Abstract

We develop a theoretical framework aimed at looking at how the presence (or the prospect of the presence) of patent thickets affects firms’ decisions to enter in a given technological field. In this set-up, we investigate the role of PTOs’ (Patent and Trademark Offices) standards in providing incentives to firms to pile up large patent portfolios, thus creating patent thickets. PTOs standards play a double role in determining the intensity of patent protection: a stricter PTO reduces the likelihood of an application to obtain protection, but it increases the quality of issued patents. We show that when patent protection is more intense firms tend to apply for more patents and to enter the same - high value - technological territory. With less intense protection, firms tend to choose different technological territories. Our analysis also suggests that while large firms can benefit from more intense patent protection, small ones undoubtedly suffer from it.

KEYWORDS: patent portfolios, PTO’s standard, technological territory.
1 Introduction

In the recent years, the number of patent applications has increased dramatically, so as the number of patents granted (Khan et al., 2011). This phenomenon has affected many industrial sectors but it is particularly relevant in the information and communication technologies (ICTs). In high-tech industries, due to the large number of patents protecting complex technologies (namely, technologies combining several different technological components) the ownership of intellectual property rights is highly fragmented. The surge in the number of applications and the related proliferation of issued patents are generating a series of potentially problematic consequences.\footnote{See Comino et al. (2019) for a recent survey of the economic literature on the controversial role of patents in ICTs} In high-tech industries, technological progress is rapidly advancing and new technologies draw upon existing stock of knowledge. Consequently, innovators need access to several complementary technologies often protected by patents, that is they need access to “thickets” of intellectual property rights in order to innovate without the fear of being taken to court for patent infringement (Shapiro, 2001).

It is commonly believed that the proliferation of patents has been largely driven by strategic motives. As a matter of fact, firms tend to amass large patent portfolios either for defensive or for offensive reasons. In the former case, firms use patent portfolios as a safeguard against the possibility of rival firms taking legal action for patent infringement (Ziedonis, 2004); in the latter, firms may want to use them aggressively against competitors (Walsh et al., 2016; Torrisi et al., 2016).

This strategic use of patents appears to be particularly relevant in ICTs where the high degree of fragmentation of patent ownership protecting complex technologies has naturally led firms to use patents strategically. In particular, it seems that large and small firms react to patent fragmentation differently. As a matter of fact, SMEs and individual inventors are less able to cope with the “cost of complexity”, namely the costs associated with the uncertainty over freedom to operate, the lack of transparency, the search of relevant prior art and legal actions (EPO, 2017). The presence of patent thickets seems to have negative effects on small firms R&D incentives too and on their decisions about where to focus their innovative efforts. Hall et al. (2013) look at how patent fragmentation influences the behaviour of entrants and find that these firms tend to patent less the more fragmented the intellectually property. And relevantly for our scopes, the authors find also that SMEs may decide not to enter the technological territories where patent thickets prevail.

Another consequence of the surge in patent applications is the alleged deterioration
of the quality of the patents issued by PTOs. Based on a sample of more than 400,000 applications at the five largest Patent and Trademark Offices (PTOs) (in China, Europe, Japan, Korea, USA), de Rassenfosse et al. (2017) find that up to 6% of the granted patents are inconsistent with the patent office’s own standard and that up to 15% is found to be of low quality in the sense that they would not have been granted were the (stricter) standards of some other patent office being applied. An explanation for this evidence is that under the pressure of increasing backlogs, patent examiners devote less time on searching and examining applications to the detriment of the quality of granted patents (de Rassenfosse and van Pottelsberghe de la Potterie, 2007). The European Patent Office defines quality as the ability of a patent to “meet the statutory patentability requirements” and to “leave little doubt as to its breadth”. A patent of low quality, is a patent which is likely to be invalidated by a court in case of a subsequent litigation. A decline in patent quality may have severe effects on the functioning of the patent system. The recent “smartphone war” - the wave of lawsuits and countersuits occurred between the major producers of smartphone/tablet devices - is a clear example of such negative effects. It is widely believed that the root cause of this surge in litigation lies in the poor quality of ICT patents and in the firms’ strategic uses of their patent portfolios.

Traditional theory of patent protection has focussed on the analysis of the effects of isolated patents on the functioning and efficiency of the market. The new landscape mentioned above calls for a new theory of strategic patenting based on the use of large patent portfolios. An attempt in this direction is in Choi and Gerlach (2017). The authors develop a theoretical model of patent portfolios in which two firms compete to develop a new product; each firm owns a patent portfolio of a given size and strength and when one firm successfully develops a product there is a chance that it infringes on some of the patents in the other firm’s patent portfolio; the probability of infringement represents the “strength” of the portfolio: the stronger the portfolio, the higher the probability that the other firm violates the intellectual property of the firm.

The main limitation of the theory developed by Choi and Gerlach (2017) is that the size and the strength of the portfolio is exogenous. In the reality, as discussed above, firms tend to apply for patent protection in order to accumulate large patent portfolios that increase their bargaining position vis a vis potential competitors. The size of firms’ portfolios is, therefore, endogenous. In addition to this, another ingredient that we want to consider in our analysis is the fact that patents are not ironclad rights, and their quality is closely linked to the standards PTOs adopt in order to verify the fulfillment of the patentability requirements; as mentioned above, patent
proliferation is associated with a decline in the quality of issued patents. In this sense, our analysis also contributes to another strand of the economic literature that investigates the role of so-called weak patents (Farrel and Shapiro, 2008) and that of PTOs (Eckert and Langinier, 2014; Schuett, 2013). As stated, it is believed that in recent years, also due to the increase in patent applications, PTOs have reduced their standards; inundated by patent applications, examiners often fail to thoroughly vet patent applications before approving them. A less stringent examination of the applications has a couple of important consequences: it makes it easier/less costly for applicants to obtain protection but, at the same time, it lowers the quality of granted patents which, therefore, are more likely to be invalidated in the event of a legal dispute. A theory of patent portfolios must take these effects into account. A reduction in PTOs examination standards may facilitate the life to firms that for strategic reasons are willing to amass large patent portfolios; at the same time, though, a lower quality of the patents reduces the strategic strength of such portfolios. It is not clear in advance which effect prevails.

In this paper we develop a theoretical framework aimed at looking at the how the presence (or the prospect of the presence) of patent thickets built by firms who pile up large portfolios strategically - i.e. to extract profits from rival companies and/or to defend themselves -, affects firms decisions to enter in a given technological field. A crucial role is played by the Patent Office (PTO): it receives the applications and according to its own standards it decides which applications to grant protection. Its activity determines the quality of the issued patents and therefore the strength of the portfolios owned by the firms and their effectiveness as a strategic tool.

2 The model

The main focus of our model is strategic patenting, that is the firms practice of piling-up large patents portfolios in order to increase their bargaining position in negotiations/litigations against rivals. We address this issue in an economy made of two adjacent markets, 1 and 2, each of which corresponds to a given technological territory; by technological territory, we mean the set of technologies aimed at manufacturing products for a given market. The two territories can, to a given extent, overlap; this occurs when technologies belonging to a territory can be used to produce products for the other market. For example, one can think to the market of mobile devices (tablets, smartphones) and that of personal computers. Clearly, a certain amount of technologies used to produce a tablet can also be used for producing PCs.
and vice versa.

Consider two firms, A and B, that are competing in the two markets; we normalise to zero their current profits in both markets. With the aim of boosting their businesses, the two firms conduct R&D activities aimed at developing and patenting new technologies. With the proprietary control of relevant technologies firms are able to extract larger market values. We model a two stage game; in the first stage A and B simultaneously choose in which technological territory to direct their R&D efforts. For the sake of simplicity, firms’ R&D costs are normalised to 0; the only cost of developing technologies within a given territory is the opportunity cost of not investing in the other one. After choosing the territory where to develop technologies, the two firms decide how many patent applications to file at the PTO. The PTO examines each applications following its own standards/level of examination and decides how many patents to issue. Firms then use their portfolio of patents to generate profits.

In our model, we assume that:

1. $\beta \in [0, 1]$ represents the appropriateness of the technologies in a given territory. Clearly, technologies that have been specifically developed within a given territory are fully appropriate for that territory, and $\beta = 1$; such technologies are less than fully appropriate for the adjacent territory, $\beta \leq 1$. Parameter $\beta$, therefore, also represents the technological proximity of the two areas. Low values of $\beta$ imply that there is little technological overlap between the two territories, while when $\beta$ tends to one, the two territories perfectly overlap, meaning that the technologies developed in one territory are fully applicable in the other territory too;

2. one territory is more valuable than the other; denoting with $\phi_i$ the maximum value that can be generated within territory $i = 1, 2$, we assume that $\phi_1 > \phi_2$. Without loss of generality, in what follows, we normalise $\phi_2 = 1$;

3. If no firm has developed technologies within territory $i$, only a fraction $\alpha(\beta) \in [0, 1]$ of $\phi_i$ can be generated. Our idea is that the potential value of a market can be realised only with technologies that have been specifically developed for that market. Technologies developed for the adjacent market can still generate value but to a lesser extent; clearly the larger the technological proximity of the two territories, the more market value can be generated with technologies developed for the adjacent market, that is $\alpha'(\beta) \geq 0$;

4. the value generated in each market is shared between firms depending on the relative strength of their portfolios. We do not model precisely how firms appro-
appropriate market value; this may occur via direct production or via licensing/cross-licensing their IP rights or also via litigation. The idea is that the stronger its portfolio vis a vis that of the rival, the higher the firm bargaining power and the larger the share of the market value the firm is able to exploit;

5. the strength of a portfolio is maximum when it is used in the market for which it has been built for, while it is lower when it is used in the other market. We justify this assumption on the existence of patent thickets, defined as the presence of overlapping sets of patent rights; patent thickets may extend their effects well beyond the specific technology they are related with, so a firm holding patents in the territory of mobile device may assert them also against firms in other territories, as those active in the market for personal computer. Clearly, the greater the technological overlap between two territories, the more patents developed within a specific territory can extend their legal protection also in the other territory.

As it will be clear below, we model firm’s profits using a very simple reduced form; as mentioned, we assume that the value that a firm can appropriate depends on the relative strength of its patent portfolio. Hence in a specific technological territory $i$, firm $j$ enjoys a share of the value that can be generated which is larger the stronger its portfolio and the weaker the portfolio of the rival. It is therefore crucial to define the strength of a portfolio. We model it as related to two factors: $i$) the size of the portfolio, namely how many patents it contains, and $ii$) the strength of the patents it contains.

As regard factor $i$), once the technological territories have been chosen, the two firms decide how may applications to file, $n_j$ with $j = a, b$. The patent office (PTO) examines the applications following certain standards; the higher the standards, the fewer the applications fulfilling them, the smaller the number of patents that the PTO actually grants. We parametrise with $x \in (0, 1)$ the standards imposed by the PTO for granting patents: the higher $x$ the higher the standard required by the PTO; when $x = 0$ all applications are granted a patent while on the contrary when $x = 1$ no applications pass the PTO’s examination process. The actual number of firm $j$’s applications that is granted patent protection is therefore $n_j(1 - x)$; this expression indicates the size of the portfolio hold by firm $j$.

Regarding factor $ii$), the strength of the patents is related to two dimensions: 1) their quality and 2) the level of technological appropriateness. The quality of a patent is related to the standards adopted by the PTO: the stricter the standards (the higher $x$), the greater the quality of the patent. A high quality patent can be interpreted
as a patent that is likely to be upheld in court in case of litigation. In relation to 2),
the portfolio is stronger when asserted in the technological territory its patents have
been intended for. When asserted in the adjacent territory, the portfolio is weaker
the farther the territory from the original technological area. Formally, we model the
strength of firm $j$’s portfolio as:

$$s_j(\beta) = n_j (1-x)x\beta,$$

where $x\beta$ indicates the quality of the portfolio as a function of PTO’s scrutiny and
the level of patent appropriateness. Clearly, $\beta = 1$ when the patents are asserted in
the same territory they have been developed for or when the two territories perfectly
overlap.

As it will become clear below, the term $(1 - x)x$ will turn out to be of particular
relevance for our analysis. This term is the product of the probability that an applica-
tion is accepted, $1 - x$, times the quality of the granted patent in its specific territory,
$x$. We interpret this product as the “intensity of the patent system”: an application
which is more likely to be protected by a high quality patent confers a more intense
protection to the patent holder. The intensity of the patent system changes with $x$;
in particular, it can be easily checked that it increases the tighter the PTO’s scrutiny
provided that $x < 1/2$, while it reduces with $x$ for larger values of the scrutiny. This
is due to the double role played by PTO’s scrutiny; a larger $x$ (i.e. a more strict
PTO) makes the patent portfolio weaker, provided that it reduces the number of
granted patents. On the other hand, it reinforces protection since the patents that
are granted are of higher quality. Balancing the two effects one can notice that the
intensity increases with $x$ when $x < 1/2$ and it decreases with $x$ otherwise.

The share of the market value a firm is able to appropriate depends on the relative
strength of its portfolio. Indicating with $s_{-j}(\beta)$ the strength of the rival’s portfolio,
we model the relative strength of firm $j$’s portfolio as:\(^2\)

$$
\frac{1}{2}(1 + s_j(\beta) - s_{-j}(\beta)), \quad \text{with} \quad 0 \leq \frac{1}{2}(1 + s_j(\beta) - s_{-j}(\beta)) \leq 1. \quad (2)
$$

From this expression it is clear that the relative strength of firm $j$’s portfolio increases in $s_j(\beta)$, decreases with $s_{-j}(\beta)$ and it is $1/2$ when the two firms portfolios have the same strength.

We are now in the position to define firms’ payoffs. They are the sum of the value that each firm is able to appropriate in both markets which, in turn, depend on the relative strength of firms’ portfolios. There are two relevant sub-games:

I) at $t_1$ one firm, lets say firm A, has chosen technological territory 1 while the other has chosen territory 2;

II) at $t_1$ both firms have chosen the more profitable technological territory 1.

Consider subgame I) where firms have chosen to patent in different territories. According to assumption 3 above, the maximum values $\phi_1$ and $\phi_2$ can be generated. How much this value each firm is able to appropriate depends on the relative strength of its portfolio.

When the two firms enter different technological territories, their expected profits are the sum of the profits in their specific territory, where their portfolio has strength $s_j(1)$ and the rivals’ $s_j(\beta)$, with those each firm can earn by asserting its patents in the other technological territory. Using expressions (2) and (1):

$$
\pi_{1,2}^a = \frac{\phi_1}{2} (1 + s_a(1) - s_b(\beta)) + \frac{1}{2} (1 + s_a(\beta) - s_b(1)) - \frac{n_a^2}{2}
$$

$$
= \frac{\phi_1}{2} (1 + (1 - x)x(n_a - \beta n_b)) + \frac{1}{2} (1 + (1 - x)x(\beta n_a - n_b)) - \frac{n_a^2}{2}
$$

\(^2\)This way to represent the strength of firm $j$’s portfolio has a clear micro-foundation. If one interprets the strength of the portfolio of firm $j$ as the probability that the rival firm violates at least one patent of firm $j$, then $s_j(1 - s_{-j})$ is the probability that firm $j$ does not violate firm $-j$ portfolio while firm $-j$ does. In this case it is reasonable to assume that firm $-j$ must stop production and firm $j$ gets the whole market value. When both firms do violate their respective portfolios, event which occurs with probability $s_j s_{-j}$, or when they both do not violate, which occurs with probability $(1 - s_j)(1 - s_{-j})$, the two firms equally share the market value. Hence, the expected value each firm gets depends on its relative strength and it can be written as: $s_j(1 - s_{-j}) + s_j s_{-j}/2 + (1 - s_j)(1 - s_{-j})/2$, which corresponds to expression (2).
and

\[ \pi_{1,2}^b = \frac{1}{2} (1 + s_b(1) - s_a(\beta)) + \frac{\phi_1}{2} (1 + s_b(\beta) - s_a(1)) - \frac{n_b^2}{2} \]

\[ = \frac{\phi_1}{2} (1 + (1 - x) x (n_b - \beta n_a)) + \frac{\phi_1}{2} (1 + (1 - x) x (\beta n_b - n_a)) - \frac{n_b^2}{2} \]

where \( n_b^2/2 \) is the cost of the applications.

Firm A and B choose \( n_a \) and \( n_b \) to maximise their profits; solving the system of first order conditions, it is possible to obtain the optimal number of applications for the two firms:

\[ n_a^* = \frac{1}{2} (1 - x) x (\phi_1 + \beta) \]

\[ n_b^* = \frac{1}{2} (1 - x) x (\phi_1 \beta + 1) \]

From these expressions it follows that i) firm A applies for more patents, \( n_a^* > n_b^* \), as its portfolio is fully appropriate for the more valuable territory, and that ii) both firms apply for more patents the larger the technological overlap, \( d n_j^*/d \beta > 0 \): the greater the overlap, the more valuable patents are in the adjacent territory and the more aggressively firms apply for patent protection.

Notably, PTO’s standard affects the number of patents firms apply for via its effect on the intensity of patent protection. In particular, following our previous definition, it is immediate to see that both firms apply for more patents the more intense patent protection. On the contrary, when applications are not very effective either because it is very unlikely that they pass the very strict PTO’s standard (\( x \) close to one) or because in case of success, the patent has very low quality (\( x \) close to zero), firms apply for very few patents.

Using \( n_j^* \), the equilibrium profits when firm A chooses the technological territory 1 and B the technological territory 2 are:

\[ \pi_{1,2}^{a*} = \frac{1 + \phi_1}{2} - \frac{1}{8} x^2 (1 - x)^2 \left[ 2 (\phi_1^2 - 1) \left( \beta^2 - 1 \right) + (\beta + \phi_1)^2 \right] \]

and

\[ \pi_{1,2}^{b*} = \frac{1 + \phi_1}{2} - \frac{1}{8} x^2 (x - 1)^2 \left[ 2 (\phi_1^2 - 1) \left( \beta^2 - 1 \right) - (\beta \phi_1 + 1)^2 \right] \]

It is immediate to see that not only firm A patents more intensively, but it also gets larger profits; indicating with \( \Delta \pi \) the difference between firm A and firm B’s
profits:
\[ \Delta \pi = \pi_{a,2}^* - \pi_{b,2}^* = \frac{3}{8} (1 - x)^2 x^2 \left( \phi_1^2 - 1 \right) \left( 1 - \beta^2 \right) > 0. \]

Interestingly, \( \partial \Delta \pi / \partial \beta < 0 \): the more the two territories overlap, the closer the equilibrium profits; when territories perfectly overlap, \( \beta = 1 \), the two firms get the same amount of profits.

It is interesting to discuss how the PTO affects firms profits. It is in fact immediate to see that different levels of PTO’s standard affect firms profits in different ways.

**Proposition 1** A change in PTO’s standards that increases the intensity of the patent system always harms firm B, while it benefits firm A if and only if \( \beta < \sqrt{\frac{2\phi_1^2 - \phi_1}{2\phi_1^2 - 1}} \).

**Proof.** From expressions (3), it follows that:
\[
\frac{d\pi_{a,2}^*}{dx} = \frac{1}{4} x (2x - 1) (1 - x) \left( \beta^2 \left( 2 \phi_1^2 - 1 \right) + 2 \beta \phi_1 - \phi_1^2 + 2 \right)
\]
\[
\frac{d\pi_{b,2}^*}{dx} = \frac{1}{4} x (2x - 1) (x - 1) \left( \left( \beta^2 - 2 \right) \phi_1^2 - 2 \beta \phi_1 - 2 \beta^2 + 1 \right)
\]

Let us focus on \( x < 1/2 \); in this case, the intensity of the patent system increases with \( x \) (when \( x > 1/2 \), the opposite occurs). Consider firm B first. The polynomial \( (\beta^2 - 2) \phi_1^2 - 2 \beta \phi_1 - 2 \beta^2 + 1 \) decreases with \( \phi_1 \); as it is negative for \( \phi_1 = 1 \), it is always negative. Hence \( \pi_{b,2}^*/dx < 0 \). In relation to firm A, the polynomial \( \beta^2 \left( 2 \phi_1^2 - 1 \right) + 2 \beta \phi_1 - \phi_1^2 + 2 \) is a convex parabola, which is positive for values of \( \beta \) lying outside the roots \( \beta_1 = -\frac{\sqrt{2\phi_1^2 - \phi_1} \pm \phi_1}{2\phi_1^2 - 1} \) and \( \beta_2 = \frac{\sqrt{2\phi_1^2 - \phi_1} \pm \phi_1}{2\phi_1^2 - 1} \). As \( \beta_1 < 0 \) and \( 0 < \beta_2 < 1 \), the polynomial is positive for \( \beta > \beta_2 \) and the derivative is negative. When \( 0 < \beta < \beta_2 \) the opposite occurs. ■

We have already seen that an increase in the intensity of the patent system induces firms to patent more aggressively. This direct effect harms both firms, and the harm is stronger the greater the technological overlap between the two territories, \( \beta \). On top of this negative effect, an increase in the intensity of the patent system impacts indirectly firms profits via the effect it has on the relative strength of the two firms in the two territories. More precisely, when the intensity of the patent system goes up, firms portfolios are stronger in their specific territory, where they increase their profits, while they are weaker in the adjacent territory, where they reduce their ability to extract value. The net effect is positive for firm A, as this firm is actively engaged in the highly valuable market 1, while it is negative for firm B, which is active in
the less valuable market. Overall, an increase in the intensity of the patent system undoubtedly hurts firm B, for which the direct and the indirect effects go in the same negative direction. In the case of firm A, instead, the indirect positive effect more than compensate the direct negative one when $\beta$ is small enough.

Interestingly, if we interpret firm B as an SME holding a small portfolio, this result seems to confirm the empirical evidence (see Hall et al., 2013) according to which small firms are those who suffer the most a strengthening of the patent system.

Let us now consider subgame II), where both firms choose the technological territory 1. As no firm has a specific portfolio of patents developed for market 2, they can only exploit a fraction $\alpha(\beta)$ of the value of this market (assumption 5). On the contrary, firms can fully exploit $\phi_1$, the value of market 1.

The strength of firm $j$’s portfolio on market 1 and 2 is respectively $s_j(1)$ and $s_j(\beta)$. Using expressions (2) and (1), the expected payoff of firm $j$ is therefore;

$$\pi_{1,1}^j = \frac{\phi_1}{2} (1 + (1-x)x(n_j - n_{-j})) + \alpha(\beta) \frac{1}{2} (1 + (1-x)x\beta(n_j - n_{-j})) - \frac{n_j^2}{2}.$$  

Firm A and B choose $n_a$ and $n_b$ to maximise their profits; solving the system of first order conditions, it is immediate to obtain the optimal number of applications for the two firms:

$$n^* = n_a^* = n_b^* = \frac{1}{2}(1-x)x(\phi_1 + \alpha(\beta)\beta).$$

Using $n^*$, the equilibrium profits are:

$$\pi_{1,1}^* = \frac{\phi_1 + \alpha(\beta)}{2} - \frac{1}{8} (1-x)^2 x^2 (\phi_1 + \alpha(\beta)\beta)^2$$  

(3)

2.1 Equilibrium in the choice of the technological territory

Going backwards, we can discuss the firms’ choice of the technological space. There are two possible Nash equilibria: $i)$ both firms choose territory 1 and $ii)$ one firm (let’s say firm A) choses territory 1 and one firm (firm B) chooses territory 2. Formally, equilibrium $i)$ occurs if

$$\pi_{1,1}^* > \pi_{1,2}^*$$

and equilibrium $ii)$ occurs otherwise. Using the expressions found above, the difference $\pi_{1,2}^* - \pi_{1,1}^*$ is

$$\frac{1}{8} x^2 (1-x)^2 \left( 2 (\phi_1^2 - 1) (\beta^2 - 1) - (\beta \phi_1 + 1)^2 + (\alpha(\beta) \beta^2 + \phi_1)^2 \right) + \frac{1 - \alpha(\beta)\beta}{2}$$
This expression is a polynomial of degree four in \( x \) of the type \( x^2(1-x)^2A + B \), where
\[
A = \frac{1}{8} \left( 2 \left( \phi_1^2 - 1 \right) \left( \beta^2 - 1 \right) - \left( \beta \phi_1 + 1 \right)^2 + \left( \alpha(\beta) \beta^2 + \phi_1 \right)^2 \right) \quad \text{and} \quad B = \frac{1 - \alpha(\beta) \beta}{2}.
\]

It is possible to show that the above expression is negative for \( x_l < x < x_h \) and positive otherwise, where:
\[
x_l = \frac{A + \sqrt{A^2 + 4A \sqrt{A^2 - AB}}}{2A} \quad \text{and} \quad x_h = \frac{A - \sqrt{A^2 + 4A \sqrt{A^2 - AB}}}{2A}
\]
with \( x_l < 1/2 \) and \( x_h = 1 - x_l \). Hence, for \( x \in (x_l, x_h) \), \( \pi_{1.2}^b < \pi_{1.1}^* \) and the equilibrium is characterised by the two firms patenting into the same technological space. Conversely, for \( x \notin (x_l, x_h) \) the two firms operate in different technological territories.

**Proposition 2** When the intensity of the patent system is sufficiently large, both firms choose the high value technological territory 1. For smaller values of the intensity of the patent system, the two firms choose different technological territories. Formally, when \( x \in (x_l, x_h) \), firm chose territory 1, while they opt to patent in different territories when \( x \notin (x_l, x_h) \).

When choosing the technological territory 2, firm B increases the value that can be generated on that market, from \( \alpha(\beta) \phi_2 \) to \( \phi_2 \). Nonetheless, by doing so, it weakens its position in the more profitable territory 1 where its portfolio is less effective than that of firm A. When intensity of the patent system is sufficiently large, this second effect dominates and firm B is induced to join firm A in territory 1.

In order to have a better understanding of the determinants of firms’ technological choices, let us resort to a graphical analysis. We do so in Figure (1) and (2) below where, for simplicity, we assume a linear \( \alpha(\cdot) \) function: \( \alpha(\beta) = \alpha \beta \), with \( \alpha \leq 1 \); the two plots have been obtained assuming \( \phi_1 = 10 \).

Figure (1) investigates the effect of technological proximity \( \beta \). An increase in \( \beta \) has two countervailing effects on the choice of firm B. On the one hand, a larger \( \beta \) increases \( \alpha(\beta) \phi_2 \), that is it increases the value that can be generated in market 2 without specifically developing technologies for that territory. This fact reduces \( \phi_2 - \alpha(\beta) \phi_2 \) and therefore the incentives to select territory 2. On the other hand, the patents that have been developed for territory 2 become stronger when asserted in territory 1. This second effect makes it less urgent for firm B to develop technologies for territory 1. The plot shows the non-linear effect of technological proximity on firm choices. Starting from low values of \( \beta \), an increase of technological proximity
augments the incentives of firm B to choose territory 1 and, as shown in the figure, the set of values of $x$ such that there is *agglomeration* (the two firms select the same territory 1) gets larger. By contrast, for larger values of $\beta$ the opposite occurs: a further increase in technological proximity induces firm B to select market 2 and therefore the set of values of $x$ where technological *separation* emerges enlarges.

![Diagram showing the relationship between $\beta$ and $x$ for technological choices of firm B.](image)

**Fig. 1**: firms choices of the technological territory - the role of $\beta$

Figure (2) focusses on the role of parameter $\alpha$, the portion of market 2’s potential value that can be extracted by the two firms when they both choose territory 1. In this case the effects are clear-cut. A larger value of $\alpha$ reduces the incentives to select territory 2, as a larger part of $\phi_2$ can be extracted also with patents developed within territory 1; in this case technological agglomeration becomes more prevalent. Putting this differently, an increase in $\alpha$ reduces the gain in value that can be obtained from developing technologies specific for territory 2, namely $\phi_2 - \alpha(\beta)\phi_2$. 

13
3 Conclusions

In this paper we develop a theoretical framework aimed at looking at the how patent thickets affect firms’ decisions to enter in a given technological field. In recent years, in fact, and especially in the ICT sectors, companies pile up large patent portfolios whose consequences on the incentives to innovate are unclear. In this context, a crucial role is played by the Patent and Trademark Offices (PTOs). PTOs receive patent applications and, according to their own standards, decide which applications to grant patent protection. PTOs therefore contribute in determining the size of thickets. At the same time, however, Patent Offices also affect the quality of patents. This means that PTOs behavior affect the intensity of patent protection in non-trivial ways. For instance a lowering of PTOs standards increases the number of granted patents but, at the same time, it reduces their quality.

In the paper, we show that a change in PTOs standards that increases the intensity of patent protection induces firms to increase the number of applications and to cluster in the same – more valuable – technological fields. With less intense protection, firms tend to choose different technological territories. In line with the recent empirical literature, we have also found that while large firms can benefit from more intense patent protection, small ones undoubtedly suffer from it.

Our analysis provides support to the evidence found in the empirical literature on patent thickets that shows their negative effect on the decision to enter in a given
technology area; this is especially the case of SMEs. More specifically, our study points out the central role of PTO’s standards in shaping the patenting and technological strategies of companies.
References


