as an indicator of patent broadness.

While the total number of different IPC codes used strongly increases overtime, this is mainly due to the higher volume of patents, as the average number of IPC codes declared per patent per year remains fixed. When referred to the ISIC classification, most referred IPCs belongs to the ISIC Electronics and Computers & Office Machines classes, as reported in the table, which lists the 10 most common IPC (accounting for about 14% of patents) and corresponding ISIC description.

Software related filed patents in EPO in the period 1995-2004 refer to 28 different designated Countries, to which the validity of patents applies; among them, Germany, United Kingdom and France each shares more than 10% of patents.

3.4.2 Sample construction and description

In order to investigate the determinants of software patenting at the firm level, a link has been established between a subset og GAUSS database (2000-03) and the "2004 EU Industrial Research Investment Scoreboard"[14], which lists the research and development spending[15] together with other relevant information, of the top 500 EU and top 500 Non-EU corporate R&D investors for the years 2000-2003. In order to establish proper linking relations, a semi-automatic data process to match companies to applicants has been performed. A specific small software application has been developed performing automatic matching between firms' values and requiring explicit operator's confirmation only in cases in which applicants were not univocally identified. In particular, we followed a three stage procedure. At the beginning, we matched firm's name from the R&D scoreboard with patent assignee name from GAUSS. After that, we re-matched the two database via the name of subsidiary companies. Those were individuated through a particular feature contained in Amadeus and Osiris database. Finally, we matched by firm's name the resulting database with both Amadeus and Osiris consolidated data in order to retreive additional information for our analysis (see figure 3.16).

A resulting dataset obtained by linking the information available in the mentioned sources is composed by ??? firms whose data concerning Research and Development spending, sector and geographic classification, number of software patents published are available for the period 2000-2003. With regard to 2003, about ??? companies revealed to have filed software patents to EPO.

[14]Produced as a part of the "Investing in research: an Action Plan for Europe COM(2003)226 - EC DG Joint Research Centre".

[15]Based on annual audited reports, calculated at consolidated group level.

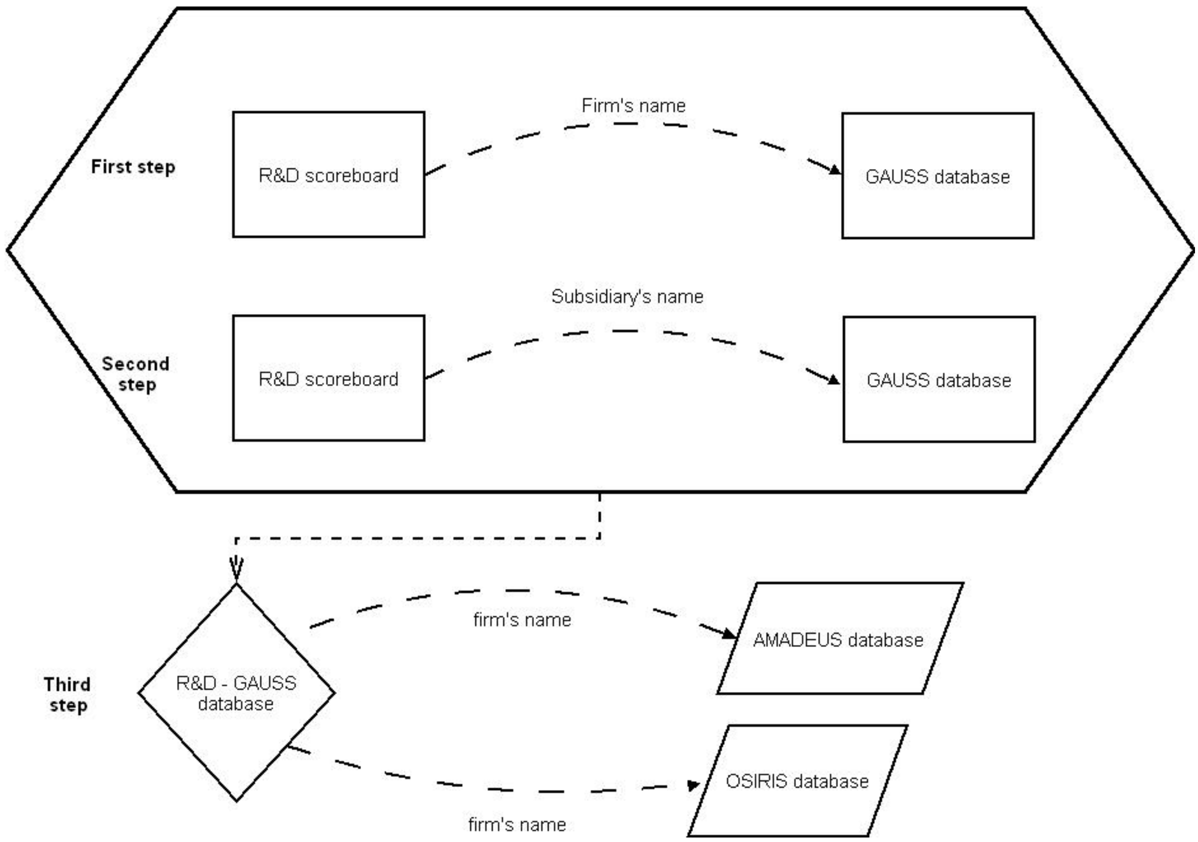


Figure 3.16: Database construction procedure

In order to check the representability of our sample we performed two main comparisons:

1. ANBERD database vs R&D-GAUSS. In this first phase we compared the representability of our dataset with data from ANBERD. The latter is a comprehensive database containing information on the R&D spending by 21 OECD countries. Our database is found to perform very well with respect to this. Indeed, it accounts for the 73% of R&D conducted by countries contained in the ANBERD database. Moreover, whether the comparison is done at the sector level R&D database accounts for the 71,35% of R&D performed[16].

2. EUROSTAT vs R&D-GAUSS. While from the R&D spending point of view we are pretty sure that the sample taken into consideration is representative, we can not say the same whether we take into account the number of enterprises. We checked for trustful statistics of the number of enterprises at the OECD level, but our attempt has been disappointed by the presence of a high quantity of missing values. So we decided to rely on European statistics, drawn from EUROSTAT.

According to the results derived from this comparisons we conclude that, as expected, our sample is not completely representative of both European and foreign companies. At the same time, we have not been able to implement a post-stratification procedure to correct for existing biases. This is due to the unavailability of OECD data for the years of interest[17]. From the previous analysis we can conclude that our sample is not representative for the whole population of companies at the EPO, but that it gives a clear and reliable picture of the R&D spending and of other relevant variables, i.e. turnover. We interpreted this fact as the capacity of our sample to describe correctly the behaviour and characteristics of large firms applying for EPO software patents [18]

Once checked for the reliability of our sample, we can shift to provide a general description of the dataset.

[16]In this second case the comparison is not as reliable as in the first case. This is mainly due to the different sector classification characterizing the analysed datasets. Indeed, while OECD data follow NACE industrial classification R&D scoreboard are organised through FTSE one. In order to compare the two data sources we have built a NACE-FTSE table of comparison, nevertheless this is far from being totally completed.

[17]We have faced two order of problems: either a lot of missing values ar present or data for more than the 20% of countries are lacking.

[18]For a more comprehensive discussion on the representability of R&D scoreboard on large companies see Frietsch (2004).

Not surprisingly, Aerospace and defence, Automobiles and parts, Electronic and electrical, Pharmaceuticals and Biotechnologies and IT hardware are sectors where the highest level of R&D takes place. Electronic and Electrical, IT Hardware, Media and Entertainment, Telecommunication services and Software and computer services sectors are found to have the highest average number of software patents filed.

Sample statistics for the final subset of the dataset are presented. Tables 3.1 and 3.2 put forward an expected pattern of the sample, namely the high number of firms not applying for any patent. Indeed, more than 50% of firms in the sample do not apply for any patent. This structure of the dataset calls for the implementation of a sound econometric model able to take into account data's specific pattern. At this respect, the choice made of adopting count data models is supported from both the nature of the depending variable and the structure of the dataset. Moreover plotting the number of filed patents against two of the relevant variables for the analysis, i.e. R&D spending and sales, highlights the better fit reached by a Poisson distribution with respect to a linear one (green line against red one in figures 3.17 and 3.18).

Table 3.1: Final sample summary statistics

Year	Stats	R&D	Turnover	Employees	Concentration	Strategic
2000	N	890.00	928.00	979.00	979.00	979.00
	mean	1603.47	8016.70	27067.51	0.32	9405.60
	max	33963.74	205863.84	449594.00	1.00	24740.00
	min	4.74	0.70	14.00	0.22	0.00
	sd	3858.68	18494.29	52050.49	0.14	9524.31
	p25	146.92	589.05	2096.00	0.24	370.00
	p50	413.78	2064.51	8336.00	0.26	4695.00
	p75	1088.51	6930.29	24985.00	0.40	12915.00
	iqr	941.59	6341.24	22889.00	0.16	12545.00
2001	N	890.00	950.00	979.00	979.00	979.00
	mean	1708.06	8214.46	26412.22	0.32	8939.12

Table 3.1 – Continued

Year	Stats	R&D	Turnover	Employees	Concentration	Strategic
	max	36261.30	187310.34	477100.00	1.00	23333.00
	min	8.63	1.11	1.00	0.21	0.00
	sd	4084.97	18433.70	51212.50	0.13	9074.41
	p25	164.97	602.46	2099.00	0.25	399.50
	p50	442.53	2093.24	7106.00	0.26	4065.75
	p75	1161.69	7251.32	26978.00	0.36	12955.75
	iqr	996.72	6648.86	24879.00	0.12	12556.25
2002	N	890.00	970.00	937.00	979.00	979.00
	mean	1800.93	8172.71	28092.79	0.32	8406.39
	max	38513.90	186564.42	445100.00	1.00	21637.05
	min	11.69	2.07	16.00	0.21	0.00
	sd	4265.76	18468.45	51243.22	0.12	8520.52
	p25	182.18	612.15	2388.00	0.24	457.05
	p50	487.85	2017.04	9169.00	0.29	3496.89
	p75	1180.45	7233.66	29682.00	0.34	12932.39
	iqr	998.27	6621.51	27294.00	0.11	12475.34
2003	N	890.00	976.00	954.00	979.00	979.00
	mean	1888.90	8485.86	27287.03	0.32	7684.41
	max	40228.82	212971.50	419300.00	1.00	19571.49
	min	19.62	1.10	15.00	0.21	0.00
	sd	4436.47	19951.28	49760.61	0.12	7782.23
	p25	201.69	619.64	2505.00	0.23	535.49
	p50	503.92	2097.23	9090.50	0.31	2995.35
	p75	1262.06	7677.92	28708.00	0.34	12295.53

Table 3.1 – Continued

Year	Stats	R&D	Turnover	Employees	Concentration	Strategic
	iqr	1060.37	7058.28	26203.00	0.11	11760.04
Total	N	3560.00	3824.00	3849.00	3916.00	3916.00
	mean	1750.34	8225.15	27204.84	0.32	8608.88
	max	40228.82	212971.50	477100.00	1.00	24740.00
	min	4.74	0.70	1.00	0.21	0.00
	sd	4166.59	18849.06	51063.54	0.13	8769.62
	p25	171.91	601.74	2237.00	0.24	451.19
	p50	468.85	2071.44	8316.00	0.26	4065.75
	p75	1179.39	7289.12	27690.00	0.39	12955.75
	iqr	1007.49	6687.38	25453.00	0.15	12504.56

Source: Own computation on R&D-GAUSS

Table 3.2: Final sample summary statistics - filed patents equal to zero

Year	Stats	R&D	Sales	Employees	Concentration	Strategic
2000	N	631.00	664.00	708.00	708.00	708.00
	mean	959.18	6332.12	19625.59	0.33	8149.83
	max	32964.81	205863.84	449594.00	1.00	24740.00
	min	4.74	0.70	14.00	0.22	0.00
	sd	2808.51	17080.79	41438.49	0.15	8902.68
	p25	102.07	386.10	1566.00	0.24	370.00
	p50	301.39	1529.04	6502.00	0.26	4695.00

Table 3.2 – Continued

Year	Stats	R&D	Sales	Employees	Concentration	Strategic
	p75	690.54	5470.73	18622.00	0.45	12915.00
	iqr	588.47	5084.63	17056.00	0.22	12545.00
2001	N	640.00	692.00	717.00	717.00	717.00
	mean	953.47	6652.76	19313.21	0.32	7845.64
	max	34213.48	187310.34	379544.00	1.00	23333.00
	min	8.63	1.11	1.00	0.21	0.00
	sd	2753.79	17608.36	38810.48	0.14	8551.94
	p25	111.92	373.08	1490.00	0.25	399.50
	p50	326.85	1595.30	5714.00	0.26	4065.75
	p75	735.50	5304.37	18380.00	0.43	12955.75
	iqr	623.57	4931.29	16890.00	0.18	12556.25
2002	N	643.00	709.00	686.00	717.00	717.00
	mean	1177.19	6441.60	20270.90	0.32	7344.71
	max	38513.90	186564.42	370677.00	1.00	21637.05
	min	11.69	2.07	16.00	0.21	0.00
	sd	3534.79	17505.39	40288.82	0.13	8050.08
	p25	121.17	416.83	1813.00	0.24	442.57
	p50	359.72	1504.44	6949.00	0.27	3496.89
	p75	789.43	5240.48	20500.00	0.34	12932.39
	iqr	668.26	4823.65	18687.00	0.11	12489.81
2003	N	712.00	788.00	771.00	791.00	791.00
	mean	1174.80	6718.81	20004.82	0.32	6915.98
	max	35458.13	212971.50	370684.00	1.00	19571.49
	min	19.62	1.10	15.00	0.21	0.00

Table 3.2 – Continued

Year	Stats	R&D	Sales	Employees	Concentration	Strategic
	sd	3213.56	18571.83	37155.59	0.13	7500.11
	p50	409.33	1623.28	6977.00	0.26	2995.35
	p75	922.83	5720.35	21131.00	0.39	12295.53
	iqr	783.58	5265.72	19243.00	0.15	11844.34
Total	N	2626.00	2853.00	2882.00	2933.00	2933.00
	mean	1069.63	6543.90	19802.93	0.32	7545.89
	max	38513.90	212971.50	449594.00	1.00	24740.00
	min	4.74	0.70	1.00	0.21	0.00
	sd	3099.05	17726.25	39379.85	0.14	8257.13
	p25	119.04	412.62	1738.00	0.24	450.47
	p50	345.01	1565.57	6540.00	0.26	3496.89
	p75	783.56	5393.33	19682.00	0.39	12932.39
	iqr	664.52	4980.72	17944.00	0.15	12481.92

Source: Own computation on R&D-GAUSS

3.4.3 Variables

In this section we will proceed to describe the variables implemented during the econometric estimation. Dependent variables change according to the type of model adopted. In particular, dependent variable is of a numeric type when either the poisson or negative binomial model is adopted. This happens cause we are interested on the number of patents filed by the single firm at year t. In this case the variable is computed as the stock of filed patents a firm files in the present year (for a description of the procedure through which the value is computed see Appendix B). On contrary, dependent variable is dichotomous when a logit model is investigated. This is due to the main goal of our analysis in this case, that is whether the firm is applying for patents or not. This is why

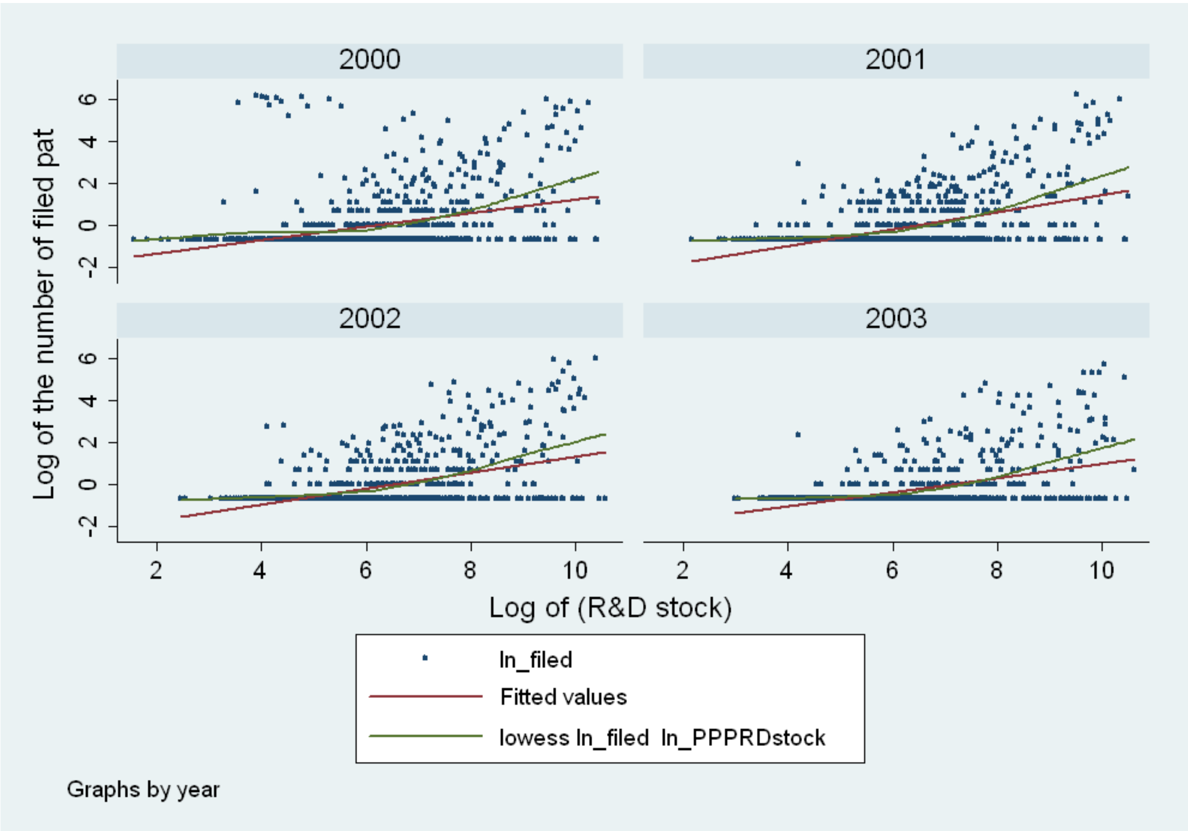


Figure 3.17: Plots of filed patents against R&D stock, 2000-03

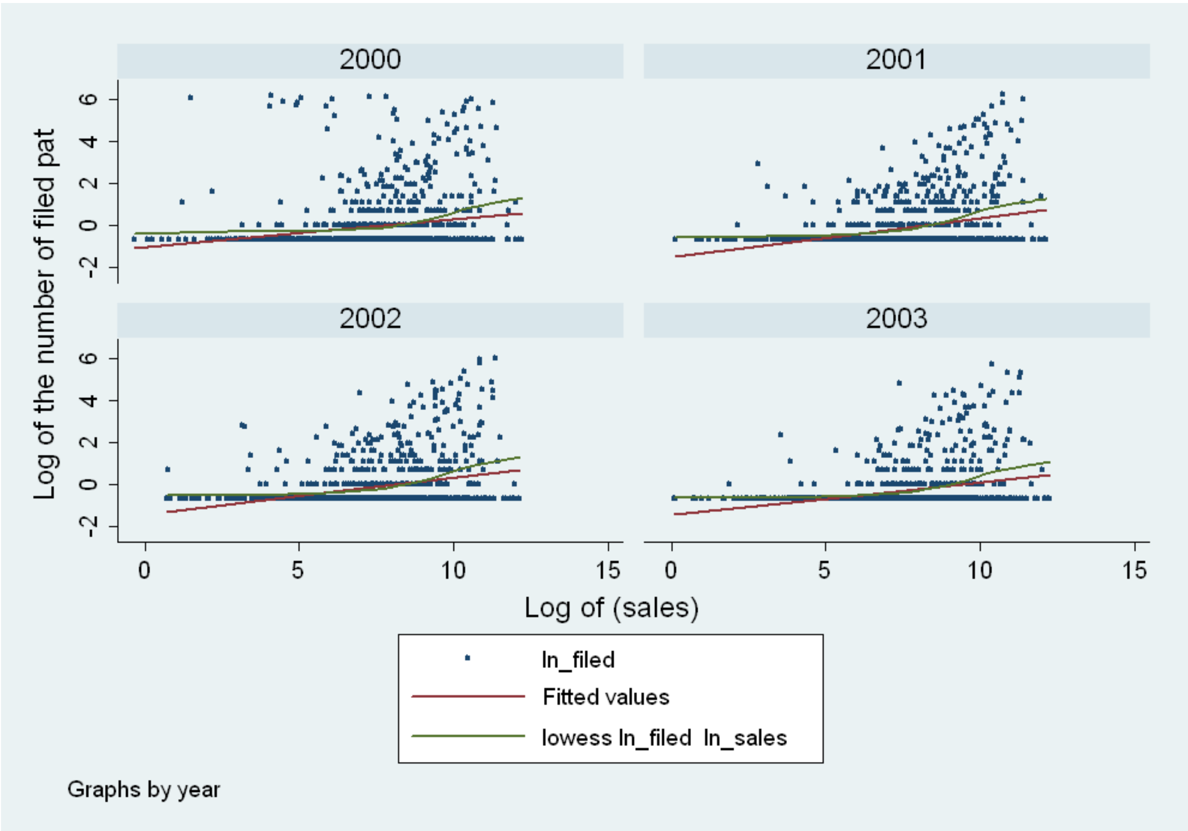


Figure 3.18: Plots of filed patents against sales, 2000-03

the variable is taking only two values: value one in case firm files a software patent, zero otherwise.

Independent variables can be divided into two main groups: structural and control variables. Structural variables include all those variables that are object of the analysis throughout different specifications. These variables are:

1. R&D spending$_{i,t}$. This is the amount of the R&D spending performed by firm i at time t. The amount has been transformed in 1995 PPP$ to allow comparability among different countries. Furthermore, it has been expressed as a stock (see Appendix B). According to our theoretical model this should be a very important variable directly related to the stock of software patents filed at the European Patent Office.

2. Sales$_{i,t}$. This is the amount of sales done by firm i in year t. The same transformations as for the R&D spending has been conducted. Indeed, both 1995 PPP$ and stock have been computed.

3. Employees. The number of employees for firm i at time t. This variable proxies for firm size and it influences the number of software patents filed. In fact, larger firms are likely to have more resources at their disposal in order to apply for more patents. This is even more likely to happen in the EU where the average cost of a patent is higher than in other patent systems (Malerba and Montobbio 2002).

4. Sector concentration. This has been computed as the total sales of the four largest firms in terms of sales in firm's i main sector of operation divided by the total sales of the sector. This has been done following the FTSE sector classification. By definition, this is based on firms operating in the same sector and it does not always reflect the impact of direct competitors. Unfortunately, this is the best approximation we have been able to make according to available data.

5. Strategic rivarly. This is the stock of software patents filed by firms belonging to the same sector of firm i in year t. This variable proxies for the influence of strategic factors on the software patenting of firms in the sample. Indeed, most of the time firms apply for sofware patents only because this is a way to strategically hinder their competitors. Patenting inventions is a way to reduce the value of other firms' innovation and to decrease their average return to R&D while affecting own market value (Noel and Schankerman 2006).

6. Stock of software patents filed in the previous year. This is the stock of software patents filed by firm i in year $t-1$. This variable takes into account the effect on software patenting decision by the number of software patents filed in the former year.

On the contrary, control variables are all those variables that are implemented in order to control for factors which are essentially country and sector specific. These variables are:

1. Year dummy. This is a dummy variable taking into account the effect of external outcomes to the knowledge production function. In particular, it gives an hint on the institutional context where the firm is operating and about the different happenings taking place.
2. Geographical proxy. We use this variable to disentangle the an effect produced by the different patent systems a firm has been used to. A firm that is used to operate inside the US have a deep knowledge concerning both the intrisic and strategic value an invention is likely to produce once patented. On the contrary, the blurred situation characterising the EU patent system should be interpreted like a hindering mechanism.
3. Sectoral/Technological proxy.

3.5 Results

Table 3.4, 3.6 and 3.5 show results for the panel data poisson regression model. Interesting results are obtained for the software and computer service sector; here R&D spending is not significantly related to the number of software patents firm applies for. This result is likely to confirm the fact that, in this sector, patent is not considered a useful appropriability instrument of the results of R&D process. In fact, the absence of a significant relationship between the two variables supports our belief that R&D contributes to the creation of knowledge capital and innovation but that software patents do not proxy well the innovation output, meaning that they are not deemed as suitable appropriability measures for firms operating in this sector. On the other side, number of employees seem to play an important role for software patenting at the firm level, pointing out the importance of the presence of a legal department handling IPRs (Lerner 1995). There are economies of scale in generating patents and larger firms can exploit them better, thanks to the rich endowment of financial resources devoted to IPRs managing departments. The last interesting result coming from our analysis refers to the significance of the variable proxying, at least partially, the role of strategic factors. The number of software patents granted to firms other than the firm applying for software patents is significant and positive. This means that the amount of software patents granted in the same year at firms belonging to the same sector of activity contributes to explain the number of software patents firm i applies for. We interpret this result as a sign of strong strategic factors inside the software sector. Firms in this sector are not likely to patent software to appropriate results of the R&D process; but, at the same time, they are eager to patent if they feel the threat of firms in the same sector of activity. This threat effect is intrinsically due to the nature of the software technology that is of a cumulative type. An increase in the amount of software patents accorded to neighbor firms can hinder future development of software by present company spurring it to apply for patents as defensing strategy.

Results for the IT hardware sector differ considerably[19]. No relationship can be individuated between $OTHERPAT_{i,t}$ variable and the number of software patents meaning that no threat effect is present by other hardware firms. Nevertheless, Firm size is still significant even if the coefficient is lower than the one found in software sector. On the contrary, R&D spending ($RDxEMPL_{i,t}$) and number of patents granted to the firm in the former year ($FILED_{i,t-1}$) have become significant factors affecting the number of patents firm applies for in the current year. But, while the latter, even if significant, has a very low value (namely 0.007), the former is both significant and sizable.

3.6 Discussion and Conclusion

The main goal of this chapter has been to give a preliminary account of a phenomenon that has been disregarded by the economic literature so far, namely software patenting in the European Union. As we saw, the fact that European Patent Convention expressively prohibits software patenting has not been a major problem for firms and inventors who have patented software as well. General statistics show the increased overall number of patents accorded by the European Patent Office (EPO) starting from the second half of the 90s. The overall upsurge has been mainly driven by patents accorded in ICTs and

[19]Results are likely to be biased upward due to the difficulty of separating the share of R&D expenditures devoted to software development and the share used for other purposes.

Biotechnology fields. Software patents are surely an important part of the former: a rough indication of this could be deduced by the number of patents falling in particular IPC classes (see table 3.3 and fig. 3.4).

A second main goal of our work was to find relevant factors explaining software patenting by firms at the EPO. First of all, a reliable database of software patents is presented. These patents are accorded by the European Patent Office and, to our knowledge, more than 40,000 software patents have been issued till now to European and Non-European firms. To this respect, a large part of them has been accorded to American and Japanese firms. The fact that nearly the majority of granted patents belong to foreign companies must be due to the higher experience that these firms has acquired dealing with their own patent system. For example, in US software is a subject of patentability since a long time; this means that firms have more expertise both in dealing with application procedures and in identifying more valuable inventions to be patented. Then, the knowledge production function (KPF) approach is adopted to understand factors affecting the output of the innovation process at the firm level. The model has been extended to incorporate factors deemed important to explain recent patenting strategies (strategic factors, firm size, technological and geographical opportunities) and to deal with our specific interests (namely software and hardware sectors). The way in which the dataset has been built and the method of estimation are then presented, putting forward also some interesting findings (average length of software patents' granting procedure, sectors applying for the majority of software patents, ownership). Finally, results of the chosen econometric model are presented. The fact that patents are not deemed as useful appropriability instruments by firms belonging to the software sector and the presence of a growing threat effect by other firms in the same sector are the main outcomes of the analysis.

We are aware of limitations to the present work. First of all, the reliability of GAUSS.ffii database must still be tested in a systematic way. Second, the EU Scoreboard, on which we rely to link firms' characteristics with number of software patents filed, allows us to take into consideration the behaviour of large firms only. Small and Medium Enterprises (SMEs) together with their software patenting strategies are totally disregarded. Third, there has not been the possibility to separate R&D expenditure used in software production from the one used for other purposes. Fourth, the number of engineers and programmers is not available from our data sources. Nevertheless, to our knowledge, our work is the first attempt to give an account of the existence, determinants and direction of a diffused phenomenon such as software patenting. Above mentioned deficiencies will be corrected in future works in order to deepen the understanding of the topic.

Table 3.3: IPC and ISIC concordance for GAUSS patents

	Number of patents	IPC	ISIC description
1	608	H04L29/06	Electronics
2	432	G06F17/30	Computers and Office Machines
3	314	H04L12/56	Electronics
4	295	G06F1/00	Computers and Office Machines
5	294	G06F17/60	Computers and Office Machines
6	255	H04Q7/38	Electronics
7	253	G06F9/46	Computers and Office Machines
8	219	H04Q11/04	Electronics
9	194	G06F9/44	Computers and Office Machines
10	186	H04N7/173	Electronics

Table 3.4: Poisson panel data estimation

Variales	**FE**	**RE (1)**	**RE (2)**	**RE (3)**
Patstock_int				
Pat_1	0.000***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
R&D	-0.053	0.083*	0.032	-0.047
	(0.048)	(0.040)	(0.039)	(0.039)
Sales	0.063***	0.058***	0.067***	0.074***
	(0.017)	(0.017)	(0.017)	(0.017)
Employees	0.002	0.133***	0.091**	0.020

Table 3.4 – Continued

Variales	**FE**	**RE (1)**	**RE (2)**	**RE (3)**
	(0.044)	(0.036)	(0.035)	(0.035)
Strategic	0.295***	0.205***	0.291***	0.167**
	(0.063)	(0.044)	(0.040)	(0.051)
Conc	0.105	0.138	0.117	0.074
	(0.070)	(0.074)	(0.067)	(0.068)
Dyear01		-0.000		
		(0.010)		
Dyear03		-0.038***		
		(0.008)		
DCusa			0.339	
			(0.619)	
DCeu			0.702	
			(0.624)	
DCjapan			0.913	
			(0.651)	
DSelectr				1.734***
				(0.481)
DSeng				-0.818
				(0.430)
DShard				1.419***
				(0.398)
DSmedia				1.624
				(0.830)
DSsoft				0.841
				(0.436)

Table 3.4 – Continued

Variales	FE	RE (1)	RE (2)	RE (3)
DStel				1.100
				(0.810)
cons		0.742	-0.349	1.014*
		(0.423)	(0.771)	(0.419)
lnalpha				
cons		2.474***	2.469***	2.418***
		(0.058)	(0.058)	(0.058)
chi2	986.624	1092.611	1085.387	1118.818
N	1109.000	2576.000	2576.000	2576.000
ll	-1706.296	-4318.334	-4326.839	-4311.906

The specification of the model relies on Wooldridge (2005).

Table 3.5: Poisson panel data estimation: a comparison between software and hardware sector.

Variales	Soft (1)	Soft(2)	Hard(1)	Hard(2)
Patstock_int				
Pat_1	-0.000	0.001***	-0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.495*	0.602*	0.068	0.086
	(0.235)	(0.296)	(0.059)	(0.060)
Sales	-0.033	0.117	0.039	0.091***
	(0.075)	(0.073)	(0.028)	(0.027)

Table 3.5 – Continued

Variales	Soft (1)	Soft (2)	Hard (1)	Hard (2)
Employees	0.418*	0.755**	0.109*	0.173**
	(0.182)	(0.241)	(0.054)	(0.054)
Strategic	-32.276***	-1.070	-53.768***	0.908*
	(4.543)	(0.741)	(7.862)	(0.377)
Dyear01	5.736***			
	(0.827)			
Dyear02	3.337***		-4.117***	
	(0.480)		(0.601)	
Conc		-0.622		0.562
		(0.779)		(0.382)
DCusa		-1.243		-0.635
		(2.284)		(1.224)
DCeu		1.251		0.033
		(2.327)		(1.269)
Dyear03			-9.611***	
			(1.397)	
DCjapan				-0.101
				(1.363)
cons	319.348***	8.111	543.408***	-5.225
	(44.823)	(7.123)	(79.076)	(3.544)
lnalpha				
cons	2.312***	2.292***	1.557***	1.735***
	(0.180)	(0.179)	(0.128)	(0.122)
chi2	329.830	293.510	398.213	347.918
N	265.000	265.000	395.000	395.000

Table 3.5 – Continued

Variales	**Soft (1)**	**Soft (2)**	**Hard (1)**	**Hard (2)**
ll	-494.812	-515.748	-1089.464	-1112.539

The specification of the model relies on Wooldridge (2005).

Table 3.6: Panel data logit estimation

Variales	**FE**	**RE_Soft**	**RE_Hard**
Pat			
R&D	6.414***	2.905***	1.140**
	(1.311)	(0.619)	(0.405)
Sales	-0.579	-0.951*	0.245
	(0.614)	(0.484)	(0.385)
Employees	6.193***	1.994***	1.225***
	(1.156)	(0.318)	(0.197)
Strategic	0.376	-32.005***	-18.012*
	(1.172)	(9.373)	(7.206)
Conc	2.454	-34.066**	-17.289*
	(2.392)	(10.549)	(8.313)
cons		263.567**	151.308*
		(80.289)	(61.927)
lnsig2u			
cons		1.981***	2.191***
		(0.211)	(0.158)
chi2	57.361	46.898	51.808

Table 3.6 – Continued

Variales	FE	RE_Soft	RE_Hard
N	474.000	354.000	528.000
ll	-147.472	-110.745	-179.285

Chapter 4

Open Source Software in the Public Sector: Results from the Emilia-Romagna Open Source Survey (EROSS)

In the present chapter we will provide a description of the study carried out for the Emilia-Romagna Region concerning the adoption of Free/Libre Open Source Software (henceforth FLOSS) by Public Administrations (henceforth PAs) located in Emilia-Romagna. This is a well-developed Italian region which has been characterised in recent years by strong commitments towards e-government investments (120 Mil in the period 2002-2005). The region is one of the few in Europe to be provided with a public administration broadband infrastructure that connects the whole territory. It has been adopting a plan on information society since 1999 and it relies on a strong tradition of efficient and innovative public administrations. Furthermore, it has been characterised by a fruitful collaboration with many universities present on the territory and conspicuous public investments in research and innovation policies. Finally, Emilia-Romagna region is a board member of European Regional Information Society Association.

As it will be shown in the following paragraphs (section 4.1 and section 4.2) Emilia-Romagna has been very active in the area of the ICTs and FLOSS, funding and directing several projects aimed at understanding them and at drawing policy conclusions.

The initiative we are going to describe here is named "Emilia-Romagna Open Source Survey (EROSS)" (section 4.3) The main unit of analysis is represented by PAs of single municipalities. Its key objective is to reveal which are the main software types adopted by the PAs with a particular emphasis posed on FLOSS. Data were initially collected via an online questionnaire submitted to the managers of information system divisions. At a second stage, collected data were integrated with information contained in UNDERSTAND[1] This bunch of data allowed us both to create the identikit of an average municipality using FLOSS and to measure the intensity through which these organisations adopt FLOSS solutions.

The results (section 4.4) show a lively pattern inside the region, with several administrations relying on FLOSS(70% of our sample). Extremely relevant is the number of organisations which are managing servers exclusively through FLOSS. At the same time, a small number of PAs decided to go even further and have adopted FLOSS applications on the desktop side. Finally, when the intensity of FLOSS utilization is compared between client and server it is found that the adoption of FLOSS has a well known pattern. It is likely that the adoption starts from the server side and, only after that it has sufficiently developed, it shifts to the client side.

The analysis concludes pointing out advantages and disadvantages connected with the adoption of FLOSS by local governments (section 4.4). The conclusive part puts forward tentative policy recommendations towards FLOSS adoption.

The present study must be taken as the initial step of a more comprehensive analysis to be carried out in the next years. The aim of future research will be to get additional useful insights which can be profitably exploited in order to develop policy actions in the direction of FLOSS adoption by PAs at both regional and national level.

4.1 The ICT regional sector: from a national to a regional perspective

It is a well recognised stylized fact that the most competitive economies all over the world are characterised by a set of common factors, i.e. the presence of a lively ICT sector together with the diffusion of the ICTs all over the society (van Ark, Inklaar, and

[1] UNDERSTAND (European Regions UNDER way towards STANDard indicators for benchmarking information society) is an Interreg IIIc project aiming at comparing and evaluating regional development of the information society by defining and applying a set of common regional e-indicators on internet usage. Ten European regions, all experienced in benchmarking information society, are partners in the project which was proposed and is leaded by Emilia-Romagna Region. UNDERSTAND collected data on ICT adoption and usage for Emilia-Romagna municipalities, for years 2004 and 2005.

McGuckin 2003). Furthermore, one of the factors contributing mostly to the productivity gap between the US and Europe is the difference in the intensity of adoption of ICT in the production of goods and services.

This means that both ICT demand and supply must be favoured by economic policies as a prerequisite for productivity growth and, as a consequence, for economic growth. To do that, ICT availability and its intensity of adoption must be encouraged as the most important strategic factors, favouring both human capital investment and competitiveness.

Given the central role played by the ICTs nowadays in both the economy and the society, it must be investigated the way through which their widespread adoption can be achieved. PAs should cover a central role at this respect, thanks to the possibility for them to adopt technologies that are not profitable in the short-run. Moreover, ICTs are likely to reduce costs and increase the quality of services provided.

In the recent years, the Emilia-Romagna regional government moved towards this direction following European guidelines. Indeed, all the projects that have been launched in the last ten years were targeted to foster the growth of the "knowledge economy" where the role of the ICTs is paramount.

In order to spur the development of the ICT sector, Emilia-Romagna put forward a set of actions aimed at:

1. Sustaining and incentivazing their adoption by both citizens and companies.
2. Guiding the expenditure in the ICTs by the PAs and, more in general, investment of local municipalities.

Examples of the programmes which have been put in practice following the mentioned guidelines are:

1. The regional program for industrial research, innovation and technological transfer (PRRIITT). Its main objective is to strengthen the regional production system by different means: (a) stimulate applied research in both competitive and innovative areas, (b) increase the innovative content in the production of goods and services and (c) stimulate the growth of the regional knowledge economy.
2. The regional telematic plan 2002-2005. It contains provisions to invest resources in the telecommunication infrastructure named LEPIDA (a regional broadband

network owned by the regional government itself). In addition, it prescribes the creation of applicative platforms devoted to several tasks, among which it is worth mentioning the modernization of the organization of labour and the rationalization of internal processes in order to provide citizens and companies with more efficient public services.

4.2 FLOSS and Public Administrations: United They Stand

The Free/Libre Open Source Software (FLOSS) is a phenomenon that has acquired of importance in recent years. Its diffusion and reliability has improved at an outstanding pace both at the public and private level. This upsurge has characterised both PAs and private enterprises. Indeed, they have started to rely heavily on the advantages characterising this alternative method of software production (Bonaccorsi and Rossi 2003).

Notably, public administrations have been at the forefront of the above mentioned dynamic. The predominance of the studies concerning public administrations can be explained via three main orders of reasons.

First of all, PA is seen as the ordinary place where FLOSS can be implemented. In fact, contrary to the private sector, public organisations respond to a set of different incentives and have different aims. Above all, they tend to provide citizens with services of high quality and, at this regard, FLOSS is likely to be a useful instrument to accomplish the task. The high technical quality and the saving on licence fees from private software vendors are factors affecting the productivity of services provided by the PAs (Lerner and Tirole 2002, Ghosh 2002).

Second, interesting case studies have shown that a structured adoption of FLOSS by local governments have fostered the rate of development of the relative local community. An emblematic example is surely Extremadura region in Spain where a concerted adoption of OSS has encouraged the entrepreneurial spirit in the Extremadura ICT sector and has spurred the creation of innovative business activities[2]

Third, the development of a bundle of high level competences is fostered by the

[2] For an exhaustive description of Extremadura case study see http://ec.europa.eu/idabc/en/document/1637/470.

adoption of FLOSS. Indeed, developing tailored solutions inside public administration is a way to invest on employees' competences (Varian and Shapiro 2003).

Many studies dealt with the state of the art of FLOSS in the PAs[3]These studies have been mainly of a descriptive type while reasons concerning the adoption of the FLOSS by public bodies and the impact of such a decision have been systematically disregarded. To our knowledge, the only contribution in this direction is the Free/Libre Open Source Software – Policy Support (FLOSSPOLS) study. The latter is a government survey conducted on both local and regional government authorities of 13 European countries in year 2005. The main results from the study have shown that FLOSS is used in about half of the EU local government authorities, while almost 70% of FLOSS users and 38% of FLOSS non-users are greedy of increasing the future use of FLOSS. We can think to the former as the supply of FLOSS by government organisations, which seems to be still quite limited, while the latter can be interpreted as users demand, which is evidently stronger. In addition to this general statement, the study has tried to give a preliminary account of both important drivers and main barriers to the adoption of FLOSS in government bodies (Ghosh and Glott 2005).

In the area of FLOSS, Emilia-Romagna government has been quite active and has put forward two main initiatives relative to software and its applications with particular interest on FLOSS. These initiatives are the observatory for innovation and technological transfer on open source software (OITOS) and the Emilia-Romagna open source survey (EROSS).

The former is a newly constituted organization mainly concentrating on FLOSS by the point of view of private enterprises. Its main objective is to provide companies with useful information about tools and standards from the ICT world with a particular emphasis on FLOSS. The latter is seen as a strategically important instrument to support both innovation and economic growth into the region.

On the contrary, EROSS deals with PAs focusing mainly on the state of the art and practices on FLOSS adoption.

[3]In addition to studies concerning the situation of government organisations in general, such as OSOSS (Ghosh and Glott 2003) and FLOSSPOLS, several studies dealt with more specific cases. An exhaustive list of European case studies is available at the Open Source Software Observatory website (see http://ec.europa.eu/idabc/en/chapter/470).

4.3 The Emilia-Romagna Open Source Survey (EROSS)

EROSS main activity has been the creation of a clear picture on the state of the art of FLOSS inside Emilia-Romagna region. In particular, we prepared a survey to investigate the intensity of adoption together with the level of penetration of FLOSS inside Emilia-Romagna municipalities.

The empirical study has been conducted in collaboration with Emilia-Romagna Region and its regional Competence Centre for e-government and information society (CRC) and it is composed of three main parts.

First, several interviews with PAs and their suppliers, both active in FLOSS adoption and distribution, have been carried out. Managers of information systems for the municipalities of Modena, Argenta, Reggio Emilia and the AUSL of Parma were interviewed. This part aimed at collecting opinions and experiences which can drive us in the difficult task of understanding factors affecting public administrations' processes together with their needs.

Second, a specific online questionnaire has been submitted to all Emilia-Romagna municipalities. The questionnaire has been built up keeping in mind experiences already accomplished at both the national and international level. In particular, the FLOSSPOLS study has played a major role in guiding us in the choice of questions and implementation procedure (Ghosh and Glott 2005).

The submission period was from May to June 2006. All the managers of information system divisions have been able to access the online questionnaire and fill it in at any time. The number of collected answers has been 90, which corresponds to a response rate of 26,4%.

At a second stage, the aggregate of the inspected municipalities has been investigated in order to check sample's representability. We noticed that municipalities from Emilia-Romagna region have been correctly pictured both at the size and geographical level of analysis.

Overall, the number of software typologies that has been individuated the survey is equal to 20. We have grouped them in four main categories according to the domain of application: client/desktop, server, web and management system.

Furthermore, in order to measure both diffusion and pervasiveness of FLOSS adoption we have built up an index of the intensity of utilization. This is simply equal to the number of the instalments of FLOSS over the total number of instalments. The construction of this index, as it will be shown in the following paragraph, will be very useful to disentangle between a marginal use of FLOSS, i.e. test or simple curiosity, and a more consistent and effective adoption.

Moreover, we created the questionnaire in a way to let it easily integrate with already available data gathered by Emilia-Romagna benchmark study UNDERSTAND (Reg 2003). In this way, we relied on a short and compact questionnaire very useful to obtain a higher response rate.

Hence, the purpose of the questionnaire was threefold: evaluating the intensity of the adoption of FLOSS in specific areas (clients, servers, web, etc.), collecting information of both FLOSS and proprietary software, and integrating it with data from other sources, in particular with data from the project UNDERSTAND.

4.4 Results and discussion

The first striking result, shown in Figure 4.1, points out the presence of unaware FLOSS adopters, i.e. municipalities answering that they do not have FLOSS instalments and, at the same time, that they own some open source applications. This pattern is present in results from FLOSSPOLS as well (Ghosh and Glott 2005). To us, this result is a hint on the small amount of knowledge available in the area of FLOSS to Emilia-Romagna municipalities.

The percentage of FLOSS adopters inferred by EROSS 2006 survey comes out to be quite high, i.e. 70% of respondents are found to adopt FLOSS. If we compare this result with the same information obtained by UNDERSTAND we find a mismatch. Indeed, there we find a percentage of FLOSS adopters lower than the 38%. On the contrary, FLOSSPOLS reports similar statistics concerning the percentage of FLOSS adopters, namely almost 80% over a total of 955 European local governments (Ghosh and Glott 2005).

The high value of our estimate, as well as the one coming out from FLOSSPOLS study, must be attributed to a self-selection mechanism by which users most interested in FLOSS are more likely to have answered to the questionnaire.

As it has been claimed so far, EROSS questionnaire has been planned to be integrated

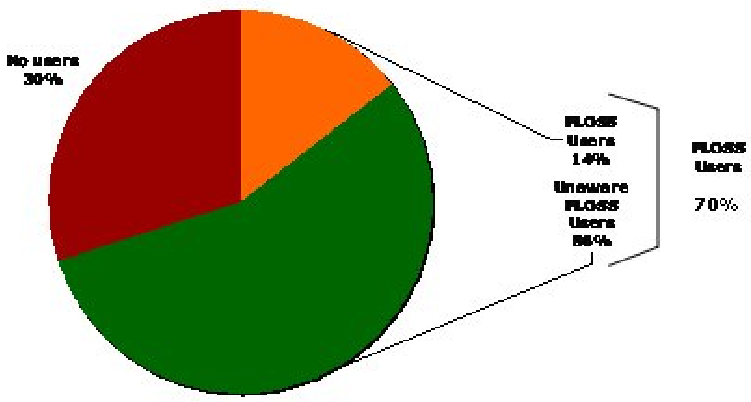


Figure 4.1: Municipalities adopting FLOSS

with data collected through UNDERSTAND survey. Merging the two datasets allowed us to display a clear picture of the characteristics of municipalities according to their FLOSS intensity of adoption. In Table 4.1 we first divide all the municipalities by the total intensity of FLOSS adoption (henceforth *ia*), i.e. no adoption (*ia*= 0%) moderate adoption (*ia*<20%) and high adoption (*ia*>20%). In this way we are able to underline the differences in the characteristics of the municipalities in their class of adoption and among them.

We can derive the main characteristics of the municipalities adopting intensively FLOSS by column 1. Indeed, municipalities with a high intensity of FLOSS adoption has, on average, a large size, they are furnished with a broadband connection and they have adopted an e-government/ICT strategy. Furthermore, the presence of a formal ICT structure, the ability to develop software internally and, finally, ICT training for employees are all relevant features. So, it looks like that the intense adoption of FLOSS

Table 4.1: Identikit of municipalities adopting FLOSS

	High intensity of adoption(ia>20%)	Moderate intensity of adoption (ia<20%)	No adoption ($ia = 0\%$)
Average size (# inhabitants)	47.788	13.580	4.654
# Municipalities	22	40	28
Do not have a broadband connection	0%	10%	21,4%
Do have a an e-government/ICT strategy	50%/50%	20%/27,5%	25%/14,3%
Do have at least an employee in the ICT division	63,6%	45%	21,4%
There is an ICT division	63,6%	42,5%	28,6%
Study and planning done internally	72,7%	35%	14,3%
Training in ICT organised since 2004	68,2%	42,5%	25%
Average interactivity of online services(2005)	46,5%	37,8%	28,6%
License fees per inhabitant	1,93	2,05	2,33
Average number of ICT suppliers	5,1	3,4	2,1

Source: UNDERSTAND 2005; EROSS 2006.

discriminates between those municipalities which see ICT as an important strategic support for institutional activities and those which are not able to, or do not want to, go into this direction.

In Table we show which elements are selected as the main obstacles for a correct adoption of the ICTs in the PAs, adopting the same classification used in Table 4.1. We note immediately that there are differences among the three groups. Municipalities with a high intensity of FLOSS adoption (column 1) rate the low flexibility of suppliers and the low interoperability of applications as the main obstacles to a correct implementation of the ICTs. For the two other groups, namely moderate intensity (column 2) and no intensity (column 3), main obstacles are the low number of employees and high costs. These differences in perceived obstacles can be interpreted as the causes that pushed some of the municipalities interviewed to experiment and, in a second instance, to adopt FLOSS solutions.

In Figure 4.2 it is shown the adoption intensity of FLOSS in the area of client/desktop. Desktop systems, e-mail clients, office automation (packages for personal productivity) and web browsing are the four sub-classifications that have been individuated in the area of client/desktop. The graph points out the fact that FLOSS desktop system is not widely adopted in the PAs of Emilia-Romagna (55 have installed Linux over a total

Table 4.2: Obstacles for the adoption of ICT inside the PAs

	High intensity of adoption (ia>20%)	Moderate intensity of adoption(ia <20%)	No adoption (ia = 0%)
Software flaws	4,55%	7,50%	17,86%
Reduced flexibility of suppliers	36,36%	7,50%	0,00%
Low interoperability of applications	59,09%	25,00%	25,00%
Low number of employees	13,64%	30,00%	57,14%
Difficulty in recruiting qualified employees	27,27%	10,00%	10,71%
Outdated ICT strategy	18,18%	20,00%	32,14%
High costs	27,27%	57,50%	57,14%
Early introduction of new versions of software	4,55%	12,50%	14,29%

Source: UNDERSTAND 2005; EROSS 2006.

of 13382). Moreover, more than the 10% of total instalments are found in only two municipalities.

On the contrary office automation, e-mail and web browsing are all cases where the intensity of adoption of FLOSS is very high (ai>50%). It is worth noting that the different levels in the intensity of adoption can be interpreted as the different stages a municipality passes through in the path to a complete migration, that are: test phase (ai <30%), experimentation (30% <ai<49%) and utilization/migration (ai>50%).

Overall, the number of municipalities adopting FLOSS from the client/desktop side is not negligible. Indeed, a complete migration towards FLOSS is very complex and this implies that the process could be slowed down by several obstacles. This is why these figures must be interpreted as very promising.

In Figure 4.4 we display the intensity of FLOSS adoption relative to the web servers. It is worth noting that few municipalities have internalized web server management and, as it is shown in Figure 4, server in general. Nevertheless, among them the major part is using FLOSS.

Moreover, 10 municipalities manage their own servers exclusively through FLOSS. Despite this, only on 44% of the web servers it is installed Apache. This is contrary to the world average that has figures equal to 60% concerning Apache[4]

From statistics obtained in Figure 4.4 we can see that 10% of municipalities manage applications, mail and file servers exclusively via FLOSS. This points out the role that FLOSS has acquired in the last 10 years in the management of critical services such as mail servers, file servers and application servers.

[4]For details see web server surveys at http://news.netcraft.com/

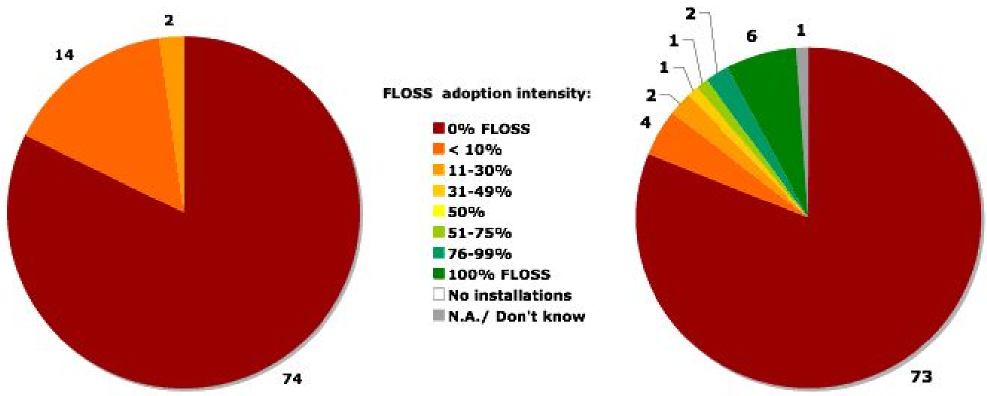


Figure 4.2: Software client/desktop (# Municipalities)

The applications devoted to the management and share of web contents (Figure 4.5) find a variegated supply of FLOSS applications which have behind them large communities composed by both developers and users. For what concerns municipalities in Emilia-Romagna we note that there is not a diffused adoption of instruments such as content management systems and groupware. Available data shows that there is not a clear predominance of one type of software compared to the other.

The answers collected on dedicated software, which is software tailored for PAs' specific needs, has been grouped in 8 different functional areas: economic-financial accounting, vital statistics, tributes, administration of the personnel, attendances, protocols, financial accounting, and management of the resolutions. These areas have not shown any adoption of FLOSS. In fact, preliminary interviews conducted on selected suppliers of the PAs has pointed out the fact that the market of dedicated software is essentially ruled by a restricted number of suppliers (11 in total) with half of them being Italians

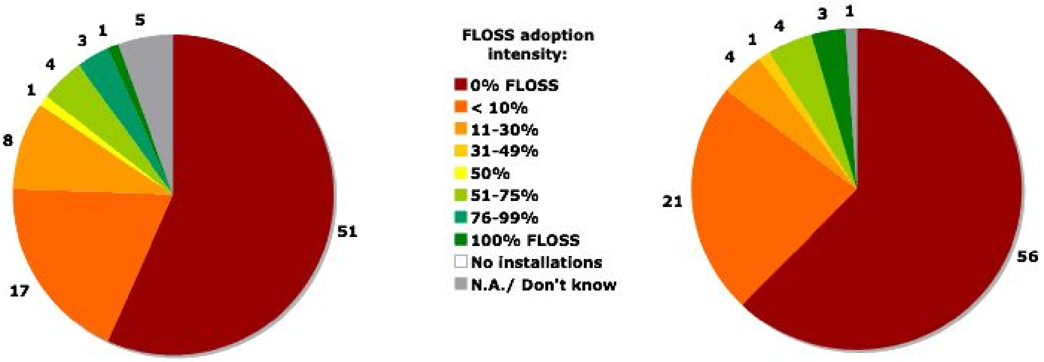


Figure 4.3: Web server (# Municipalities)

and the other half coming from Emilia-Romagna. This means that, pertaining dedicated software, customisation and strong ties with clients are very important. On the contrary, general purpose software can migrated more easily to FLOSS given the presence of lighter ties among PAs and regional companies.

In Figure 4.6 we compare FLOSS intensity of adoption in the area of client/desktop with the one on the server side. We depict single municipalities by means of bubbles of different sizes which represent the number of inhabitants. From the figure we individuate a precise path of FLOSS adoption. According to this, municipalities that first start adopting FLOSS on the desktop systems (bubbles on the horizontal axis) have previously adopted it on the servers (bubbles on the vertical axis). Indeed, the number of municipalities is heavily clustered on the left side of the graph and it is distributed almost vertically. This FLOSS path of adoption, first going upward and then turning on the right, is surely the most preferred one given minor risks municipalities are likely

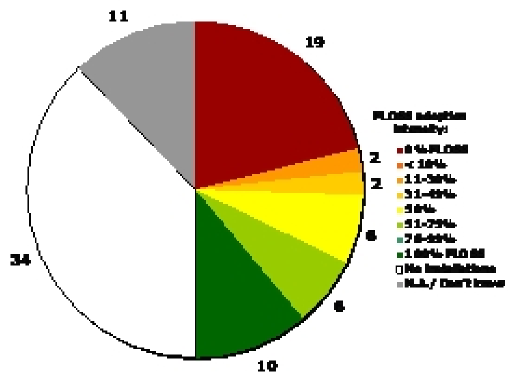


Figure 4.4: Software on the server side (% Municipalities)

to face.

The nature of this path is explained by the number of people who usually deal with migration. On the server side, few people are interested in the migration; they are usually information system administrators. On the client side, even non-expert users are concerned which means that the migration is likely to affect employees' work routines.

Finally, in Table 4.3 we present the name of FLOSS products which have been implemented in the PAs replying to the questionnaire. The fact that some of these are used almost exclusively by a relevant number of organisations can be taken as an implicit signal concerning the quality and reliableness of the product, making it a good candidate for prospective adoptions.

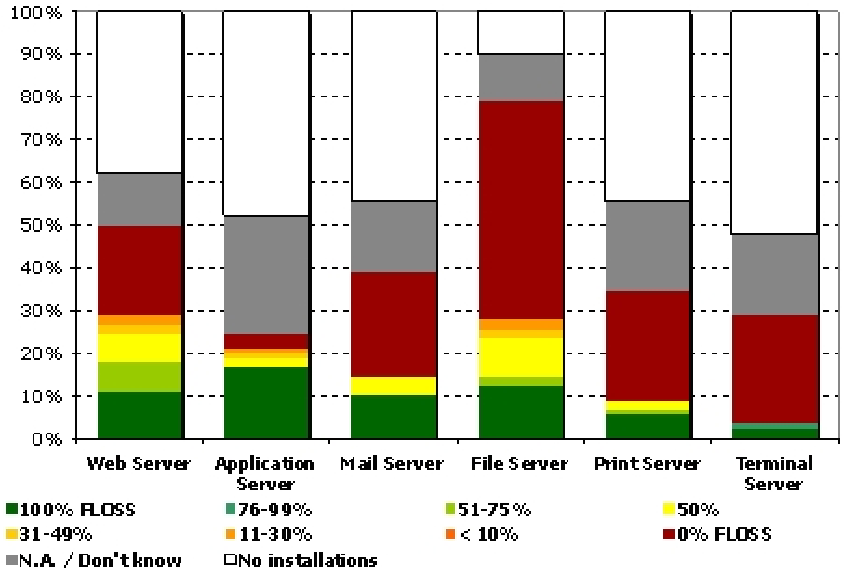


Figure 4.5: Software on the web side (# Municipalities)

4.5 The impact of FLOSS on interactive public services

On the basis of the data gathered through the survey an econometric analysis will be conducted. Indeed, in the current section we will contribute to the understanding of the effect of FLOSS adoption on interactive public services. In particular, our main concern will be to estimate the impact of FLOSS adoption, together with a set of other relevant variables, on the level of interactivity of a single Public Administration. After that, we will take into consideration which factors are likely to explain the decision to adopt FLOSS by the municipalities of Emilia-Romagna. Main results from the estimation are in Table 4.4.

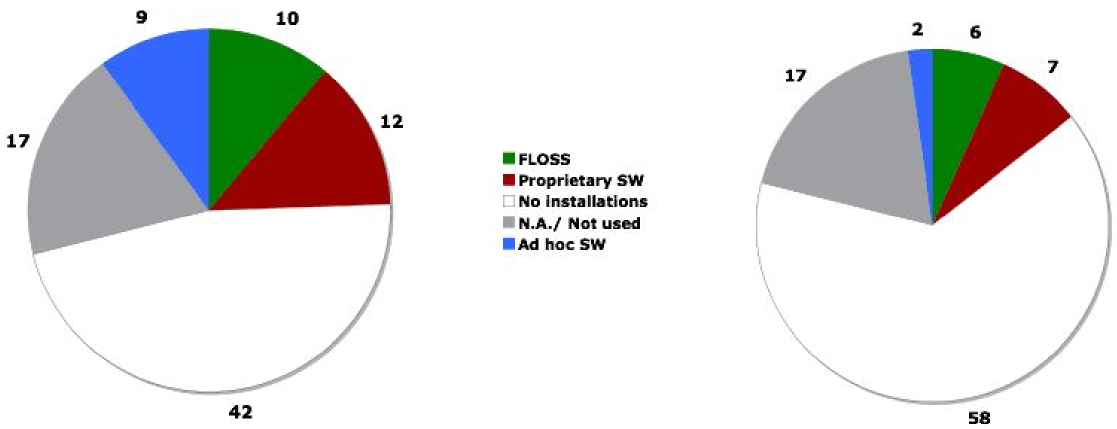


Figure 4.6: Intensity of FLOSS adoption (client/desktop vs. server)

4.6 Conclusion

The main results obtained in the present chapter can be summarized as follows:

1. The number of PAs adopting FLOSS, both aware and unaware, is relevant (70% of respondents).

2. Large size, broadband connection and the presence of e-gov/ICT strategy are all factors contributing to an intensive use of FLOSS.

3. High costs and reduced number of employees are all problems for which FLOSS is seen as a solution.

4. Municipalities have not taken into consideration the possibility to migrate their desktop systems to FLOSS. This type of software is perceived as closely tied to

Table 4.3: Type of FLOSS adopted in Emilia-Romagna municipalities

Area of adoption	Type of FLOSS	# Municipalities relying exclusively on FLOSS
Desktop/client	Linux	0
Mail	Thunderbird, Horde IMP, Opengroupware	6
Browser	Firefox, Netscape	3
Office automation	Openoffice, Staroffice	1
Web server	Apache	10
Application server	Tomcat, Jboss, Zope	15
Mail server	Postfix, Cyrus, Exim, Qmail, Sendmail, Squirrel	9
File server	Linux/Samba, Solaris	11
Print server	Linux/Cup	5
Terminal server	Open SSH, VNC	2
Content Management System	Exo, Exponent, Ez system, FlatNuke, Joomla, Mambo, Plone	10
Groupware	E Groupware, Group Office, MoreGroupware. OpenGroupware, Plone, WebGUI	6

Source: EROSS 2006.

the hardware and to employees' specific competences and, for these reasons, not susceptible of immediate transfer.

5. The use of applications in the area of client/desktop, personal productivity and office automation it is not frequent. The main reason is the incidence of network diseconomies that make it difficult the interaction with other PAs.

6. On the server side there are a number of FLOSS products which are already used by a relevant number of municipalities and whose reliability make them a good choice for other PAs as well.

7. The adoption of CMS and groupware is limited. The absence of a clear market leader and the availability of a high number of similar products make it difficult and expensive a proper evaluation activity and the choice of the most correct solution.

8. Dedicated software that are used by the municipalities interviewed are supplied under a proprietary license of either Italian or regional companies.

On the basis of the results obtained so far and given the need of refinement, we have been asked for a follow up of the present analysis for the period 2007-09.

The main activities concerning the follow-up will be:

1. More comprehensive information aimed at increasing both FLOSS adoption and development by Emilia-Romagna PAs.
2. A new survey to be conducted in the year 2007. In addition to PAs interviewed in the present survey we will add more public administrations previously left aside, i.e. provinces and chambers of commerce.
3. Both case studies and best practices will be meticulously added. These results will be of high utility for PAs approaching FLOSS for the first time.
4. A stricter collaboration between EROSS and OITOS in order to share the results of the two initiatives which will provide us with a clear picture of FLOSS in Emilia-Romagna from both public demand (PAs) and supply (private companies) point of view.
5. Informative seminars and workshops dedicated to the PAs.
6. Collaboration with European projects in order to compare our results with the one obtained from foreign partners.

To conclude, some policy recommendations can be put forward resting upon the results of our study. First of all, the increase in the demand for FLOSS from Emilia-Romagna must be followed by a comparable upsurge in the supply. Indeed, there is the necessity of incentivazing the supply of FLOSS solutions by private companies producing software and providing services to the PAs. Furthermore, the possibility for PAs to produce and distribute open source software developed internally must be taken into consideration in particular after the results of the study on 'Study on the Economic impact of open source software on innovation and the competitiveness of the Information and Communication Technologies (ICT) sector in the EU' (Ghosh 2006). Second, the adoption of FLOSS by small PAs must be encouraged by means of investments in education and "on the job" training. Finally, the high number of unaware FLOSS users points out a lack of information concerning this phenomenon. This means that appropriate diffusion of information must be done whether the aim is to increase its adoption.

Table 4.4: The reciprocal effect of public interactive services and FLOSS

Variables	Coefficient (Standard Errors)
Interactiveness	
FLOSS int	0.065
	(0.062)
ICT_exp (2004)	-0.000*
	(0.000)
# of ICT empl	4.351**
	(1.627)
Size	0.000
	(0.000)
cons	0.495***
	(0.140)
FLOSS int	
licence	-0.001
	(0.001)
Need for customisation	0.081
	(0.104)
Vendors' dep	0.055
	(0.086)
Training costs	-0.001
	(0.003)
Server management	-0.130
	(0.209)
# of ICT empl	-2.041
	(16.131)
ICT_exp (2004)	0.000
	(0.000)
cons	-2.317***
	(0.414)
N	61.000
r2_1 eq	0.355
r2_2 eq	0.100

Conclusion

Free/Libre Open Source Software (FLOSS) is acquiring of importance in recent years. Its diffusion among practitioners is a well stylized fact, nevertheless its adoption has been conducted by non-praticitioners as well. Its outstanding growth has called for a proper framework in order to understand its characteristics and its effects on the economy as a whole. Actually, FLOSS is just an example of a method of production which is completely different from the one through which protection is sought. Contrary to recent developings in the knowledge economy, where private enterprises are looking for an adequate protection for the results of their inventive activity, the open method of production suggests to freely reveal the inner content of the inventive activity knowing that it will aloow him to gain from this dynamic.

The present work presents some exploratory insights in both the appropriation method commonly adopted in the software sector, i.e. patents, and recent patterns in the area of FLOSS adoption by Public Administrations (PAs).

Appendices

Appendix A - The Knowledge Production Function: some mathematical details

In the current appendix we will concentrate on the derivation of the knowledge production function equation (3.4) which has been put forward in section 3.3.1 on page 102.

Appendix B - Research & Development and Patent stock: a derivation

The adoption of R&D spending and patent as variables for the estimation in section 3.3.1 on page 102 have not been deeply discussed. At this regard, we will now formally present the derivation of the mentioned quantities. The present appendix relies heavily on Hall, Bronwyn H., Mansfield, Edwin, and Jaffe, Adam B. (1993).

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Colophon

This thesis was made in LaTeX using the *hepthesis* class. An exception is the titlepage which has been constructed thanks to the help of Giuseppe Vittucci. The bibliography was prepared using the *econometrica* bibliographic style.