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INCENTIVES FOR PROCESS INNOVATIONS UNDER DISCRETE STRUCTURAL ALTERNATIVES OF COMPETITION POLICY[3]

This study analyses the incentives for process innovations under different conditions determined by the competition policy for intellectual property rights (IPR) and particular features of markets and technologies. Competition policy is defined by the presence or absence of compulsory licensing, markets are characterized by technological leadership or technological competition. The results of modelling show that the uncertainty engendered by technological competition may lower the intensity of innovative activities, if there are no mechanisms of coordination between participants. Voluntary licensing generally improves social welfare but does not guarantee an increase in innovative efforts. Compulsory licensing can impede innovations due to the opportunistic behaviour of market participants but certain measures of state policy can prevent this negative effect.

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1. Introduction

Innovation is at the core of sustainable economic growth and development. One of the main goals of state economic policies is to provide sufficient incentives and facilities for fast and active innovation processes.

The state has a diversified set of tools to promote innovation. The creation and maintenance of institutional framework for innovations (primarily the protection of intellectual property rights (IPR) or alternative institutional schemes providing returns for innovators), an industrial (sectoral) policy supporting specific innovative activities, and competition policy represent the most important.

Market competition is strongly associated with innovation. That is why the discussions on balancing competition (including competition *ex ante* and *ex post*), innovation, and market power considerations are among the most popular and urgent topics of contemporary industrial organization studies. This search for a balanced economic policy, and equally balanced regulations, can strongly affect incentives for innovation, and as a consequence, the sustainability of economic development in terms of the flow of innovations, first of all, product and process innovations. Shapiro (2011) and Tirole (1994) contain detailed investigations of this question. Schumpeter (1942) and Arrow (1962) formulate key positions on this interrelation. Schumpeter emphasized the role of large incumbent firms in successful innovation, implying that temporary monopolies may provide enough incentives and capabilities. Arrow focused on stronger competitive incentives for innovative activities, because of greater difference between their income *ex ante* and possible gains from innovations. Gilbert and Newbery (1982) pointed out that the monopolist will be more motivated than the entrant in a bidding for patentable result of the innovative activity in order to preserve its monopolistic position, while the gains of the entrant will be less intense. Reinganum (1983) insisted that entrants will be more active, changing the specification of the model and adding uncertainty, but she admitted the possibility of co-existence with the previous model.

Going further, Aghion and Griffith (2005) provide a detailed set of models connecting innovations and market structure. That discussion until now, from our point of view, may be summarized by the words of Gilbert (2006) also cited by Shapiro (2011): “It is not that we don't have a model of market structure and R&D, but rather that we have many models and it is important to know which model is appropriate for each market context.”

Nowadays, innovations are largely the result of intellectual action, and some of these results are protected within the framework of different regimes as objects of IPR. Protecting IPR often provides special conditions for the holder of these rights. From the point of view of antitrust authorities, such conditions may be qualified in terms of market power and/or market dominance. That is why innovative activities often encounter specific antitrust treatment or require specific competition policy. This is exactly the problem we focus on.

In this paper we consider the relationship between competition policy and innovation through the lens of different sets of competition policies as discrete structural alternatives—one of the key elements of research within New Institutional Economics.

We consider compulsory (mandatory) licensing as an instrument of competition policy. There may be reasonable doubts concerning the feasibility of the inclusion of compulsory licensing in the toolkit of competition policy. Shapiro (2011, p. 373) argues that mandatory licensing and price controls cannot "properly be called 'competition policies', at least in the United States today", and introduces a term "pro-competition policies". We do not emphasize these verbal differences assuming that the measures used by antitrust bodies (and mandatory licensing or the prosecution of refusal to license are used as antitrust remedies in different countries, including the USA (Encaoua, Hollander, 2002, p. 72-73)) and are aimed at the development of competition, and can be generally called "competition policies".

We have chosen one instrument in an attempt to identify and analyse specific measures of competition policy used in the markets for IPR-based goods and services. The role of licensing in reference to innovative activity has been studied in-depth since 1980s and early 1990s: Katz and Shapiro (1985, 1986), Gallini (1984), Gallini and Winter (1985), Kamien and Tauman (1986), Kamien, Oren and Tauman (1992). They show the limits of voluntary licensing, compare the incentives to innovate in the presence and absence of licensing, consider the results for social welfare, compare different forms of compensation for licensing (fixed fee, royalty or auctions for licenses) and different forms of oligopolistic relationships (such as Cournot, Bertrand, and Stackelberg) Our agenda is very close to this but we focus on compulsory licensing as an element of competition (or pro-competition) policy and do not choose between different modes of oligopolistic relationships and different forms of compensation presuming the existence of a fixed-fee system, and modelling the interactions between players *a la* Cournot.

Further developments in this area have led to a much more detailed elaboration of particular licensing mechanisms: auctions, fixed-fee-based or royalty-based licensing agreements and the effects of their use, especially from the theoretical point of view (Kamien, Tauman, 2002; Fan et al., 2013; Yan et al., 2012).

The discussion on the narrower question of compulsory licensing has been less intense, however, several important works may be emphasized: Gilbert and Shapiro (1996) were sceptical of compulsory licensing, while Tandon (1982) and Seifert (2013) showed the positive effects of compulsory licensing on social welfare although with some reservations, and Katsoulakos (2009) explained the applicability of different types of legal standards to refusals to license. The importance of compulsory licensing was noticed, in particular, by Acemoglu and Akcigit (2012). They explained that compulsory licensing under certain conditions (depending on distance between technologies used by competitors) may be a useful instrument providing an increase in social welfare, even in the presence of voluntary licensing.

In this work we consider the incentives for process innovations under different conditions of markets and technologies. These conditions are partially similar to those studied in Acemoglu and Akcigit (2012) but in another model specification, adding the option of opportunistic behaviour of the follower (or the firm, which was not the follower *a priori* but lost the patent race) under compulsory licensing.

In one of our scenarios we presume that there is a technological leader and a follower in the market. In this case only the former can produce innovations, while the latter will lag behind or buy a license. Another case includes technological competition: two symmetric firms are involved in a patent race with equal opportunities to win. According to the model assumptions, the market is closed. Following Gilbert (2006), we also look at the innovations with and without exclusive property rights (interpreting this as the presence or absence of an opportunity to reach seemingly analogous improvements independently) but in this paper this is considered a minor question, without the extension to the interrelations between compulsory licensing and such a dichotomy of innovations.

Our results show that the existence of technological competition engenders the emergence of a “grey zone” of possible underinvestment in innovation, in comparison with the situation of technological leadership due to the additional uncertainty surrounding firms’ decisions. This outcome exists for cases with or without licensing, in slightly different forms. There will be several equilibria in bimatrix games between market participants, and there is the probability that they choose unfavourable prudent strategies leading to the rejection of innovation projects if they do not have any mechanisms of coordination. *It does not mean that competition is worse for innovation*: the difference between technological leadership and technological competition in this model does not reflect the intensity of market competition between market players but shows their *comparative capabilities* to produce innovations. The size of this “grey zone” depends on the character of innovation: whether it is exclusive (i.e.

cannot be independently substituted by the other firm's own innovation, due to patentability or other legal or technological barriers) or non-exclusive.

Voluntary licensing, if it is permitted, will be implemented under certain conditions, namely the limited effect of the innovation and relatively small costs of production in comparison with the reserve price of demand. These results are expected based on previous studies using fixed-fee licensing arrangements (Katz, Shapiro, 1985). We show that voluntary licensing improves social welfare but does not increase innovative activity due to the absence of incentives for the follower (under technological leadership) or for each of technological competitors to invest excessively in the innovations *ex ante*, when their general licensing policies are determined, if these innovations are certainly or possibly made by the other participant.

Compulsory licensing may improve social welfare but it will limit the innovative activity due to the opportunistic behaviour of the follower (under technological leadership) or each of competitors (under technological competition). Knowing that every project is subject to licensing and trying to avoid financing the other participant's innovations, firms can implicitly boycott licensing negotiations, imposing lower licensing fees. Consequently, the incentives to invest in R&D will be diminished. However, there are policy measures, such as control over licensing fees and state guarantees for inventors, which may possibly eliminate these negative factors and even lead to the growth of investment incentives under compulsory licensing.

The paper is structured as follows. In Section 2 we introduce the basic model and main notions for our analysis. Sections 3 to 6 are devoted to the description and analysis of four general situations representing different features of the market and the firms' positions (technological leadership or technological competition) on the one hand, and the competition policy applied (the presence or absence of licensing and, in particular, compulsory licensing), on the other hand. Section 7 contains the main findings.

2. The basic model

This paper presents a two-firm model of investment in process innovations. The main goal of the model is to show the influence of different sets of conditions on firms' incentives to implement non-drastic process innovations (Tirole, 1994, p. 391-392). There is not only demand for the product made by the firm, but also antimonopoly restraints, IPR and technological peculiarities. We also pay attention to the private and social costs and benefits accompanying any decision according to the particular set of conditions.

In our model it is assumed that

(1) IPR may be sold and purchased by means of licensing;

(2) there is a market for IPR-based goods ("products");

(3) two initially symmetric incumbents compete *a la* Cournot in this market;

(4) entry to the market is blocked;

(5) market players and state regulators know the production costs and market demand, consequently, they know the payoff matrices and can use them to predict the behaviour of each other (but they do not know it determinately) and to choose their own strategy;

(6) the costs of negotiations are negligible;

(7) an incumbent may invest a fixed amount *M* in R&D (reducing all costs for process innovation to R&D is used as a simplifying assumption) to put in place completely new or considerably modernized production processes in order to obtain a decrease in the marginal costs of production from *c* to *c'* (the investment in R&D always leads to innovation but sometimes—when another player has already achieved the same innovation and protected her rights—it is impossible to use it; in the case of licensing, the innovation is always used by the innovator itself, if it does not break the exclusive rights of the initial inventor, disregarding any possible transfer of the license to the other market player);

(8) the timing of the model is as follows: the participants take simultaneous decisions concerning their licensing policies (i.e. whether they will sell and/or purchase licenses or not, if licensing is available) and their investments in R&D, then they accomplish their innovative projects (if the investment decision is positive), sell and/or purchase licenses (depending on their policies), and in the end they produce, sell and receive the payoffs. The discount rate is 0, that is, we do not take into account probable effects of the duration of innovative investments. A more detailed time axis is represented by Figure 1.

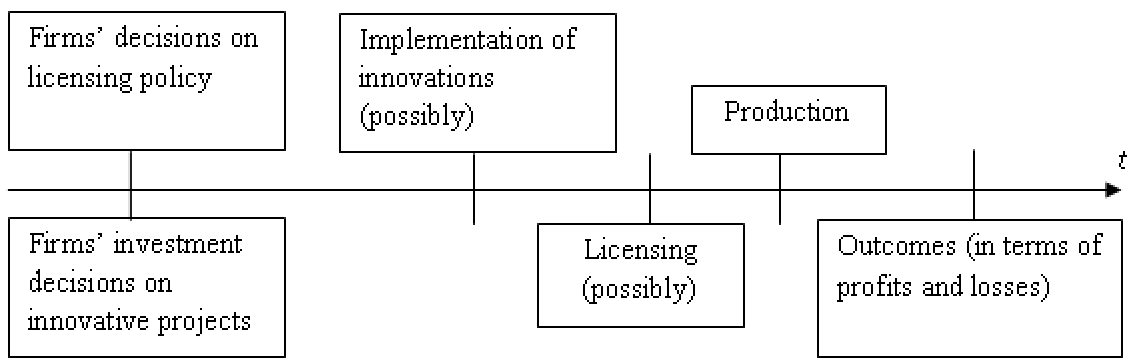

Figure 1. Time axis of the model

Market demand is specified by the equation $P = a - bQ$, marginal costs of production equal *c* in the case without an innovation and *c'* in the case of innovation *(a > c > c' > 0, b > 0).*

In the next sections we consider different situations depending on different institutional and technological conditions. The scheme of our analysis is represented on Figure 2.

Under 'ordinary' practice without innovations the outcomes are consistent with the traditional Cournot model (*Situation 0, or Basic Situation*):

$$q_1^0 = q_2^0 = \frac{a-c}{3b}; Q^0 = \frac{2(a-c)}{3b}; \tag{1}$$

$$P^0 = \frac{a+2c}{3}; \tag{2}$$

$$\pi_1^0 = \pi_2^0 = \frac{(a-c)^2}{9b}; \Pi^0 = \frac{2(a-c)^2}{9b}; \tag{3}$$

$$CS^0 = \frac{2(a-c)^2}{9b}; TS^0 = \Pi^0 + CS^0 = \frac{4(a-c)^2}{9b}, \tag{4}$$

where: q_1^0, q_2^0 are the quantities produced by the two firms in the standard Cournot model (hereinafter the specific firms are denoted by the subscripts), Q^0 is the total quantity produced, P^0 is the market price, π_1^0 and π_2^0 are the profits obtained by the two firms, Π^0 is the total profit of the two firms concerned, CS^0 is the consumer surplus, TS^0 is the total surplus.

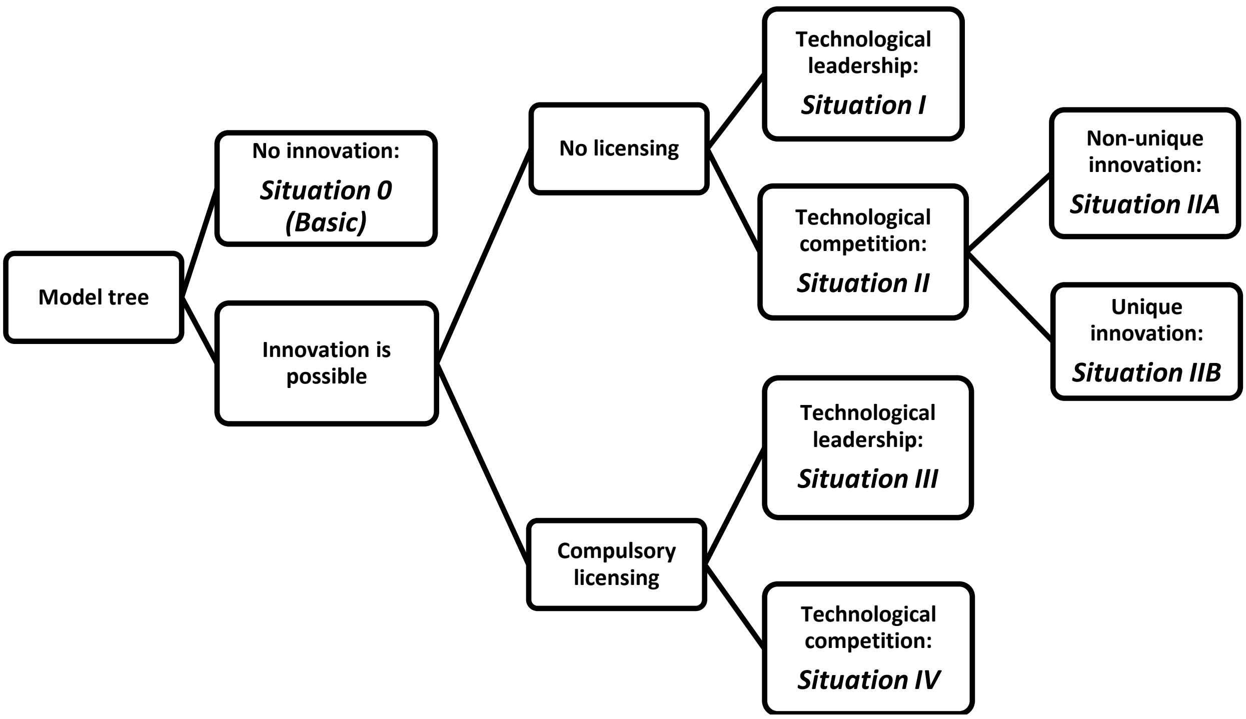

Figure 2. The set of situations under consideration

3. Situation I: innovation with technological leadership and without licensing

Here we assume that the first firm is a technological leader (having first-mover advantage) while the second firm is a potential follower. Also we do not care about where this leadership comes from. The 'first' firm invests *M* into innovation and obtains the economy on marginal costs from *c* to *c'*, while marginal costs of the second firm remain unchanged. Following the interaction *a la* Cournot with this change, the results will be:

$$q_1^I = \frac{a + c - 2c'}{3b} > q_1^0; q_2^I = \frac{a + c' - 2c}{3b} < q_2^0; Q^I = \frac{2a - c - c'}{3b} > Q^0; \tag{5}$$

$$P^I = \frac{a + c + c'}{3} < P^0; \tag{6}$$

$$\pi_1^I = \frac{(a + c - 2c')^2}{9b} - M; \pi_2^I = \frac{(a + c' - 2c)^2}{9b} < \pi_2^0; \tag{7}$$

$$\Pi^{\mathrm{I}} = \frac{(a + c - 2c')^2 + (a + c' - 2c)^2}{9b} - M, \tag{8}$$

where: q_1^I, q_2^I are the quantities produced by the two firms (hereinafter the number of the situation under consideration is denoted by the Roman numeral superscript), other variables are identical to *Situation 0*.

Here we note that quantities produced by both firms should be non-negative. It is true for the first firm, based on initial assumptions, but we should ensure that the quantity produced by the second firm from (5) is above zero by imposing the additional condition[4]:

$$a + c' > 2c.^5 \tag{9}$$

The total quantity produced is higher, and the market price is lower in comparison with *Situation 0*. This means that *Situation I* is more preferable for consumers.

Indeed,

$$CS^I = \frac{(a - P^I)Q^I}{2} = \frac{(2a - c - c')^2}{18b} > CS^0 = \frac{(2a - 2c)^2}{18b}. \tag{10}$$

However, the second firm suffers losses in terms of profit, and in terms of quantity produced:

$$\pi_2^I - \pi_2^0 = \frac{(c - c')(3c - c' - 2a)}{9b} = \frac{(c - c')\big(c - a - (a + c' - 2c)\big)}{9b} < 0. \tag{11}$$

[4] This assumption is sensitive to the model of the firms' interaction, since competition a la Bertrand might lead to zero output for follower even conditions discussed are met.

[5] Hereinafter we do not take into account borderline cases and use strict inequalities unless noted otherwise, because those cases do not change general results of the model, whilst complicating calculations.

At the same time without additional assumptions, we cannot say whether the new profit of the 'first', innovative, firm exceeds its profit in the basic situation *a la* Cournot. To provide a benchmark for future comparisons, we introduce $\bar{M}$ as a threshold—the maximal amount M that the first firm can invest to obtain a positive result from the innovation in terms of profit[6]. This interpretation of incentives to invest is similar to the approach from Tirole (1994, p. 391). Obviously, the investment will be made if the profit of the first firm in the case of innovation (*Situation I*) exceeds its profit without innovation (*Situation 0*).

Solving the inequation:

$$\pi_1^I > \pi_1^0,$$

$$\frac{(a+c-2c')^2}{9b} - M > \frac{(a-c)^2}{9b}, \qquad (12)$$

we obtain the following result:

$$0 < M < \frac{4(c-c')(a-c')}{9b}{}^{7}. \qquad (13)$$

Consequently, the maximal threshold is defined as follows:

$$\bar{M}^I = \frac{4(c-c')(a-c')}{9b}. \qquad (14)$$

The threshold level for M is directly related to (1) the absolute amount of marginal cost decrease, (2) the distance between market demand reserve price and the new level of marginal cost, (3) the sensitivity of market quantity demanded on price ($\frac{1}{b}$). Those dependencies are common (i.e., Motta, 2004).

The investment decision is taken by the first firm. That is why only the investment threshold of the first firm should be taken into consideration in this situation, when we estimate the possibility of the innovation. However, to assess consequences of the *Situation I* we can compare total surpluses:

$$TS^I = CS^I + \Pi^{\mathrm{I}} = \frac{8(a-c)(a-c') + 11(c-c')^2}{18\mathrm{b}} - M; \qquad (15)$$

$$TS^I - TS^0 = \frac{(c-c')(8a+3c-11c')}{18b} - M; \qquad (16)$$

[6] We don't pretend here to the development of the theory of thresholds for investments decision in process innovation in terms of availability of information for innovator, follower and/or regulator. Also we don't develop
idea about interrelation between probability of process innovation with particular attributes and amount of threshold investments.
[7] The inequality $M > 0$ simply means that we don't consider cases with the system of public or private grants, i. e. any R&D project will require positive spendings.

Consequently, a socially acceptable level of investment in innovation will be higher than the investment threshold for the firm-innovator:

$$\overline{M}_{TS}^{I} = \frac{(c-c')(8a+3c-11c')}{18b} > \overline{M}^{I} = \frac{(c-c')(8a-8c')}{18b}. \quad (17)$$

That is intuitive: society is ready to pay more than a single firm for such an innovation thanks to an increase in the consumer surplus. On the other hand, the result looks like as a consequence of underinvestment due to the positive externality, quantified here as $\Delta\overline{M}^{I} = \frac{(c-c')^2}{6b}$. This means that in some cases the firm would reject investment in process innovation due to the negative profit, in spite of the expected benefits for consumers.

Despite the results obtained in this and many other studies, this conclusion deserves a more detailed exploration in the framework of our model, however we do not focus on it in this paper emphasising the incentives to innovate rather than consequences on social welfare and, consequently, on different discrete structural alternatives to bridge the gap between private incentives and social benefits.

4. Situation II: innovation with technological competition and without licensing

In *Situation II* we assume that both firms are able to introduce the innovation. Each firm may invest the sum *M* (which is equal for both firms, so that neither of them has any preliminary advantages) and obtain the desirable level of costs economizing *(c-c')*. The efforts of each firm will depend on the strategic decision of the other. That is why we consider a game between two firms without first-mover advantage.

There are two options concerning the uniqueness of the innovation, that is the existence of an opportunity to obtain substitutable (in terms of production opportunities) solutions without infringing IPR. If the innovation is not patentable (for instance, if it is subject to copyright, some results are protected as know-how), or the patent is weak or narrow, the successful innovation of one firm does not exclude the opportunity of the second firm to achieve the same result (probably by slightly different way). That case—*Situation IIA*—is considered in Table 1.

If neither firm takes a positive investment decision, then the pay-off will correspond to *Situation 0* with no innovations. If only one firm decides to innovate, then the pay-off will correspond to *Situation I* with the introduction of an innovation by the technological leader. However, in this game the leadership is not set *a priori*.

Table 1. Situation IIA: a game with non-unique innovation (profit of the firm # 1; profit of the firm # 2), ***expected profits***

		Strategies of the firm # 2	
		To invest in R&D	Not to invest in R&D
Strategies of the firm # 1	To invest in R&D	$\frac{(a-c')^2}{9b} - M; \frac{(a-c')^2}{9b} - M$	$\frac{(a+c-2c')^2}{9b} - M;$ $\frac{(a-2c+c')^2}{9b}$
	Not to invest in R&D	$\frac{(a-2c+c')^2}{9b}; \frac{(a+c-2c')^2}{9b} - M$	$\frac{(a-c)^2}{9b}; \frac{(a-c)^2}{9b}$

Finally, if both firms innovate, we have the following results:

$$q_1^{IIA} = q_2^{IIA} = \frac{a-c'}{3b}; Q^{IIA} = \frac{2(a-c')}{3b}; \quad (18)$$

$$P^{IIA} = \frac{a+2c'}{3}; \quad (19)$$

$$\pi_1^{IIA} = \pi_2^{IIA} = \frac{(a-c')^2}{9b} - M; \Pi^{IIA} = \frac{2(a-c')^2}{9b} - 2M; \quad (20)$$

$$CS^{IIA} = \frac{2(a-c')^2}{9b}; TS^{IIA} = \Pi^{IIA} + CS^{IIA} = \frac{4(a-c')^2}{9b} - 2M, \quad (21)$$

which are clearly consistent with the standard Cournot model, taking into account the decrease in production costs resulting from innovations made by each firm, as well as the expenses *M* to finance the innovation. We note again that here, in the *Situation IIA*, we assume that both firms are able to apply similar innovations with identical results autonomously, without any impediments imposed by IPR.

To determine possible outcomes of the game from Table 1, we compare the profits affecting their choice of strategies. We begin with the first firm (the choice of the second one will obviously be symmetric). If the second firm does not invest, then the choice between strategies for the first firm will be identical to the *Situation I* (technological leadership). As established in (14), the threshold level of investment will be:

$$\bar{M}^{IIA1} = \frac{4(c-c')(a-c')}{9b}. \quad (22)$$

The comparison of actual investments needed with this threshold will determine the decision of the first firm if the second one does not innovate.

If the second firm does innovate, then the choice of the first firm will depend on the sign of the following expression (the difference between its profits with and without innovation respectively):

$$\frac{(a-c')^2}{9b} - M - \frac{(a-2c+c')^2}{9b} = \frac{(2c-2c')(2a-2c)}{9b} - M = \frac{4(c-c')(a-c)}{9b} - M. \qquad (23)$$

Consequently, the threshold level for this decision will be:

$$\bar{M}^{IIA2} = \frac{4(c-c')(a-c)}{9b} < \bar{M}^{IIA1}. \qquad (24)$$

Thus, considering possible values of *M*, we obtain three ranges of *M* determining the outcome of the game.

If:

$$M < \frac{4(c-c')(a-c)}{9b}, \qquad (25)$$

then the innovation is cheap enough to satisfy each one of the firms, disregarding the strategy of the opponent. Thus, the decision for this game is “to invest in R&D” by both firms.

If:

$$\frac{4(c-c')(a-c)}{9b} < M < \frac{4(c-c')(a-c')}{9b}, \qquad (26)$$

then the outcome is difficult to forecast. Here the innovation is feasible for one firm if the other one does not innovate. So, the first firm invests in innovation if the second firm does not, and vice versa. The fundamental reason for such a result is the dissipation of the rent of the innovator due to negative pecuniary cross externality.

Such combinations of preferable strategies give two possible Nash equilibria, their corresponding outcomes are described in the previous paragraph. They are equivalent to each other in terms of market price and quantity, and both of these equilibria involve the implementation of the innovation. “To innovate” in this case is equivalent to behaviour like a hawk, while “do not innovate” is equivalent behaviour like a dove (Rasmusen, 1992, p.121–123).

However, under such uncertainty the participating firms cannot choose the strategy automatically if they take decisions simultaneously as presumed in the model assumptions. Therefore we need additional hypotheses about the behaviour of the firms. If either has a first-mover advantage (probably because of the choice of business strategy, PR strategy or other circumstances), then they will be able to come to an equilibrium equivalent to technological leadership. In this case a first-mover will prefer to innovate, because if M corresponds to (26), then:

$$\frac{(a+c-2c')^2}{9b} - M > \frac{(a-2c+c')^2}{9b}, \tag{27}$$

i.e. it is better to be the leader, not the follower.

If the firms can produce credible commitments, or if they have any focal points reflecting their common expectations, one of Nash equilibria may be achieved.

However, if these mechanisms do not work, each firm may choose a “prudent”, or “protective”, maximin strategy (Arce, 1997; Fiestras-Janeiro et al., 1998). It means that if managers of each firm know exactly what strategy they will choose following the decision of their competitors but have no idea about their competitor’s real plans, while the decision should be taken immediately and they cannot use mixed strategies[8], then they can choose the strategy providing maximal *guaranteed* profit. If condition (26) is satisfied, the first firm’s guaranteed profit under each of its strategies equals its profit in the case when the second firm decides to innovate. Choosing the maximal level of these guaranteed profits, the first firm will prefer not to innovate. The same is true for the second firm. Consequently, both firms will choose the strategy “not to innovate”, and there will be no innovation in the market.

Finally, if:

$$M > \frac{4(c-c')(a-c')}{9b}, \tag{28}$$

then the innovation will be too “expensive” for the firms, and they will reject it anyway. The strategy “not to innovate” will be dominant in this case.

The *Situation IIA*, i.e. the presence of technological competition, may lead to the emergence of a “grey zone” with multiple equilibria for possible innovation. The maximal level of feasible investment (set by (22)) is as high as the one under technological leadership. If the innovation is more expensive, then in both *Situations I* and *IIA* it will not be financed. If it is cheaper, it will be financed undoubtedly under technological leadership, and it may be financed or not under technological competition if its costs are high enough to be located in the “grey zone”. We can ensure that the innovation will be financed under technological competition if its costs are even lower—below another threshold set by (25)—and we note again that there is no opportunity to share the cost of process innovation. This is an obvious spin-off for further study.

[8] Here we assume that those managers will not choose strategies on a probabilistic basis but will have to find a determined strategy.

There is another option: the existence of exclusive rights for a unique innovation, so that two firms are competing for the innovation to obtain those rights in the first period. In this framework investments can be made by both competitors but only the leader *ex interim* (i.e. specified after the investment decisions but before production and sales of final product) can use R&D results to implement the innovation. We assume that the probability of getting R&D results ready for innovation (i.e. to win the patent race) for each competitor is 0.5, if both of them invest in R&D, 1 for the only competitor investing in R&D, if the other one rejects this investment, and 0 for the player(s) without investments in R&D.

This game is shown in Table 2. All the cells are identical to Table 1 except the cell ("To invest"; "To invest"). Indeed, if one company decides to invest in innovation, and the other does not, the former will become the technological leader, while the latter will be the follower. As a result, we obtain a repeat of *Situation I* (technological leadership). It means there is at least one element protected by IPR and essential for innovation without a potential substitution within the time constraint specified, which is not available for the follower without permission from the leader. However, if both firms invest in innovation in the framework now considered, then each of them will win or lose the race with the probability 0.5. That is why the cell ("To invest"; "To invest") has changed. Its value represents the expected outcome of the competition: either the firm will be the leader or the follower. Each firm invests *M*, even if this firm does not get the option to innovate. The expected profit for each firm may be expressed in the following manner:

$$\pi_1^{IIB} = \pi_2^{IIB} = \frac{1}{2}\left(\frac{(a+c-2c')^2}{9b} - M\right) + \frac{1}{2}\left(\frac{(a-2c+c')^2}{9b} - M\right) = \\ = \frac{5(c-c')^2 + 2(a-c)(a-c')}{18b} - M, \quad (29)$$

where π_1^{IIB}, π_2^{IIB} are the expected profits in this case.

Table 2. Situation IIB: a game with unique innovation (profit of the firm # 1; profit of the firm # 2), ***expected profits***

		Strategies of the firm # 2	
		To invest	Not to invest
Strategies of the firm # 1	To invest	$\frac{(a-2c+c')^2+(a+c-2c')^2}{18b} - M$; $\frac{(a-2c+c')^2+(a+c-2c')^2}{18b} - M$	$\frac{(a+c-2c')^2}{9b} - M$; $\frac{(a-2c+c')^2}{9b}$
	Not to invest	$\frac{(a-2c+c')^2}{9b}$; $\frac{(a+c-2c')^2}{9b} - M$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$

The actual outcomes of this situation in terms of profits will differ from the expected results, being equivalent to *Situation I* (technological leadership), because of the emergence of the leader *ex interim*[9]. Quantities and price will be set by (5) and (6), and profits by (7) and (8) with one exception: both firms will invest *M* in R&D and, consequently, total profits from (8) will be diminished not by *M* but by *2M*, and the profits of each firm will be diminished by *M*.

The solution of the game is similar to *Situation IIA*. The criterion for choosing between strategies if the competitor does not invest in R&D is always set by (22) (or its equivalent (14) from the *Situation I*):

$$\bar{M}^{IIB1} = \frac{4(c-c')(a-c')}{9b}. \quad (30)$$

To make a choice between strategies if the other firm does invest, we compare profits resulting from two strategies by finding the sign of the following expression:

$$\frac{(a-2c+c')^2 + (a+c-2c')^2}{18b} - M - \frac{(a-2c+c')^2}{9b}. \quad (31)$$

We obtain the threshold $\bar{M}^{IIB2}$:

$$\bar{M}^{IIB2} = \frac{(c-c')(2a-c-c')}{6b} < \bar{M}^{IIB1}. \quad (32)$$

Following the logic of *Situation IIA* we determine three possible ranges of the scope of investment necessary for the innovation.

If:

$$M < \frac{(c-c')(2a-c-c')}{6b}, \quad (33)$$

then the innovation is “cheap” anyway for technological competitors, and the strategy “to invest” will be a dominant strategy for both firms.

If:

$$\frac{(c-c')(2a-c-c')}{6b} < M < \frac{4(c-c')(a-c')}{9b}, \quad (34)$$

then firms are in the “grey zone”, as in *Situation IIA*. The presence of coordination, first-mover advantage, focal points and other specific mechanisms may provide the opportunity to

[9] Nevertheless, leadership ex ante is simply special case of ex interim leadership when probability to win for particular firm equals 1.

achieve a Nash equilibrium, where one firms invests, and the other does not. Otherwise, both firms can choose the prudent maximin strategy, avoiding investments.

Finally, if:

$$M > \frac{4(c-c')(a-c')}{9b}, \quad (35)$$

then, like in *Situation IIA*, innovation will be too "expensive" for the firms, and the strategy "not to invest" will be the dominant strategy.

What of these two situations creates a more extensive "grey zone" of uncertainty for innovation? To define this we compare lower boundaries of "grey zones" from *Situation IIA* and *Situation IIB*.

We obtain:

$$\frac{4(c-c')(a-c)}{9b} > \frac{(c-c')(2a-c-c')}{6b}, \quad (36)$$

if:

$$2a + 3c' - 5c > 0\,. \quad (37)$$

We can transform (37) into:

$$2(a + c' - 2c) + (c' - c) > 0. \quad (38)$$

The first addend is positive from assumption (9) but the second one is negative. Consequently, the "grey zone"—result of technological competition—is narrower in the case of non-unique innovations (inequality (36)) if inequality (38) is valid, in particular, if the economy $(c-c')$ resulting from innovation is low, and the difference between the reserve price *a* and initial costs *c* is high. Otherwise, this "grey zone" will be narrower in the case of unique innovations.

In other words, the presence of technological competition in a market with blocked entry engenders the problem of additional uncertainty resulting from the race for innovation (a patent race in the case of unique innovations). The technological leader decides based on the expected additional profits from the innovation regardless of the other firm's decision because the follower cannot initiate the innovation itself and will just maximize its profits under the technological conditions imposed by the leader. The competitors face the threat of *ex ante* rent dissipation and each of them cannot be sure whether a project (if it is expensive enough) would be beneficial without any information about the other firm's behaviour. If the project is neither cheap nor expensive enough to take a clear decision at once, the competitors encounter the problem of multiple equilibria depending on themselves and their counterparts. If there are no mechanisms to overcome this uncertainty, the maximin equilibrium can lead to the absence of investment in R&D for this class of projects (which could be realized under technological leadership).

Those effects can be seen through the lens of the efficiency effect from the of works Tirole (1994, p. 393), Gilbert and Newbery (1982), involving more motivation to innovate from the leader, but we add that the uncertainty about leadership can possibly lead to the complete rejection of innovation. Uncertainty was studied in Reinganum (1983) with different results although that work focused on technological uncertainty, while we discuss behavioural uncertainty.

This problem exists both for unique (or non-substitutable) and for non-unique (or substitutable) innovation but its gravity, measured by the scope of the “grey zone”, or, more precisely, by the lowest cost of “doubtful” projects, will be greater for unique innovations if the effect of the innovation is small, and the initial marginal costs of production in the market are low in comparison to the reserve demand price. Otherwise, non-unique innovations will be more effected by the problem of the “grey zone”.

5. Situation III: innovation with technological leadership and with compulsory licensing

Now we introduce licensing into the model. We suppose that the regulatory body decides to prevent possible abuse of market power by the innovating firm, to correct market outcomes, and to promote the diffusion of innovation using the mechanism of *compulsory licensing* as a structural alternative to voluntary licensing. They both represent ways to internalize the positive externalities. In this model it means that the firm which financed R&D and realized the innovation, must provide access to the knowledge necessary for the innovation to the other firm. As a result, marginal costs of the second firm will also decrease from c to c'. The second firm gives the first firm, in exchange, a fixed sum of money F the licensing fee.

Hereinafter we address our approach to unique innovations to avoid the difficulties of cross-licensing problems. In fact, it is important only for *Situation IV*, technological competition with licensing. In *Situation III* only the technological leader is capable of producing innovations, as in *Situation I*. Thus, the legal opportunities of the second firm to produce innovations independently or to participate in patent races do not matter here. When we move to the technological competition in the *Situation IV*, however, we pay attention to those opportunities. Consequently, if we considered non-unique innovations, there would be cases with successful investment in R&D from both firms, which involved negotiations not only on licensing but also on cross-licensing beforehand (following the timeline of the model).

It is assumed that the state imposes licensing after giving the firms themselves the opportunity of setting specific conditions of licensing. Otherwise, if the firms cannot come to an agreement, the state itself sets specific conditions. Such foundations for setting licensing fees are not uncommon. For instance, in Russia, according to the national Civil Code, licensing fees are established by the court. The parties concerned can negotiate, and have the result approved by the court but if they are not able to come to an agreement, then the price is *de facto* set by the judicial authority. It might be based on specific rules of access like FRAND (Fair, Reasonable And Non-Discriminatory).

In this case the innovation will be fulfilled by both firms anyway. However, the process may differ. To start with it, we assume that there is an *ex ante* leader in the market: the first firm is the pre-determined innovator.

We obtain the following market outcomes in the case of licensing:

$$q_1^{III} = \frac{a-c'}{3b};\ q_2^{III} = \frac{a-c'}{3b};\ Q^{III} = \frac{2(a-c')}{3b}; \qquad (39)$$

$$P^{III} = \frac{a+2c'}{3}; \qquad (40)$$

$$\pi_1^{III} = \frac{(a-c')^2}{9b} - M + F; \pi_2^{III} = \frac{(a-c')^2}{9b} - F;\ \Pi^{\mathrm{III}} = \frac{2(a-c')^2}{9b} - M. \qquad (41)$$

What value of *F* will firms choose by themselves if they are able to arrange a voluntary agreement on the fee without state interference? First of all, we need to establish that *F* exists. For that reason it is necessary to find whether the expected levels of profits will exceed those levels from the *Situation I*, where licensing does not occur. To make sure that it is true, we solve the following inequalities:

$$\pi_1^{III} > \pi_1^{I}; \qquad (42)$$

$$\pi_2^{III} > \pi_2^{I}; \qquad (43)$$

From (42) we obtain conditions for the reserve supply price on innovation access of the first firm:

$$\frac{(a-c')^2}{9b} - M + F > \frac{(a+c-2c')^2}{9b} - M; F > \frac{(c-c')(2a+c-3c')}{9b}. \qquad (44)$$

From (43) we obtain conditions for the reserve demand price on innovation access of the second firm

$$\frac{(a-c')^2}{9b} - F > \frac{(a+c'-2c)^2}{9b}; F < \frac{4(c-c')(a-c)}{9b} \tag{45}$$

Obviously, a mutually acceptable value of F can exist only if inequalities (44) and (45) can be satisfied simultaneously, that is if:

$$\frac{4(c-c')(a-c)}{9b} > \frac{(c-c')(2a+c-3c')}{9b}, \tag{46}$$

which can be transformed into

$$2a + 3c' - 5c > 0\,. \tag{47}$$

This means that the voluntary licensing agreement in this model is a viable structural alternative only if the initial costs are low in comparison with the reserve price of demand (i.e. always positive, *(a – c)*) is large and the economy resulting from the innovation (i.e. always negative, *(c' – c)*) is small.

An identical inequality will be obtained if we base the reasoning on the presumption that a voluntary agreement on the price of license is possible only if the total profit of two firms under licensing will exceed their total profit without licensing (here we ignore the transaction costs of negotiations):

$$\Pi^{\mathrm{III}} > \Pi^{\mathrm{I}}. \tag{48}$$

In that case the firms together will obtain a positive surplus from licensing in comparison with the analogous situation without licensing. The scope of this surplus equals the difference of profits:

$$\Pi^{\mathrm{III}} - \Pi^{\mathrm{I}} = \frac{2(a-c')^2}{9b} - M - \frac{(a+c-2c')^2 + (a+c'-2c)^2}{9b} + M =$$

$$= \frac{(c-c')(2a+3c'-5c)}{9b}. \tag{49}$$

It may seem that if (47) is met and the transaction costs of negotiations are zero, the participants will always come to an agreement with licensing. However, behavioural uncertainty changes the picture.

The choices made by the two firms are different. The leader can innovate (invest in R&D) or not, while the follower has to decide whether she would buy the license on these or those conditions. According to the timing of the model, both choices are made by market players *simultaneously and independently*, *before* the possible investment in R&D and consequent market interaction. We these points as a generic pay-off matrix (Table 3).

Table 3. Situation III: pay-off matrix for a game with licensing (profit of the firm # 1; profit of the firm # 2), *expected profits*

		Strategies of the firm # 2	
		To buy license	Not to buy license
Strategies of the firm # 1	To invest	$\frac{(a-c')^2}{9b} - M + F$; $\frac{(a-c')^2}{9b} - F$;	$\frac{(a+c-2c')^2}{9b} - M$; $\frac{(a-2c+c')^2}{9b}$
	Not to invest	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$

When the follower decides whether to buy the license, it will compare its expected profits and find that the decision matters only if the leader innovates. The decision will depend on the inequality:

$$\frac{(a-c')^2}{9b} - F > \frac{(a-2c+c')^2}{9b}; \quad (50)$$

This inequality is satisfied if:

$$F < \frac{4(c-c')(a-c)}{9b} = \bar{F}, \quad (51)$$

which is analogous to (45).

If $F > \bar{F}$, the licensing fee will be too high, and the follower will not buy the license, despite the future loss of competitiveness without the innovation.

Here we focus on compulsory licensing, presuming that licensing will occur in this or that manner. That is why we do not consider the case of $F > \bar{F}$: if compulsory licensing is implemented, then the state will prevent such a high licensing fee, which is *de facto* prohibitive for licensing. If we provide for $F > \bar{F}$, there will be no applicants for the license, which is realized by both participants and by the state because all of them know the payoff matrix, so it will be automatically corrected by the state under such a legal regime. If the leader asks for a fee not satisfying (51) during the licensing negotiations, the follower will definitely not buy license, and there will be no other choice but the intervention by the state or the rejection of the innovation *a priori*. Consequently, following the assumptions of our model, including the possibility of state intervention, we can here consider only the strategy "to buy a license" from this matrix as a feasible option for the second firm, presuming that values of F not satisfying (51) will be corrected by the state or by the firms themselves.

If (51) is met, the second firm will prefer to buy the license instead of losing the competitive struggle. Of course, it is possible only if the leader innovates, which depends on whether the net profit from the innovation and subsequent licensing exceeds the profit without the innovation:

$$\frac{(a-c')^2}{9b} - M + F > \frac{(a-c)^2}{9b}; \quad (52)$$

or

$$M < \frac{(c-c')(2a-c-c')}{9b} + F. \quad (53)$$

(53) gives the ‘investment ceiling’ $\bar{M}^{III}$ for Situation III: the situation with licensing and technological leadership:

$$\bar{M}^{III} = \frac{(c-c')(2a-c-c')}{9b} + F. \quad (54)$$

If the condition of the voluntarily established licensing fee for the leader (44) is satisfied simultaneously with (51) and (53) (and we do not forget that (51) and (44) can be simultaneously satisfied if $2a + 3c' - 5c > 0$), then we seemingly could come into a ‘favourable’ equilibrium, where:

$\pi_1^{III} > \pi_1^0$ from (53), which makes it better for the leader to innovate and license than to reject the innovation,

$\pi_1^{III} > \pi_1^I$ from (44), which makes it better for the leader to innovate and license than to innovate without licensing,

$\pi_2^{III} > \pi_2^I$ from (51), which makes it better for the follower to buy the innovation if the first firm does innovate.

In other words, if $2a + 3c' - 5c > 0$, we have a range of values for a licensing fee F set by (44) and (51):

$$F \in \left(\frac{(c-c')(2a+c-3c')}{9b}; \frac{4(c-c')(a-c)}{9b}\right), \quad (55)$$

which will make it better for both firms to come to a licensing agreement, if the leader decides to innovate, which is ensured by (53). This equilibrium will have parameters set by (39)–

(41). Consequently, it will involve a bigger consumer surplus and bigger total surplus as compared with *Situation I*:

$$CS^{III} = \frac{2(a-c')^2}{9b}; TS^{III} = \frac{4(a-c')^2}{9b} - M. \quad (56)$$

Probably, the most important consequence for the market as whole will be the rise of the 'investment ceiling', making more innovations possible. If *F* is within the range of (55) then:

$$\bar{M}^{III} > \bar{M}^{I}. \quad (57)$$

However, this benefit exists only under the assumption of the passive behaviour of the follower. But strategic decisions taken by the follower will destroy this picture. We have not ensured that the follower would prefer this situation to the absence of innovations. Meanwhile, it is easily detected that:

$$\pi_2^{III} > \pi_2^0; \frac{(a-c')^2}{9b} - F > \frac{(a-c)^2}{9b}, \quad (58)$$

if:

$$F < \frac{(c-c')(2a-c-c')}{9b}. \quad (59)$$

This means that *F* should be less than the lower bound of the range of (55) to make it more profitable for the follower to enter a licensing agreement than to operate without any innovations in the market. That is why, if the follower is able to prevent the innovation made by the leader on its own, and if bargaining is possible, it will not choose the licensing fee *F* from the range of (55), preferring to satisfy (59). The ability to prevent the innovation by the follower may be based on the rejection of the most expensive projects of the leader, which could be profitable only with a considerable licensing fee received from the follower, and with compulsory licensing, which decreases the profitability of the innovation and means the necessity of obtaining the implicit approval of the follower for the conditions of the licensing.

To make all these reasonings clearer, we illustrate this situation in Figure 3, showing the possible licensing contracts, with the cost of the innovation *M* on the vertical axis and the level of licensing fee *F* on the horizontal axis. Here we assume that voluntary establishment of licensing fee is possible, that is, $2a + 3c' - 5c > 0$.

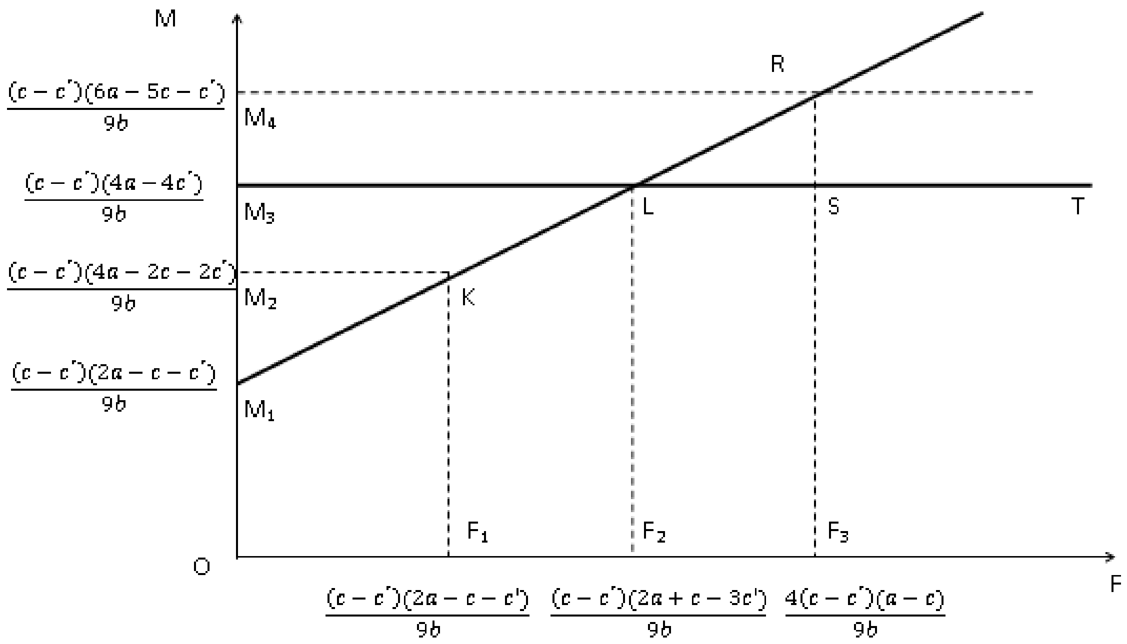

Figure 3. Combinations of investment costs *M* and licensing fees *F*, $2a + 3c' - 5c > 0$, technological leadership

If there is no licensing, the first firm will be able to perform on its own the projects below the line M_3T, because they are cheaper than M_3 representing the investment threshold (14) for the technological leader without licensing. So, the line represents the frontier of investment projects without licensing. If there is compulsory licensing, then the 'investment ceiling' for the first firm will be set by (54), which is represented by the line M_1R on the graph.

If the licensing fee F exceeds F_3, that is, (51) is not satisfied, then licensing will not occur because of the absence of incentives for the second firm: even the loss of the competitive struggle is better than the payment of such a high licensing fee. Therefore the area to the right of F_3R will be inactive in the case of licensing. If the licensing was voluntary, the firms there would move to the situation of technological leadership without licensing; but as we consider compulsory licensing, then this level of fee would not be approved by the regulator because of the well-grounded rejection by the follower.

If the cost of an innovative project are so high that it corresponds to the area above the line M_3LR, it is too expensive to innovate for the leader under any institutional frameworks.

If F is situated between F_2 and F_3 and M is below M_1R, then (44) and (51) are simultaneously satisfied, which represents an achievable 'favourable equilibrium' described earlier, with an additional triangle LRS above M_3T representing the quasi-opportunity for new expensive projects. Here, if the leader innovates, licensing will be profitable for both firms. Actually, the area LRS is the core of voluntary licensing for expensive projects. But the leader will undoubtedly innovate by itself only in F_2LSF_3. Therefore, under the regime of voluntary licensing, if the cost of innovation is lower than M_3, the firms will come to an agreement in this area. It will increase the consumer surplus and the total surplus (56).

However, the projects inside *LRS* are more expensive and will not be profitable for the leader without licensing. Here the follower is able to prevent the innovation by rejecting the licensing, and will do so because the absence of innovation is even more profitable for the follower than such a high licensing fee.

Under the regime of compulsory licensing the follower can and will prevent the innovation even for possible contracts from F_2LSF_3. The explanation is as follows: in this case the leader cannot innovate on its own and is obliged to go into negotiations anyway. As a result, the follower will use an opportunity to reject all the offers from the leader, wrecking the negotiations.

If F is situated between F_1 and F_2, then the agreement will not be the best option either for the leader, or for the follower. If the licensing was voluntary, then the leader would be able to ignore this opportunity and to innovate on its own bringing the market to the ordinary technological leadership without licensing and realizing all the projects cheaper than M_3. It will be more profitable for it because such fees do not meet the conditions for participating in licensing (44). However, such a development would be unprofitable for the follower. It would prefer to raise fees and avoid unilateral innovation, moving to the area F_2LSF_3. In the case of compulsory licensing the follower will, on the contrary, deny those prices between F_1 and F_2 and promote their further lowering.

Finally, if F is lower than F_1, then, if the regime of licensing was voluntary, the leader would still prefer to innovate without licensing, if the costs of the project did not exceed M_3, and the follower would be forced to raise fees and move to the area F_2LSF_3. But under the regime of compulsory licensing this will be imposed, and the follower will accept the deal based on prices below F_1.

To summarize consequences of the implementation of different regimes, we can conclude that if licensing was voluntary, it would lead firms to a voluntary agreement at a fee between F_2 and F_3, in the area F_2LSF_3. This agreement could make possible all the innovative projects going on under technological leadership without licensing (that is, cheaper than M_3), and could increase the profits of both firms, the consumer surplus and, consequently, the total surplus. But we should note that more expensive projects still would not be realized because of the strategy of the follower.

In the case of compulsory licensing the equilibrium with licensing will be always achieved too, involving an increase in the consumer surplus and the total surplus in comparison with technological leadership without licensing. At the same time, the 'investment ceiling' will be lower under the regime of compulsory licensing, if licensing fees are not regulated. The follower will accept a fee only lower than F_1. As a result, the 'investment ceiling' for the leader will equal M_2. That prevents the realization of expensive innovations, which were affordable without any licensing. Only the projects from the area M_1KF_1O will be realized.

This outcome might be improved. The first way is for the regulator to set reasonable minimal licensing fees. That policy even gives an opportunity to capture the previously unattainable area *LRS* and to increase the innovative potential. However, this policy will be successful only if the regulator can guarantee not only the sale by the innovator but also the purchase by the follower at that price, and this is known by both of them *ex ante*. This is the simplest way, but the ability of the regulator to perform 'fine tuning' is doubtful. Here is the incentive for the innovation-oriented regulator to set higher licensing fees promoting expensive innovations. But they will be made to the detriment of the follower, who will have great degree of uncertainty.

Another way is trickier. The regulator can shape expectations of market players about indispensable features of innovation, for instance, by providing state guarantees. In combination with compulsory licensing it will lead the players to the equilibrium with licensing at a price between F_2 and F_3, because the follower would not be able to prevent the innovation by setting low licensing fees and will choose the second-best option—purchasing the license—and the leader would be obliged to sell the license. Even the most expensive projects from the triangle *LRS* can be realized under such conditions: it is still better for the follower to participate in licensing than to lose the competitive struggle, and the leader will be able to overcome the barrier M_3T thanks to licensing.

If $2a + 3c' - 5c < 0$, that is, the condition of the possibility of voluntary (mutually beneficial) licensing is not satisfied, the result changes. This is shown in Figure 4.

The leader will innovate if the investment costs are less than M_3, below the line M_3R, if it works on its own. In the case of licensing, the 'investment ceiling' moves to M_1R. Voluntary licensing here is impossible, because it is profitable for the leader, if $F > F_2$, and for the follower, if $F < F_3$(if the leader innovates) while $F_3 < F_2$. The firms could reproduce the situation of technological leadership without licensing (*Situation I*), if they were left without public control. But as far as equilibrium with licensing involves the increase in total surplus, the regulator will probably introduce the compulsory licensing.

Under the regime of compulsory licensing, if the licensing fee is not controlled by the state, the follower will accept only the licensing fee less than F_1, which makes feasible only the investments below M_2 for the leader. Only the projects cheaper than M_2 will be realized, as in the case considered above: compulsory licensing diminishes incentives for innovation, lowering the 'investment ceiling'.

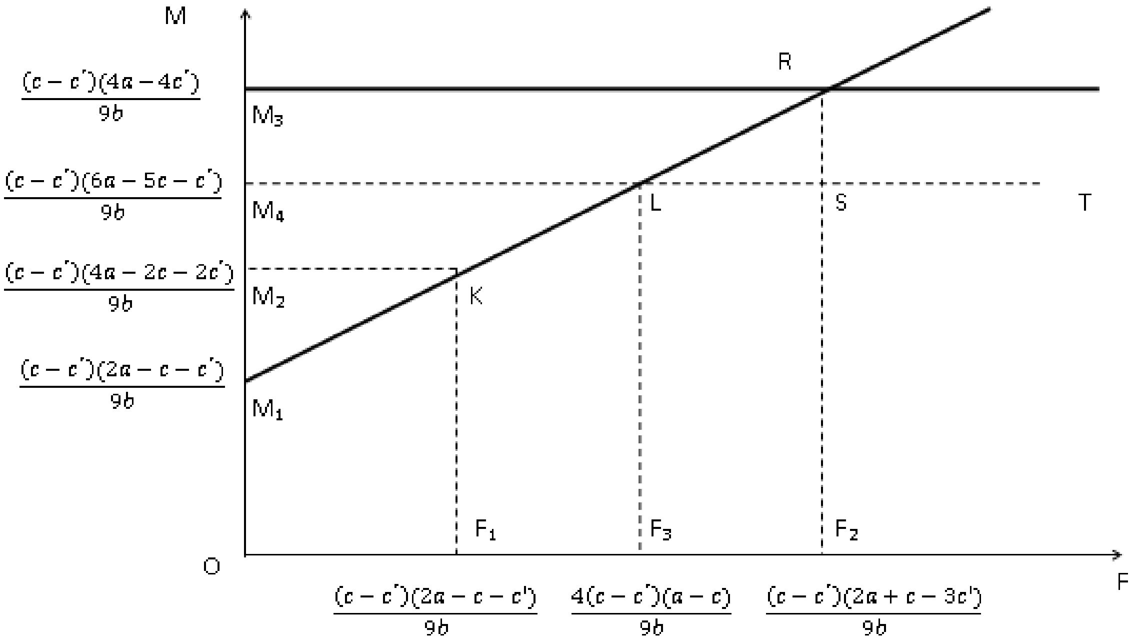

Figure 4. Combinations of investment costs *M* and licensing fees *F*, $2a + 3c' - 5c < 0$, technological leadership

The right to regulate licensing fees will give the regulator an opportunity to incentivise expensive innovations but, as mentioned above, this instrument is controversial due to a probable detrimental effect for the follower.

Another way – to shape expectations of market players by providing state guarantees for innovators– can raise the 'investment ceiling' from M_2 to M_4— – to the maximal level of licensing profitability for the follower. However this will still be lower than without any licensing, unlike in the previous case. Therefore compulsory licensing has a definite negative influence on the process of innovation, if $2a + 3c' - 5c < 0$.

6. Situation IV: innovation with technological competition and with compulsory licensing

Here we return to the assumption made in *Situation II* comprising technological competition. We suppose that both firms are able to innovate. Considering *Situation II* we looked at two options: a non-unique innovation, which can be made and used by both firms independently, and unique innovation, which can be used only by the first comer, while the loser should obtain a license. Here we introduce licensing and we focus only on the second option to avoid the problem of cross-licensing for now. In other words, we assume that only one firm will eventually innovate if both invest in R&D, and this firm will be randomly determined. The other firm can not use the innovation without paying a licensing fee.

As in *Situation II* with unique innovation, we assume that both firms can win the race for the innovation with a probability 0.5 if both firms invest. The expected licensing fee paid (if the unsuccessful firm chooses to buy a license from the other firm) or received (if the other firm chooses to buy licenses) in case of investing by both firms equals *F/2*. If only one firm invests in R&D, then this firm will automatically succeed and use R&D results for innovation.

In *Situation IV* we introduce compulsory licensing into the model. The innovator is obliged to give permission for using its R&D results for innovation in exchange for a fixed licensing fee *F*, which may be established by the regulator or by the firms themselves. At the same time, the recipient is not necessarily forced to buy this license. So, each firm has to make two choices in the first period: to invest or not to invest in the innovation, and to buy license or to reject the offer. We assume that the strategy about buying or rejecting license is accepted by each firm, before the investment in R&D is actually made and before the results of the "race for innovation" are clear.

The whole picture is shown in Table 4.

Table 4. Situation IV: pay-off matrix for a game with unique innovation and compulsory licensing (profit of the firm # 1; profit of the firm # 2), ***expected profits***

		Strategies of the firm # 2			
		To invest and to buy license	To invest and not to buy license	Not to invest and to buy license	Not to invest and not to buy license
Strategies of the firm # 1	To invest and to buy license	$\frac{(a-c')^2}{9b} - M$; $\frac{(a-c')^2}{9b} - M$	$\frac{(a+c-2c')^2+(a-c')^2}{18b} - M - \frac{F}{2}$; $\frac{(a+c'-2c)^2+(a-c')^2}{18b} - M + \frac{F}{2}$	$\frac{(a-c')^2}{9b} - M + F$; $\frac{(a-c')^2}{9b} - F$	$\frac{(a+c-2c')^2}{9b} - M$; $\frac{(a+c'-2c)^2}{9b}$
	To invest and not to buy license	$\frac{(a+c'-2c)^2+(a-c')^2}{18b} - M + \frac{F}{2}$; $\frac{(a+c-2c')^2+(a-c')^2}{18b} - M - \frac{F}{2}$	$\frac{(a+c'-2c)^2+(a+c-2c')^2}{18b} - M$; $\frac{(a+c'-2c)^2+(a+c-2c')^2}{18b} - M$;	$\frac{(a-c')^2}{9b} - M + F$; $\frac{(a-c')^2}{9b} - F$	$\frac{(a+c-2c')^2}{9b} - M$; $\frac{(a+c'-2c)^2}{9b}$
	Not to invest and to buy license	$\frac{(a-c')^2}{9b} - F$; $\frac{(a-c')^2}{9b} - M + F$	$\frac{(a-c')^2}{9b} - F$; $\frac{(a-c')^2}{9b} - M + F$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$
	Not to invest and not to buy license	$\frac{(a+c'-2c)^2}{9b}$; $\frac{(a+c-2c')^2}{9b} - M$	$\frac{(a+c'-2c)^2}{9b}$; $\frac{(a+c-2c')^2}{9b} - M$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$

To analyse this matrix, we compare the first and the second strategies of both players (the outcomes of the strategies are symmetrical for both players) from Table 4. The second strategy will be weakly dominated if, simultaneously:

$$\frac{(a-c')^2}{9b} - M > \frac{(a+c'-2c)^2 + (a-c')^2}{18b} - M + \frac{F}{2} \qquad (60)$$

and

$$\frac{(a+c-2c')^2 + (a-c')^2}{18b} - M - \frac{F}{2} > \frac{(a+c'-2c)^2 + (a+c-2c')^2}{18b} - M. \qquad (61)$$

They are both satisfied if

$$F < \frac{4(c-c')(a-c)}{9b}. \qquad (62)$$

Comparing the third and the fourth strategies (their outcomes are symmetrical for both players too) from Table 4, we obtain that the fourth strategy is weakly dominated if:

$$\frac{(a-c')^2}{9b} - F > \frac{(a+c'-2c)^2}{9b}. \qquad (63)$$

This inequality is also satisfied if (62) is valid.

This means that if (62) is *not* satisfied, then the strategies without the purchase of license will dominate, and there will be no licensing. Such an outcome would lead the market to *Situation II* without licensing. If the regulator promotes compulsory licensing, such licensing fees cannot be accepted by the state. We repeat here that compulsory licensing involves the obligation of the innovator to sell a license. But if (62) is not satisfied, i.e. licensing fees are prohibitively high, this license will not be requested by anybody. Consequently, the consideration of compulsory licensing should be made under condition (62). If it is satisfied, and strategies *with* licensing dominate, then the game from Table 4 can be reduced to the form represented in Table 5.

Table 5. Situation IV: pay-off matrix (reduced form) for a game with unique innovation and compulsory licensing (profit of the firm # 1; profit of the firm # 2), if $F < \frac{4(c-c')(a-c)}{9b}$, *expected profits*

		Strategies of the firm # 2	
		To invest and to buy license	Not to invest and to buy license
Strategies of the firm # 1	To invest and to buy license	$\frac{(a-c')^2}{9b} - M$; $\frac{(a-c')^2}{9b} - M$	$\frac{(a-c')^2}{9b} - M + F$; $\frac{(a-c')^2}{9b} - F$
	Not to invest and to buy license	$\frac{(a-c')^2}{9b} - F$; $\frac{(a-c')^2}{9b} - M + F$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$

Considering the pay-off matrix we conclude: if

$$M < F, \tag{64}$$

then both firms will choose to invest in innovations and to buy license.

If

$$M > F + \frac{(c-c')(2a-c-c')}{9b}, \tag{65}$$

then nobody will invest, and the purchase of license does not make sense.

If

$$F < M < F + \frac{(c-c')(2a-c-c')}{9b}, \tag{66}$$

then the players get into a “grey zone”, which was described in *Situation II*. Here we have two Nash equilibria, where one of firms invests and the other does not. It is difficult to predict which of these equilibriums will be achieved. Moreover, if the players have a focal point, they can get to one of Nash equilibria, if not, they could both reject innovation.

The equilibrium with the investment of both firms will have the following parameters:

$$q_1^{IV} = q_2^{IV} = \frac{a-c'}{3b}; Q^{IV} = \frac{2(a-c')}{3b}; \tag{67}$$

$$P^{IV} = \frac{a+2c'}{3}; \tag{68}$$

$$\Pi^{\mathrm{IV}} = \frac{2(a-c')^2}{9b} - 2M; \tag{69}$$

$$CS^{IV} = \frac{2(a-c')^2}{9b}; TS^{IV} = \Pi^{\mathrm{IV}} + CS^{IV} = \frac{4(a-c')^2}{9b} - 2M, \quad (70)$$

which repeat the parameters of the equilibrium with simultaneous investments in innovation by both firms from *Situation II*.

Considering *Situation IV* we implicitly presumed that the regulator promotes compulsory licensing because it involves some positive effects. Based on (70) we conclude that these effects really take place, at least for consumers because:

$$CS^{IV} > CS^{I} > CS^{0}. \quad (71)$$

The validity of inequality (71) follows from (10), and it means that the consumer surplus under technological competition *with* licensing is larger than the consumer surplus under technological competition *without* licensing (which equals CS^I, because in the case of unique innovation, technological competition will result in the technological leadership of the first comer) and also larger than the consumer surplus without innovation. Therefore the promotion of the equilibrium with investment and licensing of both firms would make the sense for the regulator.

The consumer surplus in the equilibrium with only one firm investing and another firm buying the license will equal CS^{IV} too, but it is doubtful whether the firms are able to attain this equilibrium due to the problem of the "grey zone", which is discussed above.

Despite the seemingly simple conditions for the equilibrium with both firms investing and buying licenses, there may be serious difficulties on the way to this equilibrium because of the strategic behaviour of the players. They are able to shift the parameters of the game, if the regulator gives them the right to set licensing fees. Consequently, they can prevent the move to this equilibrium if it will not be profitable for them.

It will be easier to consider different options by putting them on Figure 5. It illustrates the *Situation IV if* $2a + 3c' - 5c > 0$

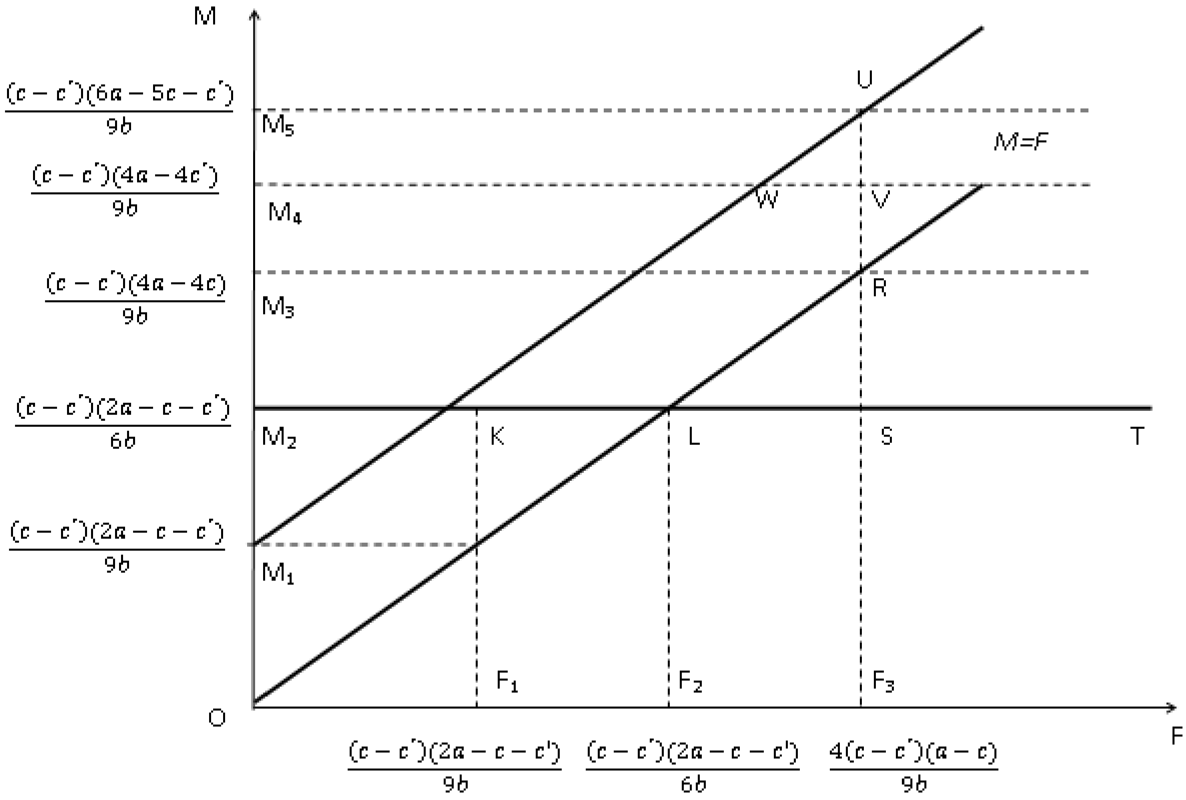

Figure 5. Combinations of investment costs *M* and licensing fees *F*, $2a+3c'-5c>0$, technological competition

As established in *Situation II*, if $M<M_2$, then both firms acting under technological competition without licensing will invest in R&D in order to innovate.

We notice that in this case the equilibrium with mutual licensing will permit them to increase their expected profits, and (72) is satisfied:

$$\frac{(a-c')^2}{9b}-M>\frac{(a+c'-2c)^2+(a+c-2c')^2}{18b}-M \qquad (72)$$

If the establishment of licensing fees was voluntary, the players would prefer to establish such levels of licensing fees *F*, that will facilitate the achievement of equilibria involving the readiness to sell and acquire a license for both of them: $F>M$. Their possible contracts will be situated inside $OLSF_3$ (remembering constraint (62)). The threshold level of investment in innovation will be:

$$\bar{M}^{IV}=\frac{(c-c')(2a-c-c')}{6b}. \qquad (73)$$

It is equal to the threshold level in *Situation II* under technological competition without licensing (not including the “grey zone”), so, the regime of voluntary licensing gives neither advantages nor disadvantages in terms of innovative activities. However, players move to the equilibrium with licensing, which increases the consumer surplus and their profits. Thus, the total surplus grows too.

But if licensing is compulsory, then both firms obtain the ability to block innovation. The logic is analogous to *Situation III*, where follower was able to reject licensing fees making the innovation feasible for the innovator. Here both firms are able to block negotiations, as far as compulsory licensing makes the deal between them indispensable for introducing the innovation. Each firm wins from the innovation with licensing in comparison with the absence of innovations only if:

$$\frac{(a-c')^2}{9b} - M > \frac{(a-c)^2}{9b} \tag{74}$$

$$M < \frac{(c-c')(2a-c-c')}{9b}. \tag{75}$$

As a result, both firms have incentives to exclude from negotiations projects more expensive than M_1, by setting artificially low licensing fees for them. The actual "investment ceiling" will be lower than the lower boundary of the "grey zone" from *Situation II* without licensing:

$$\bar{M}^{IV} < \frac{(c-c')(2a-c-c')}{9b} < \bar{M}^{IIB2} < \bar{M}^{IIB1}. \tag{76}$$

Therefore we conclude that the introduction of compulsory licensing lowers the incentives for innovation.

The remedies have been described above. One is to control the licensing fee setting and prevent excessively low fees, if the regulator is able to perform such fine tuning. The other way is to provide guarantees for the realization of innovative projects, which will shape the expectation of a positive investment decision by both investors even with low licensing fees and will force the investors to find a mutually beneficial licensing solution (or else they will find themselves in a less favourable position of autonomous innovations). Both ways can activate the area of contracts ORF_3, including the triangle *LRS*, unattainable under technological competition without licensing. Thus, the "investment ceiling" may even rise to M_3.

If the cost of innovation *M* exceeds M_2, then the players in *Situation II* enter the "grey zone". Here the benchmarking levels, to compare with them the returns from licensing, are unclear, because additional assumptions are needed to establish a specific equilibrium in the initial situation without licensing. So, the "grey zone" remains grey. If the cost of innovation *M* exceeds M_4, then investment in innovation will not be made in *Situation II* without licensing. If licensing takes place, then the investment probably will occur, with the contract inside the triangle *UVW*, but this is the "grey zone" for *Situation IV*, and nothing can be said for sure without additional assumptions.

The result changes if we assume that $2a + 3c' - 5c < 0$. This is represented in Figure 6.

The voluntary establishment of licensing fees is not a realistic option in this case. The expected profits from autonomous investing in innovation of both firms without licensing exceed their expected profits from simultaneous investments and licensing by both firms. Consequently, voluntary licensing will not occur, and compulsory licensing will lessen the theoretical “investment ceiling” from M_2 to M_3 (without taking into account the “grey zone”).

As in the previous case, the actual “investment ceiling” will be even lower, at M_1 due to the strategic lowering of licensing fees by both firms. The overcoming of this problem by means of more detailed price control or state guarantees may raise this threshold but it will still be lower than it was without licensing. Repeating the conclusion of *Situation III*, if $2a + 3c' - 5c < 0$, then compulsory licensing worsens the conditions for innovative activity

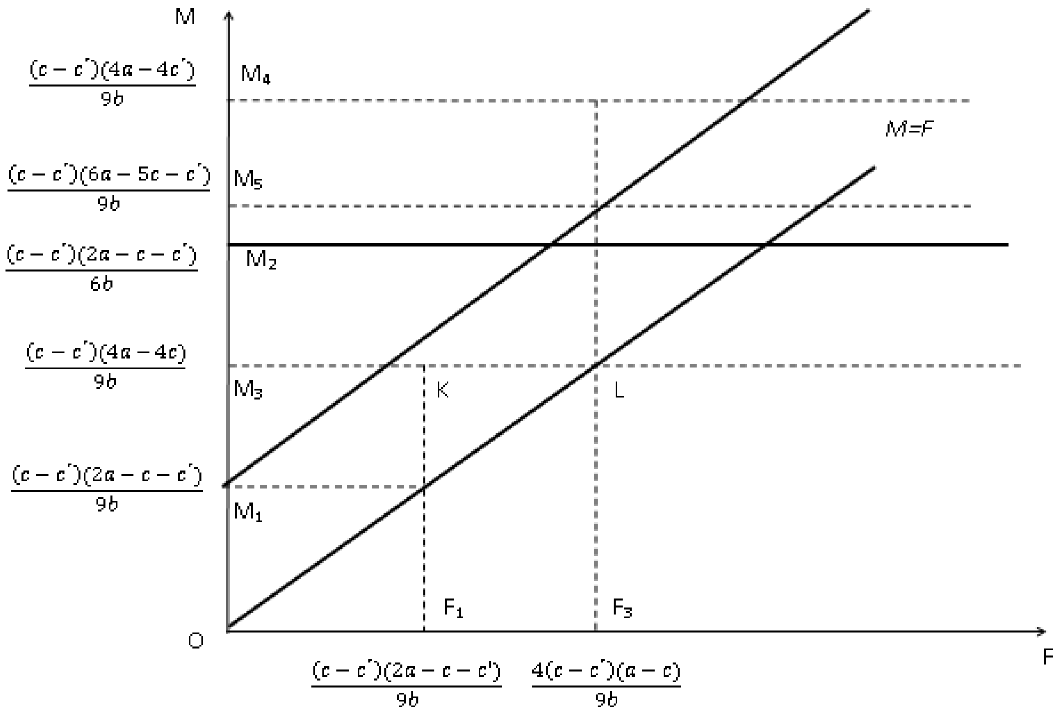

Figure 6. Combinations of investment costs *M* and licensing fees *F*, $2a + 3c' - 5c < 0$, technological competition

Conclusion

The consideration of the presence or absence of compulsory licensing and the peculiarities of specific markets (technological leadership or technological competition) affords grounds for several findings, which should be perceived keeping in mind all the restrictive assumptions of our model.

The maximum affordable costs of the process innovation—the "investment ceilings"—are equal for the cases of technological leadership (the attribution of the role of innovator to a single firm) and technological competition (the participation of both firms in innovative activities). However, the existence of technological competition leads to the emergence of a "grey zone" below the investment ceiling, where the realization of investment projects is undefined due to the additional—behavioural—uncertainty surrounding the decisions of the firms. That means that some projects affordable for the technological leader may not be implemented under technological competition. The opportunity of coordination (based on commitments) or the existence of focal points may provide a chance for innovation but, in the absence of those circumstances, the choice of a prudent maximin strategy by the firms may prevent the innovation. This point illustrates complicated challenges for the rule of reason under antitrust enforcement.

The higher boundaries of the "grey zone", i.e. the highest levels of potentially affordable investment spending, are equal for non-unique innovations (which can be produced and used by two firms independently) and unique innovations (the production of such innovations by one firm automatically excludes access to this innovation by the other firm without the permission of the first one, for instance, because of patenting). But the lowest boundaries of the "grey zone", i.e. the highest levels of definitely feasible investment spending, differ. The "grey zone" is narrower for non-unique innovations if the economy engendered by the innovation is low and marginal costs of production are small in comparison with the reserve price of demand. Otherwise, the "grey zone" is narrower for unique innovations.

If compulsory licensing is introduced and the voluntary establishment of licensing fees is available, firms can choose this as a better strategy only if the economy engendered by the innovation is relatively low and marginal costs of production are relatively small in comparison with the reserve price of demand. Such licensing does not extend the opportunities for innovations but it leads to the growth of the well-being of consumers and society in general. Consequently, it can improve social welfare by finding a feasible compromise between the leadership of a single innovator and the "catch-up" by followers providing compensation in the form of licensing fee. But this solution is based on private costs and benefits differing from social ones.

The regulator can use compulsory licensing even when this is unprofitable for the firms. This action may raise the consumer surplus and the total surplus but negatively affects the incentives for innovation. Compulsory licensing creates incentives for the strategic (and opportunistic) behaviour of the agent obtaining a license. That is true for both technological leadership and technological competition. These negative effects may be weakened by careful state regulation including control over licensing fees to prevent their artificial lowering, and state guarantees to ensure the expectation of positive investment decisions in the market. However, if the conditions for voluntary licensing are not satisfied, the effects of compulsory licensing on the scope of innovative activities still remain negative.

But if the conditions for voluntary licensing are satisfied, i.e. the economy engendered by the innovation is relatively small, and costs of production are relatively low, compulsory licensing accompanied by the above mentioned measures of state regulation may even raise the scope of innovative investments compared to the situation without licensing or with voluntary licensing.

LITERATURE

1. Acemoglu, D., Akcigit, U. (2012). Intellectual property rights policy, competition and innovation // *Journal of the European Economic Association*. Vol. 10, No. 1. P. 1 – 42.
2. Aghion, P., Griffith, R. (2005). *Competition and growth: reconciling theory and evidence*. MIT Press.
3. Arce, D. (1997). Correlated strategies as Institutions // *Theory and Decision*. No. 42. P. 271 – 285.
4. Arrow, K. (1962). Economic welfare and the allocation of resources for invention / *The rate and direction of inventive activity: Economic and social factors*. P. 609 – 626. NBER.
5. Encaoua, D., Hollander, A. (2002). Competition policy and innovation // *Oxford Review of Economic Policy*. Vol. 18, No. 1. P. 63 – 79.
6. Fan, C., Jun, B., Wolfstetter, E. (2013). Licensing process innovations when losers' messages determine royalty rates // *Games and Economic Behavior*. No. 82. P. 388 – 402.
7. Fiestras-Janeiro, G., Borm, P., van Megen, F. (1998). Protective and Prudent Behaviour in Games // *Journal of Economic Theory*. Vol. 78, No. 1. P. 167 – 175.
8. Gallini N. (1984). Deterrence by market sharing: A strategic incentive for licensing // *American Economic Review*. Vol. 74, No. 5. P. 931 – 941.
9. Gallini, N., Winter, R. (1985). Licensing in the theory of innovation // *Rand Journal of Economics*. Vol. 16, No. 2. P. 237 – 252.
10. Gilbert, R. (2006). Looking for Mr. Schumpeter: Where are we in the competition-innovation debate? // *Innovation Policy and the Economy.* Vol. 6. P. 159 –215.
11. Gilbert, R., Newbery, D. (1982). Preemptive Patenting and the Persistence of Monopoly // *The American Economic Review*. Vol. 72, No. 3. P. 514 – 526.
12. Gilbert, R., Shapiro, C. (1996). An economic analysis of unilateral refusals to license intellectual property / *Proceedings of the National Academy of Science*. Vol. 93, No. 23. P. 12749 – 12755.
13. Kamien, M, Tauman, Y. (1986). Fees versus royalties and the private value of a patent // *The Quarterly Journal of Economics*. Vol. 101, No. 3. P. 471 – 491.
14. Kamien, M., Tauman, Y. (2002). Patent licensing: the inside story // *The Manchester School.* Vol. 70, No. 1. P. 7 – 15.
15. Kamien, M., Oren, S., Tauman, Y. (1992). Optimal licensing of cost-reducing innovation // *Journal of Mathematical Economics*. Vol. 21, No. 5. P. 483 – 508.

16. Katsoulacos, Y. (2009). Optimal Legal Standards for Refusals To License Intellectual Property: A Welfare-Based Analysis // *Journal of Competition Law and Economics*. Vol. 5, No. 2. P. 269 – 295.
17. Katz, M., Shapiro, C. (1985). On the licensing of innovations // *Rand Journal of Economics*. Vol. 16, No. 4. P. 504 – 520.
18. Katz, M., Shapiro, C. (1986). How to license intangible property // *The Quarterly Journal of Economics*. Vol. 101, No. 3. P. 567 – 589.
19. Motta, M. (2004). *Competition policy: theory and practice.* Cambridge University Press.
20. Rasmusen, E. (1992). *Games and Information. An Introduction to Game Theory*. Blackwell Publishers, Oxford.
21. Reinganum, J. (1983). Uncertain Innovation and the Persistence of Monopoly // *The American Economic Review*. Vol. 73, No. 4. P. 741 – 748.
22. Schumpeter J. (1942). Schumpeter, J. A. (2013). *Capitalism, socialism and democracy.* N. Y.: Harper & Brothers.
23. Seifert, J. (2013). Compulsory Licensing, Innovation and Welfare //http://www.econstor.eu/bitstream/10419/79778/1/VfS_2013_pid_58.pdf
24. Shapiro, C. (2011). Competition and Innovation: Did Arrow Hit the Bull's Eye? / *The Rate and Direction of Inventive Activity Revisited*. University of Chicago Press. P. 361 – 404.
25. Tandon, P. (1982). Optimal patents with compulsory licensing // *Journal of Political Economy*. Vol. 90, No. 3. P. 470 – 486.
26. Tirole, J. (1994). *The theory of industrial organization*. The MIT Press.
27. Yan, Q., Xu, S., & Zhu, L. (2012). Optimal Licensing Schemes for Quality-Improving Innovation in the Bertrand Market / *Software Engineering and Knowledge Engineering: Theory and Practice.* Springer Berlin Heidelberg. P. 467 – 473.

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