The Effects of Firm Size in Software-Patent Litigation; The Case of EU Software Patents

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Abstract

The aim of this paper is to examine if, in patent litigation cases, an out-of-court-settlement is more likely to be reached when there is a notable size difference between the infringing and the plaintiff company. The argument is that size a) endows a firm with lower litigation costs and b) enhances the firm's ability to successfully incorporate new ideas into its pool of prior art. The latter effect allows large firms to create better products, decreasing the demand for the products of small firms. The model suggests that no cross licensing will take place if the infringer is of small size compared to the plaintiff. This line of approach may shade some light on the expected introduction of patent protection for computer-implemented inventions in the EU, indicating that software patents may result in excess litigation.

Keywords: Intellectual property, litigation, size, software patents.

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1 Introduction

A proposed Directive is currently being read by the European Parliament, which introduces patent protection for computer-implemented inventions. This Directive, following the example of the US[1] and Japan,[2] is aimed at stimulating the already vibrant software industry. Bearing in mind that software is usually a bundle of smaller ideas,[3] and that, similar to microprocessors (or biotechnology), it is very hard for software developers to avoid making use of the existing pool of ideas, the interested groups opposing the Directive argue that the introduction of EU patents makes most EU software developers infringers to existing US patents, most of which are held by large corporations.

This is a valid point that has not yet created any problems to industries that face similar constraints. In fact, as Hall and Ziedonis (2001) argue, for technology sectors (such as microprocessors) where innovators are interlocked in using each other's technology, patents act as a "secondary defense" in protecting innovation and firms regularly cross-license their patents to rival firms. In all, one could expect a similar situation prevailing soon in the EU software industry, creating the base for further growth.

Notwithstanding the above, the case for patents stimulating innovation is not a straightforward one. Using the software share of a firm's patents as a proxy for the cost of patenting, Bessen and Hunt (2003) find that software patents substitute for R&D. Those firms that increased the share of software patents in their patent portfolios tend to reduce their R&D spending relative to sales in the

[1] In 1981 the US Supreme Court held that software that was part of manufacturing system or process was patentable (Diamond v. Diehr), in addition, in 1998 the CAFC upheld a patent on a software system that performs real-time accounting calculations and reporting for use by mutual fund companies (State Street Bank&Trust Company v. Signature Financial Group). This decision explicitly rejected the notion that business methods were inherently unpatentable.

[2] The introduction of software patents in Japan formally took place in 1997 with the introduction of new guidelines for examining inventions by the JPO.

[3] The United States of America copyrights law (title 17 of the US code) at section 101 defines a computer program as, *"a set of statements or instructions to be used directly or indirectly in a computer in order to bring about a certain result"*.

1990s. In addition, Cohen, Nelson and Walsh (1997) find, through a survey, that despite the fact that firms are taking out many more patents, managers do not perceive patents to be any more effective. Such critical views are not restricted to the empirical literature. From a theoretical perspective, O'Donaghue, Scotchmer and Thisse (1998) also cast doubt on the above view, noting that true as it may be that a patent rewards the present innovator, it nevertheless hinders all future re-innovation. For a literature review see, Gallini (2002).

What this paper shows is that the introduction of software patents in the EU is unlikely to lead to licensing. Instead, as I argue, it is possible that EU firms may be faced with excess litigation. The paper's intuition concentrates on the differences in size between large and small firms, assuming that software producers choose to protect their intellectual property and abstain from distributing it for free, as in Panagopoulos (2003) and Ben-Shahar and Jacob (2001). In doing so, the paper identifies two ways through which size benefits a software developer. First, large firms are widely acknowledged to face lower litigation cost, Lanjouw and Lerner (2001). Furthermore, a large size endows a firm with a large pool of ideas (i.e. prior art in the form of a patent portfolio) and better managerial and R&D expertise. Subsequently, a large firm may find it easier to bundle to its existing prior art any idea that it car reverse engineer. By doing so it will be able to create a product whose quality is better than the one created by any developer of smaller size.[4] Therefore, when a small firm competes against a large rival who has the ability to reverse engineer the original idea and bundle it into his own product, the firm is faced with greater obsolescence in an industry were products become obsolete within 2 to 3 years.

The above two caveats for small firms are introduced in a simple model where demand depends on the technological attributes that have been incorporated, through R&D, into the product. In this framework, upon being infringed the software developer has the choice to do nothing or to litigate, where litigation can also lead to an out-of-court-settlement (licensing). As the model shows, when faced with an infringer of smaller size the plaintiff will always avoid any out-of-court-settlement solemnly

[4]Evidence connecting size to innovation in the software industry is offered by Prusa and Schmitz (1991).

pursuing litigation. Refining the model to explicitly account for R&D, and than making it dynamic does not change the above result.

Within a different context, my results are similar to Barton (1998), who argues that in biotechnology, an industry where almost everyone is likely to be infringing everyone else's patents and producers amass patent portfolios for strategic reasons, *"litigation incentives become quite perverse. There is more incentive to sue outsiders seeking to enter the industry than to sue other major participants, for these major participants can reply in kind"*. The strategic component that Barton mentions is also discussed by Lanjouw and Schankerman (2004), who note that repeated interaction through courts may facilitate cooperation. As they argue, firms (operating in technology areas where patenting is dominated by fewer firms) are unlikely to be involved in patent infringement cases. These firms are more likely to encounter the same disputants over time, so theory predicts greater incentives for settlement. In what follows, I abstain from addressing this issue because the model concentrates on the attributes of size (in terms of patent portfolio) and size changes very slowly. Hence, the friction points between a large and a small firm do not change in time, allowing the same results to be repeated overtime.

In addition, the model's results are related to Aoki and Hu (1998) who show that a patentee may decide to license his technology to prevent imitation. This occurs when, the litigation cost and probability of winning make the patent owner unable to credibly threaten with an infringement suit, or the patentee credibly threatens to sue, but the potential infringer's litigation cost is so low that he is not willing to go to court.

The model is not without its limitations. To start with, in order to concentrate on technological competition, the model abstains from focusing on price/quantity competition. In addition, to simplify the analysis, it makes the assumption that all patents have equal significance in R&D and in production. Thus, the model concentrates on valuable/important patents only. Lastly, the model assumes that the damages that a court will decide on are equal to the foregone royalties that the two firms would independently decide on in case of licensing. However, intuitive as this assumption may be, as the case of Polaroid Corp. v. Eastman Kodak Co (16 USPQ2d 1481) indicates, even though the court had set specific outlines on how to measure damages, in reality it is by all means not an easy task.[5]

In what follows, section 2 reviews the literature, section 3 elaborates on the model's assumptions, section 4 introduces a simple static model, which is refined in section 5, becoming dynamic in section 6, and it is followed by the conclusions.

2 Linking litigation to size

As indicated by Bessen and Hunt (2003), PTO data suggests that up to now more than 150000 software patents have been granted in the US and 20000 software patents are now granted each year, comprising to over 15% of all patents. The growth in software patents accounts for over 2% of the total growth in the number of patents between 1976 and 2001. These authors also find that software patents are more likely to be assigned to firms than individuals, especially larger US firms.

This evidence accords with the data provided by Allison and Lemley (2002), who study 1000 utility patents issued in the US during 1996-1998, where 76 out of 1000 were software patents. They find that with respect to the size of the patent applicants in software, 5 were by individuals, 3 by small business, 2 by non-profits, 10 by small enterprises and 66 by large enterprises. Apparently, larger firms have had the ability to create large patent portfolios. Their use of these patent portfolios varies from firm to firm. Several firms, including Texas Instruments, Intel, Wang Laboratories, and Digital Equipment, have established groups that demand royalties on old patents. In many cases, they have been successful in extracting license agreements (or past royalties).[6]

Over all technology fields, Lanjouw and Schankerman (1997) estimate that US patents from the early 1980's will, by the time they expire, generate more than one suit for every hundred patents. The

[5] For an outline of the decision, which details how the court interprets damages and compensation, see http://www.patenting-art.com/economic/kodak0.htm

[6] Texas Instruments, for instance, is estimated to have netted 257$ million in 1991 from patent licenses and settlements because of its aggressive enforcement policy, Rosen (1992).

cost of such settlements can cost from 1$ million to several millions, Merges (1999). Lerner (1994) reports that, from July 1989 to June 1990, 1318 patent related suits were initiated in the US Federal court and approximately 3900 procedures within the US PTO. Based on historical costs, he estimates that these cases will involve legal expenditures of about one billion 1991 dollars. This is a sizable sum compared to the expenditures on basic research by US firms in 1991, which was 3.7 billion dollars.

It seems that litigation is an easier path to follow for firms with large patent portfolios. For example, Lanjouw and Schankerman (2004) find that having a larger portfolio of patents reduces the probability of filling a suit on any individual patent in the portfolio. Furthermore, as their research indicates, large firms (with large patent portfolios) have the experience and the ability to settle disputes by pooling or trading intellectual property. Therefore, if imperfect capital markets limit the capacity of smaller firms to finance litigation, larger firms may be able to extract better terms because they pose more credible litigation threats in confronting smaller firms.

The latter point is emphasized by Bhagat, Brickley and Coles (1994), who examine the market reaction to the filing of 20 patent infringement suits reported in the Wall Street Journal during the 1981-1983 period. They find that in the two-day window ending on the day the story appears in the Journal, the combined market-adjusted value of the firms fell on average of 3.1%. Research by Lerner (1995), using data on 26 patents suits between biotechnology firms, supports the above results. Lerner finds that on average the combined market-adjusted value drops by 2%. This represents a median loss of shareholder wealth of 20$ million. Such drop in market value heavily handicaps small firms, for if a defendant is unable to raise capital to finance litigation through external capital markets, he may be forced to settle the dispute, no matter what the ultimate merits of his case are.

Additional support, showing that smaller firms may be at a disadvantage, comes form Lanjouw and Lerner (2001), who find that legal expenses are likely to be higher for smaller firms and for individuals, because of higher financial cost and their greater reliance on external legal counsel. In addition, preliminary injunctions are a remedy that may be available only to financially strong plaintiffs. This accords with Cohen, Nelson and Walsh (2000), who find that smaller firms are disproportionately dissuaded from applying for patents due to the cost of their defense, and Lerner (1995), who observes that the cost of patent litigation discourages smaller firms from patenting. Furthermore, Lanjouw and Lerner (1997) note that patent litigation cases involving small firms disproportionately involve trade secrets, suggesting that this source of intellectual property protection is more critical to these companies. This result is consistent with the view that less established firms employ trade secrecy because their direct and indirect costs of patenting are relatively high.

3 Assumptions

Having offered some empirical backing for the link between size and litigation, in this section I will explain the assumptions that I will be using in creating an economic model, to be used in studying litigation for software patents. Accordingly, assume two firms i, j, that produce software. For example, i, j can be video game producers. This is a market where firms compete in quality, marginal (average) cost is very low, and prices between products display little variation.[7] Furthermore, the success of such products rests on the game's *engine* (a bundle of subroutines that generate the graphics) and on the plot. With respect to the first, producers invest on developing software that can deliver faster and more realistic graphics.

Firms patent their software in order to protect their innovation. Nevertheless, they face two caveats. Primarily, it is relatively easy for a competitor j to reproduce $i's$ innovation through reverse engineering.[8] To this, one should add that firms face a high degree of obsolescence, as newer and better games are introduced. In practical terms, a game is fully obsolete 2-3 years from its launch date.

[7] Since marginal cost is very low and disproportional to observed prices, while prices display little or no variation, one can preclude Bertrand competition.

[8] Mansfield et al. (1982) surveyed of 48 (patented and unpatented) product innovations of major US firms in the chemicals, drug, electronics, machinery industry. Sixty percent of patented innovations in their sample were imitated within four years of introduction.

In what follows, the role of i is to develop and patent software (a subroutine) and for j to copy it and use it. In this framework, i and j differ only in size, where $s_i = \sigma s_j$ is the size of i, $\sigma > 0$, and $s_j = 1$ is the size of j. Size in this context is not an output indicator, instead it is used in displaying differences in the size of patent portfolios and research potential in general. The idea is that large firms will be more successful in using any innovation that they can reverse engineer to create a product of superior quality compared to that of the original patent holder. For example, if i has created some subroutine that generates more realistic graphics, a j of large size will be able to bundle this subroutine (using his existing patent portfolio and his enhanced R&D and managerial expertise) better than i, and thus j will create a more successful game. The notion connecting size to innovation is backed by Prusa and Schmitz (1991), who display that even though new firms have a comparative advantage in developing new categories of software, established firms have a comparative advantage in developing improvements to existing software. In addition, Tether (1998) shows that true as it may be that small firms have more innovations per employee, large firms develop more important innovations.

Following the rational introduced in the above paragraphs, j will copy $i's$ idea producing a game that is better (worse) than $i's$. In response, i has only two choices. He can either do nothing, or he can litigate. Litigation is a lengthy process and in reality any case will start at a district court before it slowly finds its way to the CAFC,[9] or the country's High Court. The later courts are the ones taking the final decision on the case. Henceforth, for simplicity, I will assume that there only exists one court, the one making the final decision. Therefore, one can consider the interval from filing the case until the time that the court meets as, the period the case has to spend in district court, or in out-of-court-counseling, whose aim is to reach a settlement. Subsequently, at any point in time (since filing the case) i has the choice to either reach an out-of-court-settlement with j (effectively to license his patent), or to solemnly pursue litigation.

The above discussion precludes the plaintiff from pursuing a settlement strategy without filing the case first. In addition, having filed the case the plaintiff cannot simply decide that it is best to

[9] EU countries lack the equivalent of the CAFC.

abstain from taking any action that may lead to a settlement or to court; effectively doing nothing. Concentrating on the first assumption, it is straight forward to show that, in this context, i and j will never settle absent the threat of litigation. Therefore, i cannot license his patent to j without first filing the case.

Turning my attention to the latter assumption, one can restate it as, if for reasons of either asymmetric information or diverging expectations i discovers (post filling) that the merits of his case are less than expected, he cannot pursue a policy of doing nothing. The underlying reasoning in support of this assumption is that, on average, the plaintiff understands the merits of his case and he is not going to file the case (abstaining from following a strategy where he takes no action against the infringer) initiate litigation (or an out-of-court-settlement) proceedings, and incur the cost that these proceedings imply, in order to end up following a strategy where he does nothing. Hence, the plaintiff having paid the cost cannot just change his mind.

In addition to the above, for simplicity, I will assume that if the case reaches the court it is impossible to have an out-of-court-settlement, and thus both parties must accept the court's decision, where $\mu \in (0, 1)$ indicates the plaintiff's chances of winning the case.[10] In reality, a plaintiff can drop the case (and settle) even at the last minute. However, the overwhelming majority of settlements take place before the court meets. Accounting for the above, I will denote the three strategies that are available to i and j as, N (if i decides to do nothing), L (if i files the case and solemnly concentrates on a strategy that will lead to a court decision), and S (if, after filing the case, both i and j jointly decide to reach an out-of-court-settlement).

Having elaborated on the strategies that i and j can follow, I will now concentrate on the cost they incur if they go to court. This is the cost that each party incurs when defending his case (in describing this cost I will employ the term litigation cost), plus court fees. Bearing in mind that it has already been established that greater size leads to a lower litigation cost, I will model this cost as a negative function of size. Furthermore, since no matter how big firms are (and no matter how

[10] In reality, μ is never equal to one, nor to zero.

large their in-house legal expertise is) they always have to incur some litigation cost, I will allow for decreasing returns to scale with respect to size.

With respect to court fees there exist two different systems. The first one is the American system, where both parties (winner and looser) have to pay such a fee. The second one is the British system, where only the looser pays the court fees. Bearing in mind that in patent litigation cases the litigation cost is disproportionately greater than court fees, in what follows I will only concentrate on litigation cost. This implies that both parties must incur this cost, and it does not depend on who wins the case (if the case reaches the court). Hence, this cost will be covered by each individual party irrespectively of what system is in application (American or British).

It suffices to say that if the plaintiff wins, he is entitled to damages as a compensation for his foregone profits. The most reasonable compensation must be the one that the two firms would have independently decided on during a licensing negotiation. Schankerman and Scotchmere (1999) note that reasonable royalties have historically been interpreted to mean that the infringer pays as damages the royalty that the patentee and the infringer would have agreed to in a hypothetical licensing negotiation in which both parties knew that the patent was valid and a license was needed to avoid infringement. Thus, a royalty must be equal to the profits that i looses (in terms of its profits when there is no conflict) if it decides not to follow strategy S.

4 A simple model

In what follows, I will elaborate on the demand and the profits that the two firms i and j face. Initially, I will describe, as a benchmark, the simplest case when there is no conflict (infringement) between the two firms. And I will elaborate on each of the three strategies later on. Accordingly, firms i, j face the following demand functions,

$$q_i = B_i - b_j p_i + b_i p_j \ , \ \ q_j = B_j - b_i p_j + b_j p_i \tag{1}$$

where q_i indicates the demand for the product produced by i, and p_i, p_j indicate the price of the product of each firm respectively. In addition, $\{b_i, b_j\} > 0$ indicate the technological attributes incorporated into the product as a result of R&D. I will loosely refer to $\{b_i, b_j\}$ as the technological quality of i and $j's$ product. If i is the only firm in this market, then $q_i = B_i - p_i$ and $q_j = 0$. Hence, b affects demand only when a substitute exists. In the absence of a substitute, since there will only exist one product in the market, its demand is affected only by its price. Bearing in mind that in the video games market prices show limited variation, I will assume that both i and j charge the same price, which I will use as a numeraire. Therefore, equation (1) becomes,[11]

$$q_i = B_i - b_j + b_i \ , \ \ q_j = B_j - b_i + b_j \tag{2}$$

In this section the technological quality of each product $\{b_i, b_j\}$, which is the result of the firm's R&D, will be treated as simple monotonic function of firm size. For example, if there is no infringement,

$$b_i = s_i \ \ , \ \ b_j = s_j \tag{3}$$

The intuition behind this simple formulation rests on the Newtonian view of innovation as *"standing on the shoulders of giants"*, i.e. resting on the existing prior art, which in this case is manifested through the firm's existing patent portfolio, as indicated by firm size. The above formulation assumes that history (prior art) is an indicator of how good a firm is in doing R&D, therefore a fixed term (expressing individual ability) is not included. Moreover, equation (3) implicitly assumes that all s_i, s_j, patents carry an equal weight in production and in R&D. However, not all patents have the same impact.[12] Therefore, the model concentrates only on valuable patents i.e. patents which make infringement worthwhile.

[11] Another, perhaps more intuitive way, to capture the effects of b, is to assume that, $q_i = b_i - b_j - p_i + p_j$. The drawback of this approach is that it assumes market size ($b_i - b_j$ in this case) as endogenous on firm size, while allowing demand, similar to equation (1), to be a linear function of s_i, s_j.

[12] Hall, Jaffe and Trajtenberg (2000), note that there is considerable difference between the use that various patents enjoy in research and production.

With respect to B_i and B_j, the fixed terms in equation (1), I will assume that the fixed demand for a product must be a function of the technological characteristics that it has already incorporated. Therefore it must again be a function of the firm's existing prior art. Subsequently, if there is no infringement,

$$B_i = M + s_i \ , \ \ B_j = M + s_j \ \ , \ \ M > 0 \tag{4}$$

Accounting for the above, the profits of each firm in the absence of conflict are,

$$\pi_i = q_i \left(1 - c_i\right) \ \ , \ \ \pi_j = q_j \left(1 - c_j\right) \tag{5}$$

where,

$$c_i = c_0 + s_i^{-\alpha} \ \ , \ \ c_j = c_0 + s_j^{-\alpha} \tag{6}$$

depict R&D and production cost as a negative function of firm size.

Having elaborated on the benchmark case, I will now concentrate on strategy N, where j is infringing over $i's$ patents, but i chooses to take no action. For simplicity, I will assume that j is infringing over the whole patent portfolio of i (making its patent portfolio $s_j + s_i$) and not just a few patents. One could view this as if the model deals with only a fraction of $i's$ portfolio i.e. the disputed patents. However, having allowed all patents to curry an equal weight, the larger a firm is the greater its disputed patent portfolio should be. Subsequently, the model's intuition, which links size to cost and technological capability does not change. Nevertheless, since the size of j has been normalized to one, and $\sigma > 0$, s_i can take values below one. Therefore, the disputed patent portfolio can take the form of patent denominations, as patent claims, subclaims, or simple ideas incorporated into the patents.

With the above in mind, equations (2)-(6) become,

$$q_i^N = B_i^N - b_j^N + b_i^N \ , \ \ q_j^N = B_j^N - b_i^N + b_j^N \tag{7}$$

$$b_i^N = s_i \ \ , \ \ b_j^N = s_i + s_j \tag{8}$$

$$B_i^N = M + s_i \ , \ \ B_j^N = M + s_i + s_j \tag{9}$$

$$\pi_i^N = q_i^N \left(1 - c_i^N\right) \quad , \ \ \pi_j^N = q_j^N \left(1 - c_j^N\right) \tag{10}$$

$$c_i^N = c_0 + s_i^{-\alpha} \quad , \ \ c_j^N = c_0 + \left(s_i + s_j\right)^{-\alpha} \tag{11}$$

Focusing on strategy S, where i and j reach an out-of-court-settlement for the s_i infringed patents, one should expect that i will license these patents to j (making $j's$ portfolio $s_j + s_i$) for a royalty. As I noted, this royalty must be equal to the profits that i looses (in terms of its profits when there is no conflict) if it decides not to follow strategy S, i.e. $\pi_i - \pi_i^S$. Considering the above, when i follows a strategy S equations (2)-(6) become,

$$q_i^S = B_i^S - b_j^S + b_i^S \ , \ \ q_j^S = B_j^S - b_i^S + b_j^S \tag{12}$$

$$b_i^S = s_i \quad , \ \ b_j^S = s_i + s_j \tag{13}$$

$$B_i^S = M + s_i \ , \ \ B_j^S = M + s_i + s_j \tag{14}$$

$$\pi_i^S = q_i^S \left(1 - c_i^S\right) + \left(\pi_i - \pi_i^S\right) \quad , \ \ \pi_j^S = q_j^S \left(1 - c_j^S\right) - \left(\pi_i - \pi_i^S\right) \tag{15}$$

$$c_i^S = c_0 + s_i^{-\alpha} \quad , \ \ c_j^S = c_0 + \left(s_i + s_j\right)^{-\alpha} \tag{16}$$

Turning my attention to strategy L, if j wins the case (with probability $1 - \mu$) its patent portfolio becomes $(1 - \mu)\, s_i + s_j$. Furthermore, if i wins the case j must compensate i. Since, as I noted, reasonable damages must be equal to the royalties that the firms would have decided on when licensing, i will receive a $\left(\pi_i - \pi_i^S\right)$ compensation with probability μ. No matter though who wins the case both parties must incur some litigation cost (per patent)

$$\widetilde{c}_i = \widetilde{c}_0 + s_i^{-\beta} \quad , \ \ \widetilde{c}_j = \widetilde{c}_0 + s_j^{-\beta} \ , \ \beta > 0 \tag{17}$$

respectively. This litigation cost must be a function of *ex-ante* size s_i, s_j because it represents the overall litigating capability of the firms when going to court and prior to any judgment being made with respect to $j's$ use of the s_i patents. Accounting for the above, when the case goes to court equations (2)-(6) become,

$$q_i^L = B_i^L - b_j^L + b_i^L \ , \ q_j^L = B_j^L - b_i^L + b_j^L \tag{18}$$

$$b_i^L = s_i \ \ , \ b_j^L = (1-\mu)\, s_i + s_j \tag{19}$$

$$B_i^L = M + s_i \ , \ B_j^L = M + (1-\mu)\, s_i + s_j \tag{20}$$

$$\pi_i^L = q_i^L \left(1 - c_i^L\right) + \mu \left(\pi_i - \pi_i^S\right) - \widetilde{c}_i s_i \ \ , \ \pi_j^L = q_j^L \left(1 - c_j^L\right) - \mu \left(\pi_i - \pi_i^S\right) - \widetilde{c}_j s_i \tag{21}$$

$$c_i^L = c_0 + s_i^{-\alpha} \ \ , \ c_j^L = c_0 + \left((1-\mu)\, s_i + s_j\right)^{-\alpha} \tag{22}$$

4.1 The dominant strategy

The aim of this section is to determine what strategy i is going to follow. One must keep in mind that if i decides to license it must be in agreement with j, because if either party wants to avoid licensing the case ends up in court. Accounting for the above, concentrating on the subgame, I will first examine when i (in agreement with j) will follow L instead of S. In order to derive intuitive results I will restrict the model to costs that display constant returns to size, allowing α, β to be equal to one. Lastly, all the fixed parameters M, c_0, $\widetilde{c}_0$ will be considered as insignificant, allowing size to be the main driving force of all costs and of the fixed demand. Any other assumption regarding the above parameters requires a numerical solution, in which case the slopes of the dominant strategies (in the figures that follow) change, without altering the essence of the graphs.

Specifically, for i, if L is to dominate S, and $\pi_i^L > \pi_i^S$ the following condition must be true with respect to μ,

$$\mu > \frac{1+\sigma}{3\,(-1+\sigma)} \tag{23}$$

By the same token, focusing on j, if L is to dominate S, and $\pi_j^L > \pi_j^S$ the following condition must be true with respect to μ,

$$\mu > \frac{G \pm \sqrt{G^2 + 4\sigma\,(1+\sigma)^3\,(1+\sigma)\,((-1+\sigma)+4\sigma)}}{2\sigma\,(1+\sigma)\,((-1+\sigma)+4\sigma)} \tag{24}$$

where $G = 3\sigma + (-1+\sigma)\,(1+\sigma)^2 + \sigma^2\,(2+\sigma+2\,(1+\sigma))$.

Having elaborated on the subgame, I will henceforth concentrate on the game, finding when litigation (settlement) dominates doing nothing. In this case, I will focus only on i, because (contrary to the subgame when even if j wanted to go to court i had to abide by $j's$ choice) i is the only firm that needs to decide. Overall, L dominates N, and $\pi_i^L > \pi_i^N$ if,

$$\mu > \frac{2}{3(-1+\sigma)} \tag{25}$$

In addition, S dominates N when,

$$\frac{-1+\sigma}{2} > 0 \tag{26}$$

which suggest that if $\sigma > 1$ it will be profitable for i to settle than do nothing.

I will plot equations (23)-(26) for $\mu \in [0,1]$ and $\sigma \in [0,5]$, which suggests that i can have a size that verges from infinitely small (compared to j), to five times larger.[13] With the above in mind, the following figure (figure one) emerges, which includes the subgame, the main game as well as both of them together. Specifically, in the graph that denotes the subgame the downward slopping line indicates all the μ above which L dominates S for firm i. Moreover, the upward sloping curve indicates all the μ above which L dominates S for firm j. In the graph that represents the main game the downward slopping curve indicates the $\mu's$ above which L dominates N. Overall, as the last graph (which brings the game and the subgame together) indicates, in the upper right part is the area where litigation is the dominant strategy. The mid part of the graph (from $\sigma = 1$ to the upper downward slopping curve) indicates the area where settling is the dominant strategy, while the remaining part of the graph is the area where doing nothing is dominant.

Figure one indicates that for plaintiffs of small sizes the dominant strategy for the plaintiff is to avoid taking any action. Similarly, if the infringer is of a size that is similar to that of the plaintiff the best course of action seems to be to settle the dispute by licensing. The situation drastically changes for plaintiffs of large sizes, where the area under which litigation is possible increases with the size of the plaintiff.

[13] For values larger than five the plot does not change in all cases.

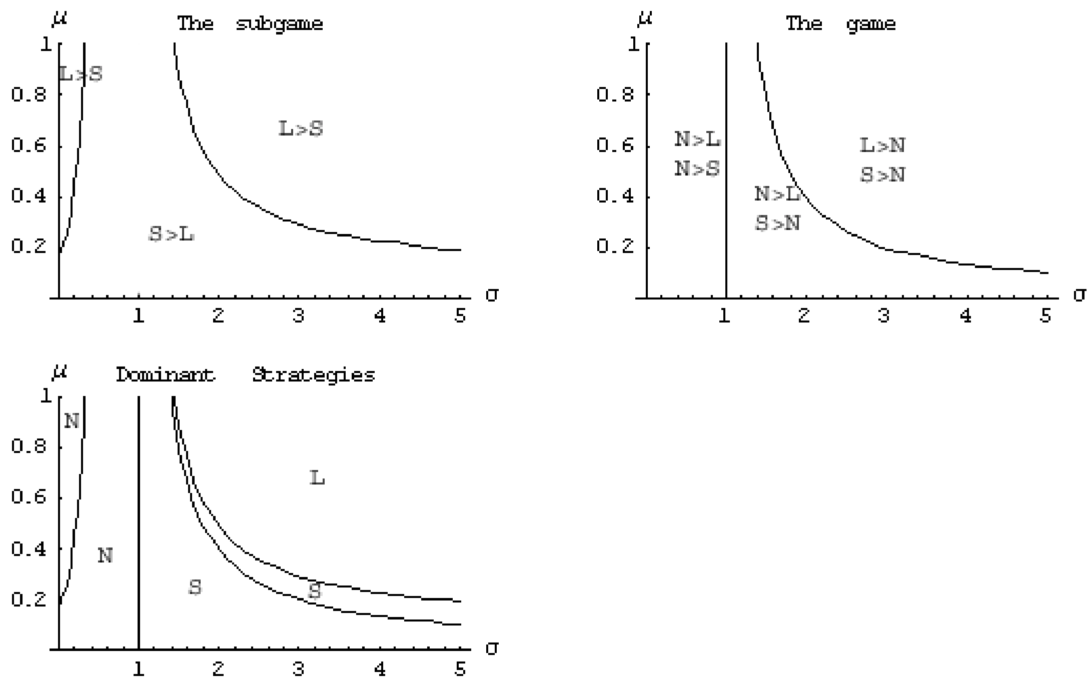


Figure 1:

5 Refining R&D

In the preceding section I built a model that tried to explain firm behavior accounting for the technical attributes incorporated into their products, through b. In this case b was the result of the firm's R&D, which led to newer and better technological attributes that were incorporated into a firm's product. However, this treatment of R&D was rudimentary, simply assuming that R&D is the result of research that is based on the prior art, which is already incorporated into the firm's existing patent portfolio.

For example, restricting the analysis to prior art, as Segerstrom (1998) noted, the more complicated the existing prior art becomes the harder it is to innovate. Thus, the existing prior art does not only positively affect R&D, but it also has a negative effect on R&D, one that becomes more evident as this prior art becomes more complex. To the above, one should also add that R&D is understood to be resource based. Therefore, the more resources one puts into R&D the better the results should in general be. In this framework, firms spend c in R&D and production cost (per unit of production), and out of the total cost c a δ percent is used in R&D, while the remaining is spent in production. Thus, firms (in this context) spent δcq in R&D. Accounting for the above, in what follows I will enhance the model of section (4) to include (apart from the elementary effect of prior art, which acts as a base for current R&D), the negative effect that prior art may have by complicating research, as well as the positive effect that an increase in R&D expenditures will have on the developed technology.

I will henceforth express b_i and b_j (equation (3)) as,

$$b_i = s_i + \delta \frac{c_0 + s_i^{-\alpha}}{s_i + s_j} q_i \quad , \quad b_j = s_j + \delta \frac{c_0 + s_j^{-\alpha}}{s_i + s_j} q_j \tag{27}$$

where, in b_i, the first term s_i indicates the effect of prior art of firm i, $\delta \left(c_0 + s_i^{-\alpha}\right) q_i$ represents R&D effort (the money spend on R&D), and $(s_i + s_j)^{-1}$ depicts the increase in complexity as the total prior art $s_i + s_j$ increases. Along the same lines, equations (8), (13), (19) will be re-expressed as,

$$b_i^N = s_i + \delta \frac{c_0 + s_i^{-\alpha}}{s_i + s_j} q_i^N \quad , \quad b_j^N = (s_i + s_j) + \delta \frac{c_0 + (s_i + s_j)^{-\alpha}}{s_i + s_j} q_j^N \tag{28}$$

$$b_i^S = s_i + \delta \frac{c_0 + s_i^{-\alpha}}{s_i + s_j} q_i^S \quad , \quad b_j^S = (s_i + s_j) + \delta \frac{c_0 + (s_i + s_j)^{-\alpha}}{s_i + s_j} q_j^S \tag{29}$$

$$b_i^L = s_i + \delta \frac{c_0 + s_i^{-\alpha}}{s_i + s_j} q_i^L \quad , \quad b_j^L = ((1 - \mu) s_i + s_j) + \delta \frac{c_0 + ((1 - \mu) s_i + s_j)^{-\alpha}}{s_i + s_j} q_j^L \tag{30}$$

Substituting q_i^N, q_j^N, q_i^S, q_j^S, q_i^L, q_j^L into the above equations one is faced (for each strategy) with a system of two equations with two unknowns. Solving these systems, the following b is derived when there is no conflict,

$$b_i = \sigma + \frac{2}{1 + \sigma} \quad , \quad b_j = \frac{2}{1 + \sigma}$$

If the plaintiff decides to take no action, or in case the firms settle, the following $b's$ are derived,

$$\begin{aligned} b_i^S &= b_i^N = \sigma + \frac{1}{1 + \sigma} + \frac{1 + \sigma}{1 - \sigma\left(-1 + \sigma\left(2 + \sigma\right)\right)} \\ b_j^S &= b_j^N = 1 + \sigma + \frac{1}{1 + \sigma} - \frac{\sigma}{1 - \sigma\left(-1 + \sigma\left(2 + \sigma\right)\right)} \end{aligned}$$

Lastly, in case of L,

$$b_i^L = \sigma + \frac{1}{1+\sigma} + \frac{(1+(1-\mu)\sigma)(1-\mu\sigma)}{1+\sigma(1-\sigma(2+\sigma)+\mu(-1+\sigma+\sigma^2))}$$
$$b_j^L = 1+\sigma(1-\mu) + \frac{1}{1+\sigma} - \frac{\sigma(1-\mu\sigma)}{1+\sigma(1-\sigma(2+\sigma)+\mu(-1+\sigma+\sigma^2))}$$

When examining the subgame for i, while accounting for the above equations, if L is to dominate S, and $\pi_i^L > \pi_i^S$ the following condition must be true with respect to μ (the equivalent of equation (23)),

$$\mu > \sigma\frac{5+\sigma(2+\sigma)(5+\sigma(-9+\sigma(-8+\sigma(7+4\sigma)))) \pm \sqrt{A_1}}{2(-1+\sigma)\sigma(-3+\sigma(2+\sigma)(-3+\sigma(4+3\sigma)))} \tag{31}$$

where,

$$A_1 = 1+\sigma(16+\sigma(34+\sigma(-46+\sigma(-143+B_1))))$$
$$B_1 = \sigma(20+\sigma(197+\sigma(-106+\sigma(17+4\sigma(5+\sigma)))))$$

Equivalently, for j, if L is to dominate S, and $\pi_j^L > \pi_j^S$ the following condition must be true with respect to μ (the equivalent of equation (24)),

$$\mu > \frac{3+\sigma(4+\sigma(-11+\sigma(-19+\sigma(8+\sigma(15+4\sigma))))) \pm \sqrt{A_2}}{2\sigma(3+\sigma(-1+\sigma(-17+\sigma(1+5\sigma(3+\sigma)))))} \tag{32}$$

where,

$$A_2 = 9+\sigma(36+\sigma(-42+\sigma(-322+\sigma(-79+\sigma(960+B_2)))))$$
$$B_2 = \sigma\left(701+\sigma\left(-1046+\sigma\left(-1178+\sigma\left(136+\sigma(593)+260\sigma+36\sigma^2\right)\right)\right)\right)$$

Along these lines, L dominates N, and $\pi_i^L > \pi_i^N$ (the equivalent of equation (25)) if,

$$\mu > \frac{5+\sigma(9+\sigma(-14+\sigma(-20+\sigma(7+3\sigma(4+\sigma))))) \pm \sqrt{A_3}}{2(-1+\sigma)\sigma(-3+\sigma(2+\sigma)(-3+\sigma(4+3\sigma)))} \tag{33}$$

where,

$$A_3 = 1+\sigma(18+\sigma(53+\sigma(-20+\sigma(-238+\sigma(-122+B_3)))))$$
$$B_3 = \sigma(386+\sigma(254+\sigma(-235+\sigma(-184+\sigma(34+3\sigma(16+3\sigma))))))$$

In addition, S dominates N when,

$$\frac{(-1+\sigma)\,\sigma\,(1+\sigma\,(3+\sigma))}{2\,(-1+\sigma\,(-1+\sigma\,(2+\sigma)))} > 0 \tag{34}$$

which suggest that it will always be profitable for i to settle than do nothing.

Bearing in mind that in software (and in the video games industry in particular) the bulk of the profits is frequently re-invested in R&D, I will generalize allowing δ to be one. With the above in mind, using the same assumptions regarding α, β, M, c_0, $\widetilde{c}_0$ as in the previous section, equations (31)-(33) lead to figure two, which is the equivalent of figure one.

Similar to figure one, for plaintiffs of large sizes litigation prevails. Contradicting figure one, litigation may also be dominant for firms of similar sizes. In fact, the greater μ is the greater the litigation area becomes. However, for plaintiffs of small sizes litigation is never dominant. In this case settlement is. Overall, both static models seem to agree that for plaintiffs of small sizes litigation is never the best strategy. However, when the plaintiff is much larger than the infringer the best course of action seems to be none other but litigation.

6 A dynamic model

In this section I will extent the model of the previous section making the model dynamic. In this context, a dynamic model should account for two things. To start with, the effect of prior art (that has been the backbone of the model's R&D analysis) must account for the known lag between prior art and actual R&D. This is because it takes time until a known idea is incorporated into current research. The most important issue though that a dynamic framework must account for is that courts do not meet immediately after the case has been filed. In fact, the average waiting time is 12 years from the time one files for a patent. Thus setting the issue of preliminary injunctions aside, [14] I will assume that every period a case has a $\tau_t = 1 - \varepsilon^t$, $\varepsilon \in (0,1)$ probability of being decided by the court.

[14] A preliminary injunction suggests that infringement stops immediately, reducing the argument to that of sections (4) and (5).

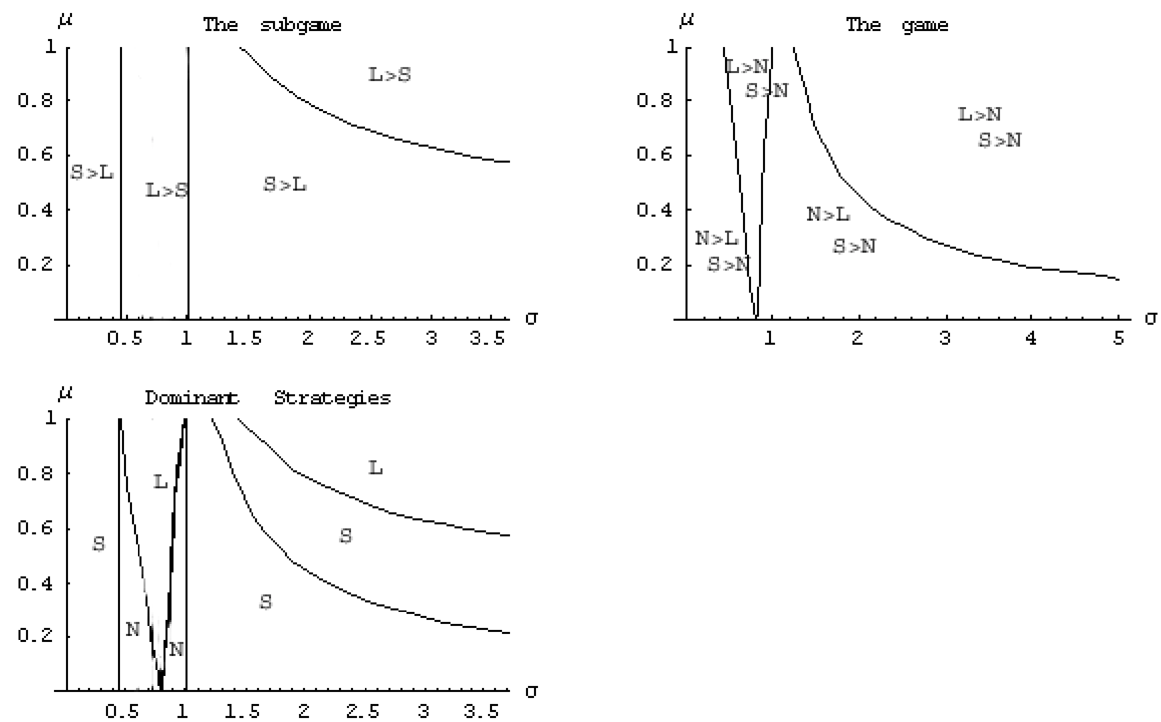

The subgame
μ
σ
S>L
L>S
S>L
L>S
The game
L>N
S>N
L>N
S>N
N>L
S>N
N>L
S>N
Dominant Strategies
S
L
N
N
L
S
S

Figure 2:

In the latter equation, ε accounts for how quickly the case will be decided by the court. If ε is small then $\tau_{t=1}$ is large, hence the courts are expected to decide on the case soon after filing; effectively reducing the discussion to that of the static model. If by contrast ε is close to one, the $\tau_{t=1}$ is very small, and courts are expected to meet quite a while after filing the case. It suffices to say that in the waiting period (until the court finally meets) the plaintiff is faced with no choice but doing nothing, i.e. following strategy N.

Accounting for the above, following the intuition introduced in the previous sections, if there is no conflict then the demand for the product is given by,

$$q_{i,t} = B_{i,t} - b_{j,t} + b_{i,t}, \quad q_{j,t} = B_{j,t} - b_{i,t} + b_{j,t}$$

where,

$$B_{i,t} = M + s_{i,t} \ , \ \ B_{j,t} = M + s_{j,t} \ \ , \ \ M > 0$$

and the production/R&D cost is,

$$c_{i,t} = c_0 + s_{i,t}^{-\alpha} \ \ , \ \ c_{j,t} = c_0 + s_{j,t}^{-\alpha}$$

Hence, $b_{i,t}$ and $b_{j,t}$ are,

$$b_{i,t} = s_{i,t-1} + \delta \frac{c_0 + s_{i,t}^{-\alpha}}{s_{i,t} + s_{j,t}} q_{i,t} \ \ , \ \ b_{j,t} = s_{j,t-1} + \delta \frac{c_0 + s_{j,t}^{-\alpha}}{s_{i,t} + s_{j,t}} q_{j,t}$$

where the lag in the first term accounts for the time it takes a new idea until it is incorporated into R&D. The profits of the firms are,

$$\pi_{i,t} = q_{i,t} \left(1 - c_{i,t}\right) \ , \ \pi_{j,t} = q_{j,t} \left(1 - c_{j,t}\right)$$

Following the same reasoning, if the plaintiff decides on no action, strategy N, the above equations become,

$$q_{i,t}^{N} = B_{i,t}^{N} - b_{j,t}^{N} + b_{i,t}^{N} \ , \ \ q_{j,t}^{N} = B_{j,t}^{N} - b_{i,t}^{N} + b_{j,t}^{N}$$

$$B_{i,t}^{N} = M + s_{i,t} \ , \ \ B_{j,t}^{N} = M + s_{i,t} + s_{j,t}$$

$$c_{i,t}^{N}=c_0+s_{i,t}^{-\alpha}\quad,\quad c_{j,t}^{N}=c_0+\left(s_{i,t}+s_{j,t}\right)^{-\alpha}$$

$$b_{i,t}^{N}=s_{i,t-1}+\delta\frac{c_0+s_{i,t}^{-\alpha}}{s_{i,t}+s_{j,t}}q_{i,t}^{N}\quad,\quad b_{j,t}^{N}=\left(s_{i,t-1}+s_{j,t-1}\right)+\delta\frac{c_0+\left(s_{i,t}+s_{j,t}\right)^{-\alpha}}{s_{i,t}+s_{j,t}}q_{j,t}^{N}$$

$$\pi_{i,t}^{N}=q_{i,t}^{N}\left(1-c_{i,t}^{N}\right)\quad,\quad \pi_{j,t}^{N}=q_{j,t}^{N}\left(1-c_{j,t}^{N}\right)$$

While if the firm decides to settle the case,

$$q_{i,t}^{S}=B_{i,t}^{S}-b_{j,t}^{S}+b_{i,t}^{S}\ ,\ \ q_{j,t}^{S}=B_{j,t}^{S}-b_{i,t}^{S}+b_{j,t}^{S}$$

$$B_{i,t}^{S}=M+s_{i,t}\ ,\ \ B_{j,t}^{S}=M+s_{i,t}+s_{j,t}$$

$$c_{i,t}^{S}=c_0+s_{i,t}^{-\alpha}\quad,\quad c_{j,t}^{S}=c_0+\left(s_{i,t}+s_{j,t}\right)^{-\alpha}$$

$$b_{i,t}^{S}=s_{i,t-1}+\delta\frac{c_0+s_{i}^{-\alpha}}{s_{i,t}+s_{j,t}}q_{i,t}^{S}\quad,\quad b_{j,t}^{S}=\left(s_{i,t-1}+s_{j,t-1}\right)+\delta\frac{c_0+\left(s_{i,t}+s_{j,t}\right)^{-\alpha}}{s_{i,t}+s_{j,t}}q_{j,t}^{S}$$

$$\pi_{i,t}^{S}=q_{i,t}^{S}\left(1-c_{i,t}^{S}\right)+\left(\pi_{i,t}-\pi_{i,t}^{N}\right)\quad,\quad \pi_{j,t}^{S}=q_{j,t}^{S}\left(1-c_{j,t}^{S}\right)-\left(\pi_{i,t}-\pi_{i,t}^{N}\right)$$

Up to this point, excluding the lag in prior art the model is identical to that of the previous section. This is not so for the case of strategy L. Specifically, if the court meets with probability τ_t then firm j must have a size that is equal to, $\tau_t\left(\left(1-\mu\right)s_i+s_j\right)+\left(1-\tau_t\right)\left(s_{i,t}+s_{j,t}\right)$, while $i's$ size is always the same. Therefore, the demand that firms face is,

$$q_i^{L}=B_i^{L}-b_j^{L}+b_i^{L}\ ,\ \ q_j^{L}=B_j^{L}-b_i^{L}+b_j^{L}$$

while $B_{i,t}^{L}$ and $B_{j,t}^{L}$ must account for this change in size and must thus be equal to,

$$B_{i,t}^{L}=M+s_{i,t}\ ,\ \ B_{j,t}^{L}=M+\tau_t\left(\left(1-\mu\right)s_i+s_j\right)+\left(1-\tau_t\right)\left(s_{i,t}+s_{j,t}\right)$$

In addition, the production and R&D cost must be equal to,

$$c_{i,t}^{L}=c_0+s_{i,t}^{-\alpha}\quad,\quad c_{j,t}^{L}=c_0+\tau_t\left(\left(1-\mu\right)s_i+s_j\right)^{-\alpha}+\left(1-\tau_t\right)c_{j,t}^{N}$$

incorporating the $c_{j,t}^{N}$ that j faces if the court does not meet that period. Subsequently, b_i^{L} and b_j^{L} are,

$$\begin{aligned}
b_i^{L} &= s_{i,t-1}+\delta\frac{c_0+s_{i,t}^{-\alpha}}{s_{i,t}+s_{j,t}}q_{i,t}^{L}\\
b_j^{L} &= \left(\begin{array}{c}\tau_{t-1}\left(\left(1-\mu\right)s_{i,t-1}+s_{j,t-1}\right)+\left(1-\tau_{t-1}\right)\left(s_{i,t-1}+s_{j,t-1}\right)\\ +\delta\frac{c_0+\left(\tau_t\left(\left(1-\mu\right)s_i+s_j\right)^{-\alpha}+\left(1-\tau_t\right)c_{j,t}^{N}\right)^{-\alpha}}{s_{i,t}+s_{j,t}}q_{j,t}^{L}\end{array}\right)
\end{aligned}$$

while the profits of the two firms are now given by the following equation,

$$\pi^L_{i,t} = \tau_t \left(q^L_{i,t} \left(1 - c^L_{i,t}\right) + \mu \left(\pi_{i,t} - \pi^S_{i,t}\right) - \widetilde{c}_{i,t} s_{i,t} \right) + (1 - \tau_t)\, \pi^N_{i,t}$$
$$\pi^L_{j,t} = \tau_t \left(q^L_{j,t} \left(1 - c^L_{j,t}\right) - \mu \left(\pi_{i,t} - \pi^S_{i,t}\right) - \widetilde{c}_{j,t} s_{i,t} \right) + (1 - \tau_t)\, \pi^N_{j,t}$$

which accounts for the $\pi^N_{i,t}$, $\pi^N_{j,t}$ profits that the firms have if the court does not meet this period. Lastly, the litigation cost (being an *ex-ante* cost) is given by,

$$\widetilde{c}_{i,t} = \widetilde{c}_0 + s^{-\beta}_{i,t} \ , \ \widetilde{c}_{j,t} = \widetilde{c}_0 + s^{-\beta}_{j,t} \ , \beta > 0$$

Solving the model in a fashion identical to the previous section one can find the equivalent of equations, (31)-(34). This means that one can plot a figure similar to the figures that denote the dominant strategies of figures one-two.

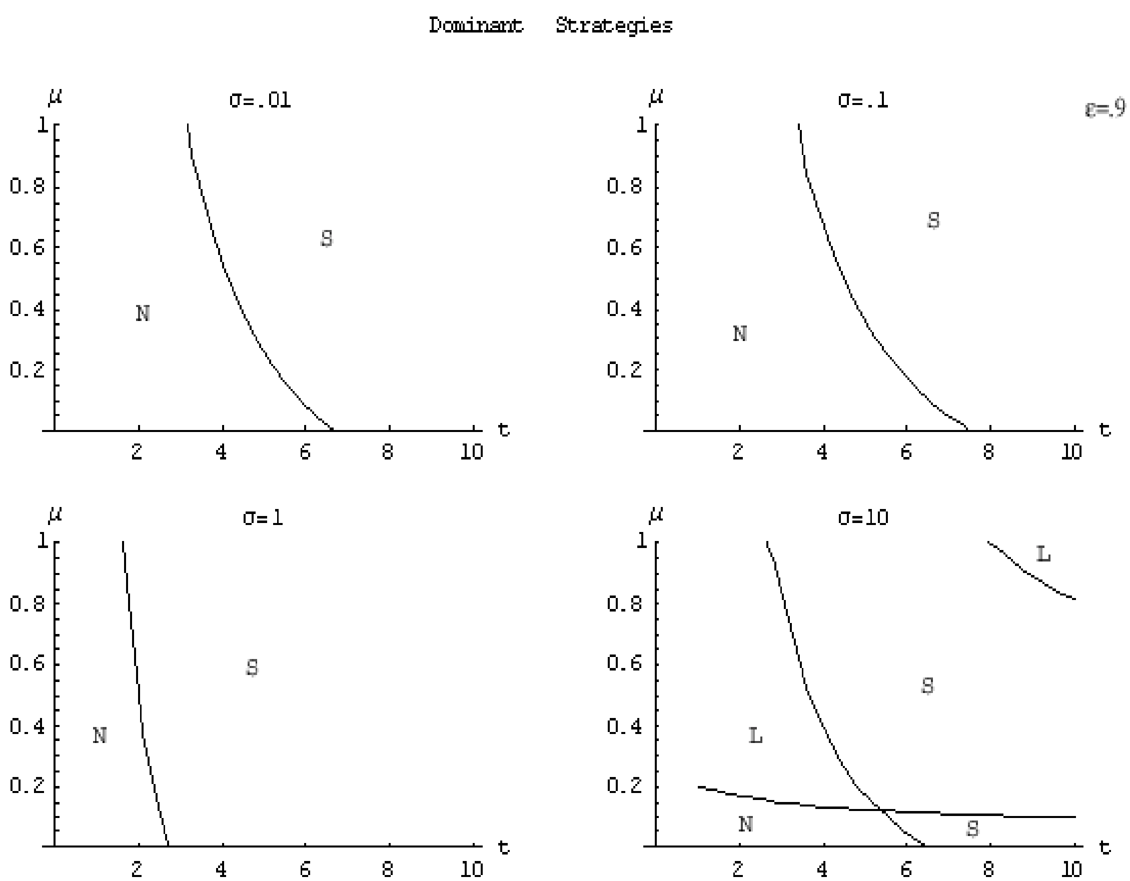
Bearing in mind that size changes very slowly, and that it is difficult to *a priori* know if σ will increase (or decrease) in the course of time, I will shift the emphasis of this section from σ to t. Subsequently, varying σ from some size very close to zero to sizes that are much larger than zero, I will plot the dominant strategies for $\mu \in [0, 1]$ and for $t \in [0, 10]$. The choice of ten as an upper barrier for t is consistent with the long waiting period (in years) for the courts to meet. Thus, using the same assumptions regarding α, β, δ, M, c_0, $\widetilde{c}_0$ as in the previous section, allowing ε to be close to one, the following figure is derived. Figure three (plotted for values of σ that are equal to $\{.01, .1, 1, 10\}$, shows that no litigation should take place for plaintiffs that are of small size. Instead, one is faced with either lack of action or settlement. By contrast, if the plaintiff is much larger than the infringer then one should expect litigation to dominate. Changing the value of ε to 0.5 (suggesting speedier justice) does not change the outcome. Again, as figure four indicates, for large values of σ litigation is likely, but the dominant strategy for small values of σ is settlement.

If one is to use the average US value for μ, which is roughly 0.5, figures one-four indicate that for a $\sigma >> 1$ litigation will always prevail. Notwithstanding the above, the EU legal system is different from the US one, and it is difficult to *a priori* have an accurate expectation of μ. To start with, due to the lack of an equivalent of the CAFC, the EU system is fragmented and, on top of the EPO, a plaintiff, in order to fully protect his patent, needs to take his case to 25 different national courts, many of which lack experience in patent litigation. Therefore, μ may vary from country to country.

In addition, the proposed Directive on computer-implemented inventions states that patents will only be granted to software that can display some *technical effect*. The latter term has already proved controversial in the way it is interpreted. For example, US courts, contrasting Japanese ones, have literary applied the requirement in a way that some commentators argue that software will always be found to have some technical effects. A casual reading of the Directive indicates that the EU interprets *technical effect* in a more restrictive way. Such an interpretation seems to suggest that in the EU μ may prove to be lower than in the US. Nevertheless, only practice will show how different courts and the EPO interpret the term *technical effect*.

7 Conclusions

The EU is currently considering the introduction of patent protection for software. This is indented as stimuli for innovation in a market that is already considered as innovative. The hope is that patents will allow EU software developers, which are of small to medium size, to compete in better terms against their much larger US rivals. Considering that software is a bundle of many different subroutines (ideas), for which EU software developers were not permitted patent protection, and that their US counterparts have amassed over 200,000 patents during the last few years (most of them going to large US firms), one should expect that most EU software developers will be infringing one or many US patents. Up to now, this has not created major problems in the EU, because US software patents were not valid in the EPO. With the new Directive on the patentability of computer-implemented inventions, which is now at the European Parliament for a second reading, this is going to change, allowing any US patents that have been granted within the context of the Patent Cooperation Treaty


Dominant Strategies
σ=.01
σ=.1
ε=.9
σ=1
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S
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0.2
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1
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4
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8
10

Figure 3:

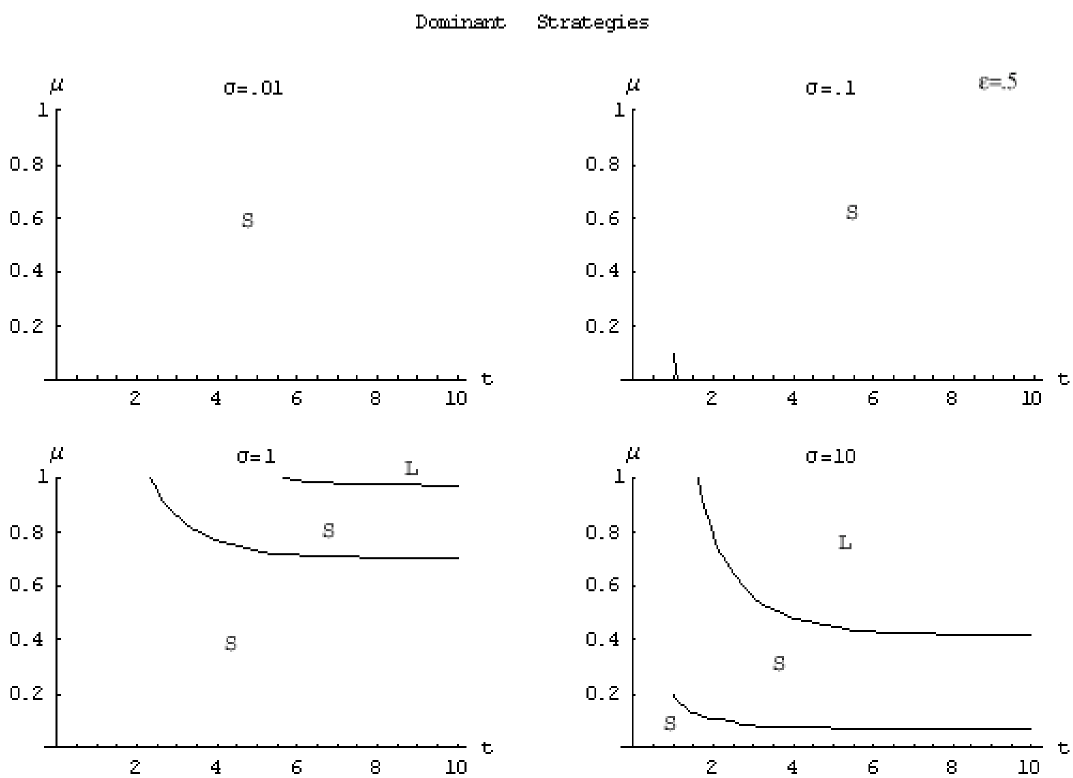

Figure 4:

to apply within the EU as well.[15]

As the model shows, bearing in mind that (at least in the US) the probability of winning a patent infringement case is greater than 50%, when a firm of large size initiates infringement proceedings against a small rival firm, it will always litigate, avoiding settlement. This is due to the smaller litigation cost that large firms have, and on the ability of large firms to bundle new ideas to their existing prior art better than smaller firms. The latter effect allows large firms to create better products, increasing the obsolescence rate that small firms are faced with. Accounting for the above, the model concludes that large US firms will choose to initiate infringement proceedings when the infringer is a smaller EU firm, avoiding settlement. This finding coincides with the empirical results of Lanjouw and Schankerman (2004), who observe that patents which are part of a small patent portfolio are more likely to find themselves at the center of litigation, compared to patents that are part of a large patent portfolio. As they note, *"for a (small) domestic unlisted company with a small portfolio of 100 patents, the average probability of litigating a given patent is 2%. For a company with a similar profile but with a moderate portfolio of 500 patents the figure drops to 0.5%."*.

On account of the above, considering that the EU lacks the equivalent of the Court of Appeals of the Federal Circuit, in order to protect his monopoly rights a plaintiff must argue his case before many different national courts, some of which lack any experience on patent prosecution. Subsequently, the cost of patent litigation may prove to be much higher than the already sizable US cost, which is possibly acting as a deterrent to innovative activity. Evidence of such deterrence is provided by Lerner (1995) who finds that, in biotechnology, well-protected (litigated) patents act as a barrier to new entries.

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