Incentives for process innovations under discrete structural alternatives of competition policy[1]

Andrey Shastitko[2] & Alexander Kurdin[3]

Abstract

The study is devoted to the analysis of incentives for process innovations under different conditions determined by the alternative regimes of competition policy for intellectual property rights 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 modeling show that the uncertainty engendered by technological competition may lower the intensity of innovative activities, if there are no mechanisms of coordination between participants. Compulsory licensing will most probably impede innovations due to an opportunistic behaviour of market participants but certain measures of state policy can prevent this negative effect.

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[2] Professor, Head of the Chair of Competition Policy and Industrial Policy, Department of Economics, Lomonosov Moscow State University; Director of the Center for Competition and Economic Regulation Studies, The Russian Presidential Academy of National Economy and Public Administration.

[3] Research fellow at the Chair of Competition Policy and Industrial Policy, Department of Economics, Lomonosov Moscow State University, Associate professor at the Chair of World Economy, Department of World Economy and World Politics, National Research University - Higher School of Economics, E-mail: aakurdin@gmail.com, phone: +79104623441.

Introduction

Innovations are at the core of sustainable economic growth and development. One of the main goals of economic policies of the state is to provide sufficient incentives and facilities for innovations.

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

In this paper we study incentives for process innovations under discrete structural alternatives of competition policy assuming compulsory (mandatory) licensing as the instrument of this policy.

The paper is structured as follows. Section 1 contains the review of relevant literature with the specification of approach presented in this article. In Section 2 we introduce the basic model and main notions for our further analysis. Sections from 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 competition policy applied (absence or presence of compulsory licensing), on the other hand. Section 7 contains main findings.

1. Literature review and intuition

Market competition is strongly associated with innovations. That is why the discussion on balancing competition (including competition *ex ante* and *ex post*), innovations, and market power considerations is 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, sustainability of economic development in terms of the flow of innovations (first of all, product and process innovations). The comprehensive and profound survey made by Shapiro (2011) and earlier classic book of Tirole (1994) contain detailed investigation of this question. Following main milestones of this work, we should inevitably mention fundamental works of Schumpeter (1942) and Arrow (1962) formulating key positions upon the interrelation concerned. Schumpeter emphasized the role of big incumbent firms in the successful innovation process, implying that temporary monopolies may provide enough incentives and capabilities for it. Arrow focused the attention 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 a patentable result of the innovative activity, in order to preserve her 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, without trying to enumerate all the developments in the models of competition and innovation, we feel a necessity to mention the book (Aghion, Griffith, 2005) providing a detailed set of useful models connecting innovations and market structure. That discussion until now may be summarized by the words of Gilbert (2006): "*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's 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 innovations through the lens of different sets of competition policies as discrete structural alternatives – one of the key elements of research mode within the New Institutional Economics.

We consider compulsory (mandatory) licensing as the instrument of competition policy. There may be reasonable doubts concerning the feasibility of inclusion of compulsory licensing in the toolkit of competition policy. Shapiro (2011, p. 373) argues that mandatory licensing, as well as price controls cannot "properly be called "competition policies", at least in the United States today", and introduces a term "procompetition policies". We do not emphasize these verbal differences assuming that those measures, which are 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, can be generally called "competition policies".

We have chosen one of instruments in an attempt to identify and analyze specific measures of competition policy used in the markets for IPR-based goods and services. The role of licensing in reference to the innovative activity has been studied in-depth since 1980s and early 1990s in the pioneer works of Katz and Shapiro (1985, 1986), Gallini (1984), Gallini and Winter (1985), Kamien, Oren and Tauman (1992). They show the limits of voluntary licensing, compare the incentives to innovate in the presence and in the absence of licensing, consider the results for the social welfare, compare different forms of compensation for license (fixed fee, royalty of auctions for licenses) and different forms of oligopolistic relationships.

Our research agenda is close to this list of accents but we focus on compulsory licensing as an element of competition (or procompetition) 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 modeling the interactions between players *a la Cournot.* Further developments in this area led to a much more detailed elaboration of particular licensing mechanisms and their effects,(Kamien, Tauman, 2002; Fan et al., 2013; Yan et al., 2012).

The discussion on a narrower question of compulsory licensing was less intense, however, several important works may be emphasized: Gilbert and Shapiro (1996) were skeptical of compulsory licensing, while Tandon (1982) and Seifert (2013) showed positive effects of compulsory licensing on social welfare 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 have explained that compulsory licensing under certain conditions (depending on distance between technologies used by competitors) may be a useful instrument providing the 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, 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 are the technological leader and the 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 entry to the market is blocked.

Our results show that the existence of technological competition engenders the emergence of a "grey zone" of possible underinvestment in innovations, in comparison with the situation of technological leadership due to the additional uncertainty surrounding firms' decisions. This outcome exists for cases with licensing, as well as for cases without it, in slightly different forms. There will be several equilibria in bimatrix games between market participants, and there is a probability that they choose unfavorable 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. 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 expenses to finance 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 a growth of investment incentives under compulsory licensing.

2. The basic model

The paper presents two-firm model of investments 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 product made by the firm, but also antimonopoly restraints, intellectual property rights regime and technology peculiarities. We also pay attention to private and social costs and benefits accompanying any decision according to the particular set of conditions.

In the following model it is assumed that:

(1) intellectual property rights (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) the entry to the market is blocked;

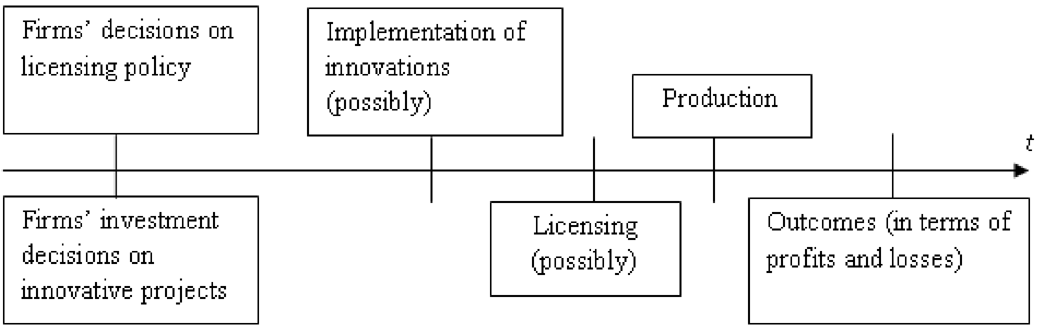
(5) market players and state regulators know production costs and market demand, consequently, they know payoff matrices and can use them to predict the behavior of each other (but they do not know it determinately) and to choose their own strategy;

(6) 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 marginal costs of production from c to c';

(8) the timing is as follows: the participants make simultaneous decisions concerning their licensing policies (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. Discount rate is 0,(we do not take into account probable effects of duration of investments). Time axis is represented by Graph 1.

Graph 1. Time axis of the model



Market demand is specified by the equation $P = a - bQ$, marginal costs of production equal c *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 Graph 2.

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

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

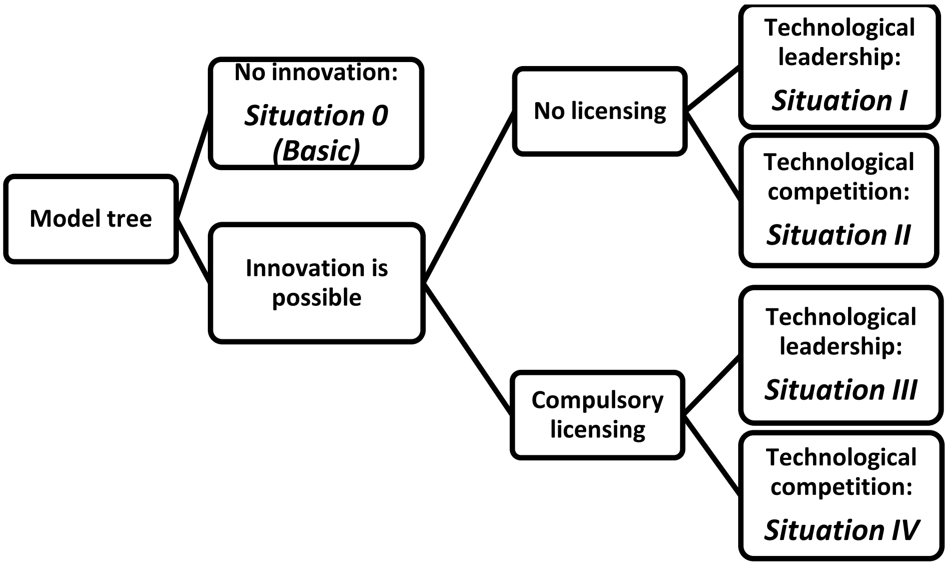
$$P^0 = \frac{a+2c}{3}; \quad (2)$$

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

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

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

Graph 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 move advantage) while the second firm is a potential follower. Also we don't care about where this leadership comes from. The 'first' firm invests *M* into an 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:

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

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

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

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

where: q_1^I, q_2^I – 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 the previous *Situation 0*.

Here we notice that quantities produced by both firms should be non-negative. It is true for the first firm, basing 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]:

$$a + c' > 2c.^5 \qquad (9)$$

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

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

The second firm suffers losses in terms of profit, as well as in terms of quantity produced:

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

We cannot say whether the profit of the innovating firm exceeds its profit in the basic situation. To provide a benchmark for future comparisons, we introduce a $\bar{M}$ as a threshold – the maximal amount *M* that the first firm can invest to obtain 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). The investment will be made if the profit of the first firm in the case of innovation

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[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.

[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.

(*Situation I*) will exceed its profit in the case without innovation (*Situation 0*).

Solving the inequation:

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

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

we obtain the following result:

$$0 < M < \frac{4(c-c')(a-c')}{9b}\text{[7]}. \quad (13)$$

Consequently, the maximal threshold will be defined as follows:

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

This threshold is directly related to (1) absolute amount of marginal cost decrease, (2) distance between market demand reserve price and the new level of marginal cost, (3) 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's why only the investment threshold of the first firm should be taken into consideration here, when we try to estimate the possibility of the innovation. Also, to assess consequences of the *Situation I* we can compare total surpluses:

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

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

Consequently, socially acceptable level of investment into the 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 does not contradict the intuition: the society is ready to pay more than a single firm

[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.

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

This conclusion deserves a detailed exploration but we don't focus on it in this paper laying an emphasis on incentives to innovate rather than consequences on social welfare and discrete structural alternatives to bridge the gap between private incentives and social benefits.

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

In the situation labeled *'II'* we assume that both firms are able to innovate. Each firm may invest the sum *M* (which is equal for both firms) in order to obtain the desirable level of costs economizing *(c – c')*. But the actual result of each firm will depend on the strategic decision of the other one. We consider a game between two firms without first move advantage.

We assume the existence of exclusive rights for an innovation, so that two firms are competing for the innovation to obtain those rights before production. 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 to get R&D results ready for innovation (to win the patent race) for each competitor is 0.5, if both of them invest in R&D, 1 for the single competitor investing in R&D, and 0 for the player(s) without investments in R&D.

This game is shown in Table 1. If no one of firms takes a positive investment decision, then the pay-off will correspond to the *Situation 0* with no innovations. If only one of two firms decides to innovate, then the pay-off will correspond to the *Situation I* with the introduction of an innovation by technological leader. However, in this game the leadership is not set *a priori*. As a result, we obtain the repeating *Situation I* (technological leadership). It means there is at least one element protected as IPR and essential for innovation without potential substitution within the time constraint specified, which is not available for the follower without a 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.

Table 1. Situation II: a game with innovation under technological competition (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 value of the cell ("To invest"; "To invest") represents the expected outcome of the competition: either the firm will be a leader or a follower. Anyway, each firm invests *M*, even if this firm does not get option to innovate. The expected profit for each firm may be expressed in the following manner:

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

where π_1^{II}, π_2^{II} – expected profits in this case.

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

The solution of the game is as follows. The criterion for choosing between strategies if the competitor does not invest in R&D is always set by (14) from the *Situation I*:

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

$$\bar{M}^{II(1)} = \frac{4(c-c')(a-c')}{9b}. \qquad (19)$$

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:

$$\frac{(a-2c+c')^2 + (a+c-2c')^2}{18b} - M - \frac{(a-2c+c')^2}{9b}. \qquad (20)$$

We obtain the threshold $\bar{M}^{II(2)}$:

$$\bar{M}^{II(2)} = \frac{(c-c')(2a-c-c')}{6b} < \bar{M}^{II(1)}. \qquad (21)$$

It is possible to determine three possible ranges of the scope of investment necessary for the innovation. If:

$$M < \frac{(c-c')(2a-c-c')}{6b}, \qquad (22)$$

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

If:

$$\frac{(c-c')(2a-c-c')}{6b} < M < \frac{4(c-c')(a-c')}{9b}, \qquad (23)$$

then firms are in the “grey zone”. Here the outcome is difficult to forecast; the innovation is feasible for one single firm if the other one doesn’t innovate. The fundamental reason for such a result is the dissipation of the rent of innovator due to negative pecuniary cross externality.

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

However, under such an uncertainty the firms cannot choose the strategy automatically if they take decisions simultaneously as it was presumed in the model assumptions. That’s why we need additional hypotheses about the behavior of the firms. If any one of them has a first-mover advantage (thanks to 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 (23), then:

$$\frac{(a+c-2c')^2}{9b} - M > \frac{(a-2c+c')^2}{9b}, \qquad (24)$$

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). If managers of each firm know exactly what strategy they will choose following the decision of their opponents but have no idea about their opponents’ real plans, while the decision should be taken immediately and they cannot use mixed strategies[9], then they can choose the strategy providing maximal *guaranteed* profit. If the condition (23) 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.

The presence of coordination, first-mover advantage, focal points and other mechanisms may provide the opportunity to achieve a Nash equilibrium, with the investment by a single firm.. Otherwise, both firms can choose the prudent maximin strategy, avoiding investments.

Finally, if:

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

then the innovation will be too “expensive” for the firms, and the strategy “not to invest” will be a dominant strategy.

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

The presence of technological competition in the market with blocked entry engenders a problem of uncertainty resulting from the race for innovations (patent race). The technological leader makes a decision based on expected profits from the innovation regardless other firm's decision because the follower cannot innovate and will just act under 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 would be beneficial without the information of the other firm's behaviour. If the project is neither cheap nor expensive to take an immediate decision, the competitors encounter the problem of multiple equilibria. 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 (while they could be realized under technological leadership).

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

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

Now we introduce the licensing in 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*. In this model it means that the firm, which financed R&D and realized the innovation, must provide it to the other firm by means of licensing. As a result, marginal costs of the second firm will also decrease from c to c'. The second firm gives to the first firm, in exchange, a fixed sum of money F – licensing fee.

It is assumed that the state imposes the licensing while giving an opportunity of setting specific conditions of licensing to the firms themselves if they are able to find mutually satisfying solution. Otherwise, if the firms cannot come to an agreement, the state sets specific conditions, namely a price, on its own. It might be based also on specific rules of access like FRAND (Fair, Reasonable And Non-Discriminatory). Such mechanisms are not uncommon. For instance, in Russia, according to the national Civil Code, a licensing fee is established by the court. It means that parties concerned can negotiate and approve the result in the court but if they are not able to come to an agreement, then the price is *de facto* set by the judicial authority.

In this case the innovation will be fulfilled by both firms anyway. But,the process may differ. To start with it, we assume that there is the 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:

$$q_1^{III} = \frac{a-c'}{3b};\ q_2^{III} = \frac{a-c'}{3b};\ Q^{III} = \frac{2(a-c')}{3b}; \qquad (26)$$

$$P^{III} = \frac{a+2c'}{3}; \qquad (27)$$

$$\pi_1^{III} = \frac{(a-c')^2}{9b} - M + F; \pi_2^{III} = \frac{(a-c')^2}{9b} - F;\ \Pi^{\text{III}} = \frac{2(a-c')^2}{9b} - M. \qquad (28)$$

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

$$\pi_1^{III} > \pi_1^{I}; \qquad (29)$$

$$\pi_2^{III} > \pi_2^{I}; \qquad (30)$$

From (29) we obtain conditions for reserve supply price on innovation access of the first firm:

$$\frac{(a-c')^2}{9b} - M + F > \frac{(a+c-2c')^2}{9b} - M; F > \frac{(c-c')(2a+c-3c')}{9b}. \qquad (31)$$

From (30) we obtain conditions for reserve demand price on innovation access of the second firm:

$$\frac{(a-c')^2}{9b} - F > \frac{(a+c'-2c)^2}{9b}; F < \frac{4(c-c')(a-c)}{9b} \qquad (32)$$

Obviously, mutually acceptable value of F can exist only if inequalities (31) and (32) can be satisfied simultaneously, that is if:

$$\frac{4(c-c')(a-c)}{9b} > \frac{(c-c')(2a+c-3c')}{9b}, \qquad (33)$$

which can be transformed into

$$2a + 3c' - 5c > 0\,. \qquad (34)$$

It means that voluntary licensing agreement in this model is a viable structural alternative only if the initial level of costs is low in comparison with the reserve price of demand ($(a-c)$ is big) and the economy resulting from the innovation $(c-c')$ is rather small. The identical result will be obtained if we compare total profit of two firms under licensing and their total profit without licensing (here we neglect transaction costs of negotiations):

$$\Pi^{\mathrm{III}} > \Pi^{\mathrm{I}}; \qquad (35)$$

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

$$= \frac{(c-c')(2a+3c'-5c)}{9b}. \qquad (36)$$

It may seem that if (34) is met and transaction costs of negotiations are zero, the participants will always come to an agreement with voluntary licensing – and compulsory licensing changes nothing. However, relaxing assumptions mentioned changes the picture.

The choices made by 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 present these points as a generic pay-off matrix (Table 2).

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

$$\frac{(a-c')^2}{9b} - F > \frac{(a-2c+c')^2}{9b}; \quad (37)$$

This inequality is satisfied if:

$$F < \frac{4(c-c')(a-c)}{9b} = \bar{F}, \quad (38)$$

Table 2. 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	$\frac{(a-c)^2}{9b}; \frac{(a-c)^2}{9b}$	$\frac{(a-c)^2}{9b}; \frac{(a-c)^2}{9b}$

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

Here we focus the attention on the compulsory licensing. That's why we don't consider the case of $F > \bar{F}$: if compulsory licensing is implemented, then the state will prevent such a high level of 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,. If the leader will ask for a fee not satisfying (38), the follower will not buy license definitely, and there will be no other choice but the intervention by the state or the rejection of innovation project *a priori*. Following the assumptions of our model including the possibility of the state intervention, here we can consider only the strategy "to buy license" from this matrix as a feasible option for the second firm, presuming that values of *F* not satisfying (38) will be corrected by the state or by the firms themselves.

If (38) is met, the second firm will prefer to buy license instead of losing the competitive struggle. Of course, it is possible only if the leader innovates, which depends on whether her net profit from innovation and subsequent licensing exceeds her profit without the innovation:

$$\frac{(a-c')^2}{9b} - M + F > \frac{(a-c)^2}{9b}; \tag{39}$$

$$M < \frac{(c-c')(2a-c-c')}{9b} + F. \tag{40}$$

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

$$\bar{M}^{III} = \frac{(c-c')(2a-c-c')}{9b} + F. \tag{41}$$

If the condition of the voluntaryly established licensing fee for the leader (31) is satisfied simultaneously with (38) and (40) (and we do not forget that (38) and (31) can be simultaneously satisfied if $2a + 3c' - 5c > 0$), then we seemingly could come into a 'favourable' equilibrium:

$\pi_1^{III} > \pi_1^0$ (40): the leader prefers to innovate and license than to reject the innovation,

$\pi_1^{III} > \pi_1^I$ (31): the leader prefers to innovate and license than to avoid licensing,

$\pi_2^{III} > \pi_2^I$ (38): the follower prefers 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 (31) and (38):

$$F \in \left(\frac{(c-c')(2a+c-3c')}{9b}; \frac{4(c-c')(a-c)}{9b}\right), \tag{42}$$

which will make it better for both firms to come to a licensing agreement, if the leader decides to innovate, which is ensured by (40). This equilibrium will have parameters set by (26) – (28). It will involve bigger consumer and total surpluses as compared with the *Situation I*:

$$CS^{III} = \frac{2(a-c')^2}{9b}; TS^{III} = \frac{4(a-c')^2}{9b} - M. \tag{43}$$

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 (42) then:

$$\bar{M}^{III} > \bar{M}^I. \tag{44}$$

However, strategic decisions of 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:

$$\pi_2^{III} > \pi_2^0 ; \frac{(a-c')^2}{9b} - F > \frac{(a-c)^2}{9b} , \tag{45}$$

if:

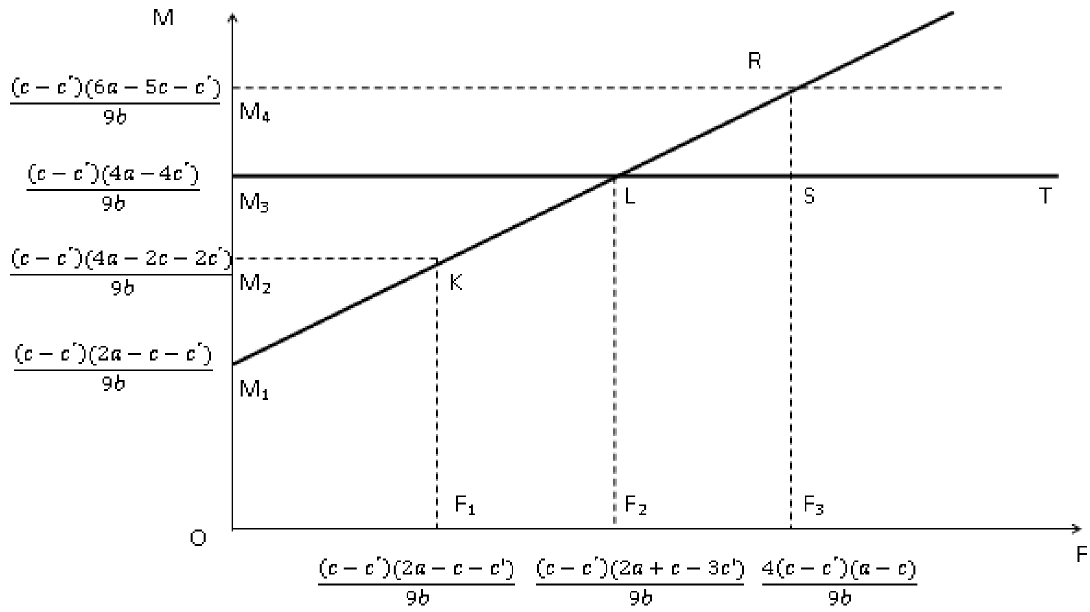
$$F < \frac{(c-c')(2a-c-c')}{9b}. \tag{46}$$

It means that *F* should be less than the lower bound of the range (42) to make it more profitable for the follower to enter a licensing agreement than to operate without any innovations in the market. If the follower is able to prevent the innovation made by the leader on her own and if bargaining is possible, she will not choose licensing fee *F* from the range (42), preferring to satisfy (46). The ability to prevent the innovation by the follower is based on the rejection of the most expensive projects of the leader, which could be profitable only with the considerable licensing fee received, and on the compulsory licensing, which means the necessity to obtain an implicit approval of the follower for the conditions of licensing.

This situation is illustrated by Graph 3 of 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, $2a + 3c' - 5c > 0$.

If the licensing fee *F* exceeds F_3, that is (38) is not satisfied, then the licensing will not occur because of the absence of incentives for the second firm: even the loss of competitive struggle is better for her than the payment of such a high licensing fee. That's why 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 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.

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



If the costs of an innovative project are so high that it corresponds to dots higher than 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 (31) and (38) are simultaneously satisfied, which represents a seemingly 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 himself only in F_2LSF_3. That's why, 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 consumer surplus and total surplus (43).

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 she will do it because the absence of innovation is even more profitable for the follower then 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 her own and is obliged to go into negotiations. 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 neither for the leader, nor for the follower. If the licensing was voluntary, then the leader would be able to ignore this opportunity and to innovate on her 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 him because such fees do not meet his condition of participation in licensing (31). However, such a development would be unprofitable for the follower. She 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.

At last, 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 the follower will accept only the deal based on prices below F_1.

To summarize consequences of the implementation of different regimes, we can conclude that if the regime of licensing was voluntary, that 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 profits of both firms, consumer surplus and, consequently, 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 the increase in consumer surplus and 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 the 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.

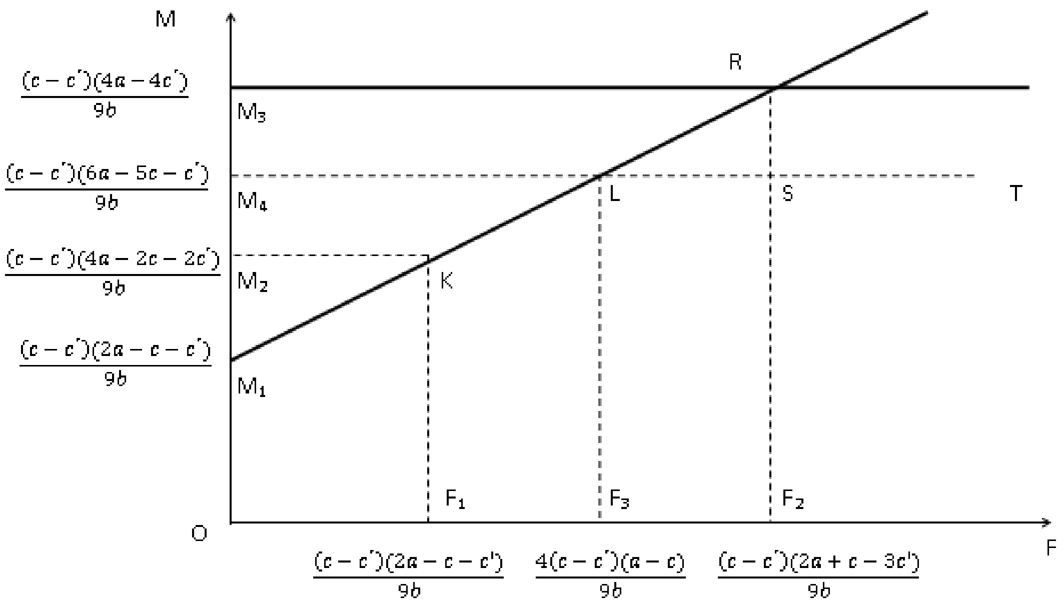
This outcome might be improved. The first way for the regulator is to set reasonable minimal licensing fees. That policy even gives an opportunity to capture previously unattainable area *LRS* and to increase innovative potential. However, this policy will be successful only if the regulator can guarantee not only the sale by the innovator but also the purchase of 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, which involves a great degree of uncertainty for her.

Another way is trickier. The regulator can shape expectations of market players about an indispensable character 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 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 possibility of voluntary established (mutually beneficial) licensing fee is not satisfied, the result changes. This is shown on Graph 4.

The leader will innovate if the investment costs are less than M_3, below the line M_3R, if he works on his own. In the case of licensing the frontier of '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.

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



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: compulsory licensing diminishes incentives for innovation, lowering the ‘investment ceiling’.

The right to regulate licensing fees will give to a regulator an opportunity of incentivizing expensive innovations but, as it was mentioned above, this instrument is highly 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 rise the ‘investment ceiling’ from M_2 to M_4 – to the maximal level of licensing profitability for the follower – but it will still be lower than without any licensing, unlike in the previous case. That’s why the 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 the *Situation II* comprising technological competition. We suppose that both firms are able to innovate. We conserve the assumption from the *Situation II:* only one firm will eventually innovate if both invest in R&D, and this firm will be randomly determined. Then the other firm could not use the innovation without paying licensing fee. We assume that each firm can attain success in the race for the innovation with the probability 0.5 if both firms invest in the innovative activity. That's why the expected licensing fee paid (if the firm chooses to buy licenses 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 definitely succeed and use R&D results for innovation.

In this *Situation IV* we introduce the compulsory licensing in the model. The innovator is obliged to give permission for using her R&D results for innovation in exchange for a fixed *F* (licensing fee), which may be established by the firms themselves or by the regulator. 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 3. To analyze 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:

$$\frac{(a-c')^2}{9b} - M > \frac{(a+c'-2c)^2 + (a-c')^2}{18b} - M + \frac{F}{2} \qquad (47)$$

and

$$\frac{(a+c-2c')^2 + (a-c')^2}{18b} - M - \frac{F}{2} > \frac{(a+c'-2c)^2 + (a+c-2c')^2}{18b} - M. \qquad (48)$$

Table 3. Situation IV: pay-off matrix (enlarged form) for a game with technological competition 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	$\frac{(a+c'-2c)^2}{9b}$; $\frac{(a+c-2c')^2}{9b}-M$	$\frac{(a+c'-2c)^2}{9b}$; $\frac{(a+c-2c')^2}{9b}-M$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$

They are both satisfied if

$$F < \frac{4(c-c')(a-c)}{9b}. \qquad (49)$$

Comparing the third and the fourth strategies from Table 3 for both players, we obtain that the fourth strategy is weakly dominated if:

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

This inequality is also satisfied if (49) is valid.

It means that if (49) is *not* satisfied, then the strategies without the purchase of license will dominate, and there will be no licensing. If the regulator promotes compulsory licensing, such licensing fees cannot be accepted. If (49) is not satisfied, i. e. licensing fees will be prohibitively high, this license will not be requested by anybody. Consequently, consideration of compulsory licensing should be made under the condition (49). If it is satisfied, then strategies without licensing are dominated, and the game from Table 3 can be reduced to Table 4.

Considering the pay-off matrix we conclude: if

$$M < F, \qquad (51)$$

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

If

$$M > F + \frac{(c-c')(2a-c-c')}{9b}, \qquad (52)$$

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

If

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

then the players get into a “grey zone”, which was described in the *Situation II*. Here we have two Nash equilibria, where one of firms invests and the other does not. It is difficult to predict, what 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 the innovation.

Table 4. Situation IV: pay-off matrix (reduced form) for a game with technological competition 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	$\frac{(a-c')^2}{9b} - F$; $\frac{(a-c')^2}{9b} - M + F$	$\frac{(a-c)^2}{9b}$; $\frac{(a-c)^2}{9b}$

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

$$q_1^{IV} = q_2^{IV} = \frac{a-c'}{3b}; Q^{IV} = \frac{2(a-c')}{3b}; \quad (54)$$

$$P^{IV} = \frac{a+2c'}{3}; \quad (55)$$

$$\Pi^{IV} = \frac{2(a-c')^2}{9b} - 2M; \quad (56)$$

$$CS^{IV} = \frac{2(a-c')^2}{9b}; TS^{IV} = \Pi^{IV} + CS^{IV} = \frac{4(a-c')^2}{9b} - 2M, \quad (57)$$

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

Considering this *Situation IV* we implicitly presumed that the regulator promotes compulsory licensing because it involves some positive effects. Basing on (57) we can conclude that these effects really take place, at least for consumers because:

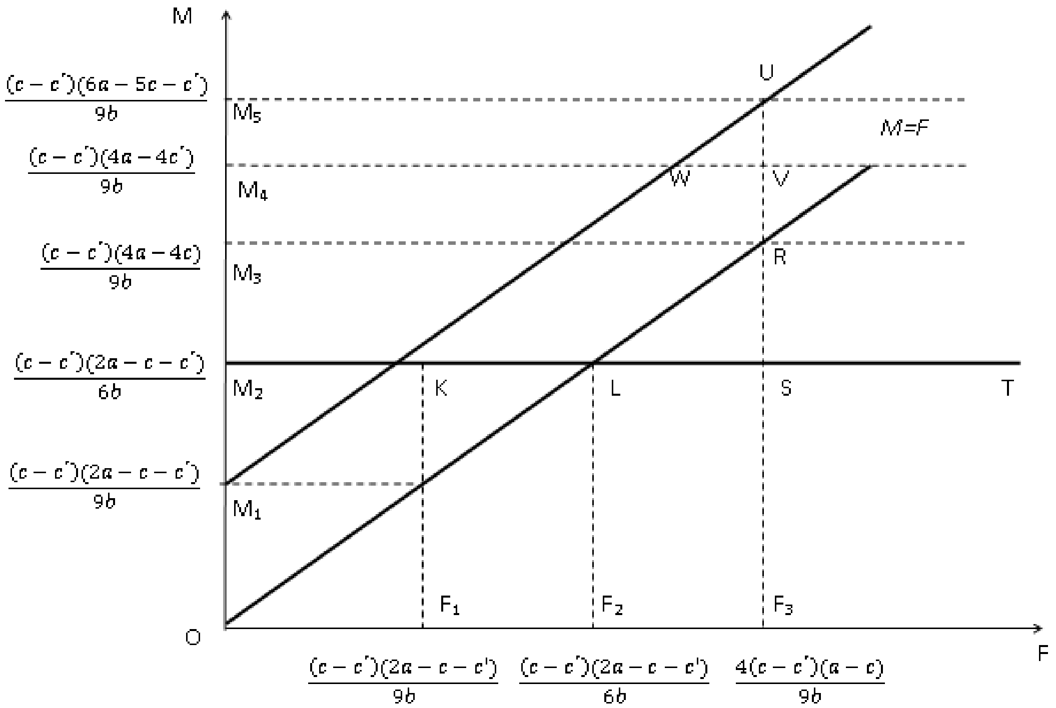
$$CS^{IV} > CS^{I} > CS^{0}. \quad (58)$$

The validity of the inequality (58) follows from (10), and it means that consumer surplus under technological competition *with* licensing is bigger than consumer surplus under technological competition *without* licensing (which equals CS^I, because technological competition will eventually result in technological leadership of the first comer) and also bigger than consumer surplus without the innovation. That is the reason, why the promotion of the equilibrium with investment and licensing of both firms might make sense for the regulator.

Despite seemingly easy 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. It should be noted that they are able to shift the parameters of the game, if the regulator leaves the right to set licensing fees at their disposal. 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 Graph 5. It illustrates the *Situation IV if* $2a + 3c' - 5c > 0$.

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



As it was established in the *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, as well as (59) is satisfied:

$$\frac{(a-c')^2}{9b} - M > \frac{(a+c'-2c)^2 + (a+c-2c')^2}{18b} - M. \qquad (59)$$

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 $OLSF_3$. The threshold level of investment in innovation will be:

$$\overline{M}^{IV} = \frac{(c-c')(2a-c-c')}{6b}. \qquad (60)$$

It is equal to the threshold level in the *Situation II* under technological competition without licensing (not including the “grey zone”), so, the regime of compulsory licensing with voluntarily established fees changes nothing in terms of innovative activities, if we do not take into account the opportunistic behaviour. Players move to the equilibrium with licensing, which increases consumer surplus and their profits. Thus, total surplus grows too.

But as far as licensing is compulsory, then both firms obtain an ability to block the innovation. The logic is analogous to the *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:

$$\frac{(a-c')^2}{9b} - M > \frac{(a-c)^2}{9b} \qquad (61)$$

$$M < \frac{(c-c')(2a-c-c')}{9b}. \qquad (62)$$

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*:

$$\bar{M}^{IV} < \frac{(c-c')(2a-c-c')}{9b} < \bar{M}^{II(2)} < \bar{M}^{II(1)}. \quad (63)$$

That's why we conclude that the introduction of compulsory licensing lowers the incentives for innovations. The remedies against this problem has been described above. One of them is to control licensing fee setting and preventing excessively low fees. The other way is to provide guarantees for the realization of innovative projects, which will shape the expectation of positive investment decision by both investors and will force them to find a mutually beneficial licensing solution. Both ways permit to 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 the *Situation II* entered the "grey zone". Here the benchmarking levels to compare with them the returns from licensing in the *Situation IV* are unclear.

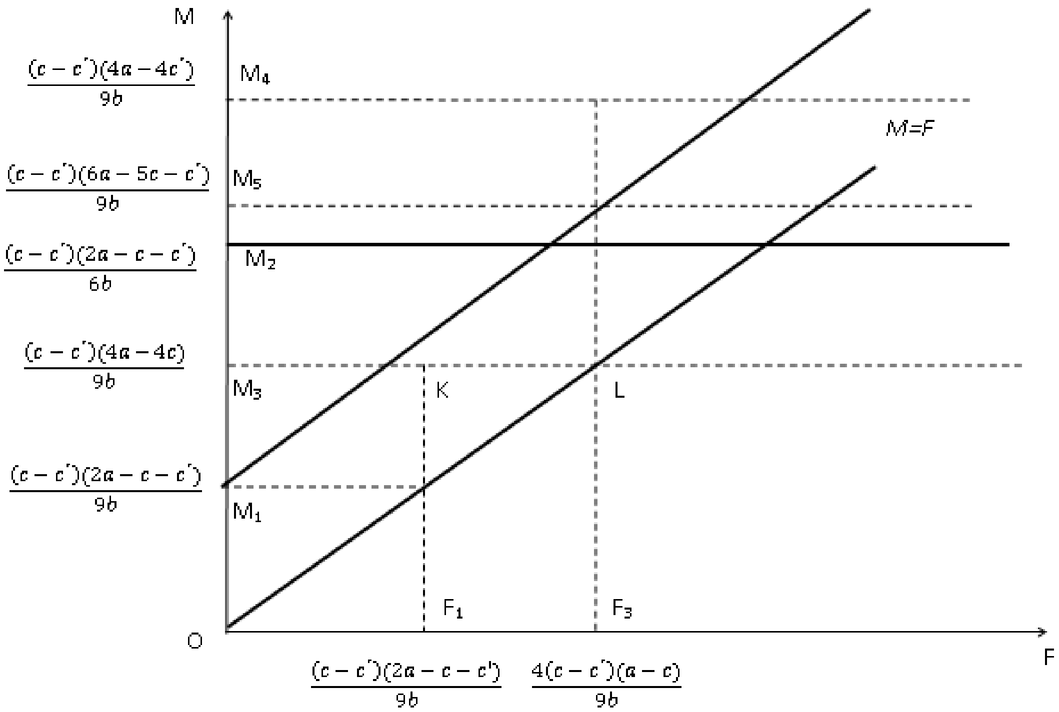
If the cost of innovation *M* exceeds M_4, then investment in the innovation will not be made in the *Situation II* without licensing. If licensing takes place, then the investment probable will occur, with the contract inside the triangle *UVW*, but this is the "grey zone" for the *Situation IV*, and nothing can be said for sure without additional assumptions.

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

Voluntary establishment of licensing fees is not a realistic option for this case. Expected profits from autonomous investing in innovation of both firms without licensing exceed their expected profits with 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, on the level M_1 due to 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 any licensing. Repeating the conclusion of the *Situation III*, if $2a + 3c' - 5c < 0$, then compulsory licensing worsens the conditions for innovative activity.

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



7. Conclusion

The consideration of different situations concerning alternative sets of institutional conditions (presence or absence of compulsory licensing) and peculiarities of specific markets (technological leadership or technological competition) affords ground for several findings, which should be perceived keeping in mind all the restrictive assumptions of our model analysis.

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 put into question due to the additional circumstances – behavioural uncertainty – surrounding the decisions of the firms. 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 the 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 rule of reason under antitrust enforcement..

If compulsory licensing is introduced and voluntary establishment of licensing fees is available, firms can choose it 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 demand price. Such a licensing does not extend the opportunities for innovations but it leads to the growth of well-being of consumers and society in general. It gives a chance to improve the social welfare by finding a feasible compromise between the leadership of a single innovator and the "catch-up" by followers providing him a compensation in the form of licensing fee. But this solution will be 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 consumer surplus and total surplus but negatively affects the incentives for innovations. Compulsory licensing creates incentives for the strategic (and opportunistic) behaviour of the agent obtaining a license. That is true for an industry with technological leadership, as well as for an industry with technological competition. These negative effects may be weakened by a 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 voluntarily chosen 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 abovementioned measures of state regulation may even raise the scope of innovative investments in comparison to the situation without licensing.

REFERENCES

1. Acemoglu, D., Akcigit, U. (2012). Intellectual property rights policy, competition and innovation // *Journal of the European Economic Association*, 10 (1), pp. 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*, 42, pp. 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, pp.* 609 – 626. NBER.
5. Encaoua, D., Hollander, A. (2002). Competition policy and innovation // *Oxford Review of Economic Policy*,18 (1), pp. 63–79.
6. Fan, C., Jun, B., Wolfstetter, E. (2013). Licensing process innovations when losers' messages determine royalty rates // *Games and Economic Behavior*, 82, pp. 388–402.
7. Fiestras-Janeiro, G., Borm, P., van Megen, F. (1998). Protective and Prudent Behaviour in Games // *Journal of Economic Theory*, 78 (1), pp. 167–175.
8. Gallini N. (1984). Deterrence by market sharing: A strategic incentive for licensing // *American Economic Review*,74 (5), pp. 931–941.
9. Gallini, N., Winter, R. (1985). Licensing in the theory of innovation // *Rand Journal of Economics*,16 (2), pp. 237–252.
10. Gilbert, R. (2006). Looking for Mr. Schumpeter: Where are we in the competition-innovation debate? // *Innovation Policy and the Economy*, 6, pp. 159–215.
11. Gilbert, R., Newbery, D. (1982). Preemptive Patenting and the Persistence of Monopoly // *The American Economic Review*, 72 (3), pp. 514–526.
12. Gilbert, R., Shapiro, C. (1996). An economic analysis of unilateral refusals to license intellectual property / *Proceedings of the Nat. Acad. of Science*, 93 (23), pp. 12749– 12755.
13. Kamien, M., Tauman, Y. (1986). Fees versus royalties and the private value of a patent //

*The Quarterly Journal of Economics,*101 (3), pp. 471–491.

14. Kamien, M., Tauman, Y. (2002). Patent licensing: the inside story // *The Manchester School,* 70 (1), pp. 7–15.
15. Katsoulacos, Y. (2009). Optimal Legal Standards for Refusals To License Intellectual Property: A Welfare-Based Analysis // *Journal of Competition Law and Economics,* 5 (2), pp. 269–295.
16. Katz, M., Shapiro, C. (1985). On the licensing of innovations // *Rand Journal of Economics,* 16 (4), pp. 504–520.
17. Katz, M., Shapiro, C. (1986). How to license intangible property // *The Quarterly Journal of Economics,* 101 (3), pp. 567–589.
18. Motta, M. (2004). *Competition policy: theory and practice.* Cambridge University Press.
19. Rasmusen, E. (1992). *Games and Information. An Introduction to Game Theory.* Blackwell Publishers, Oxford.
20. Reinganum, J. (1983). Uncertain Innovation and the Persistence of Monopoly // *The American Economic Review,* 73 (4), pp. 741–748.
21. Schumpeter J. (1942). *Capitalism, socialism and democracy.* N. Y.: Harper & Brothers.
22. Seifert, J. (2013). Compulsory Licensing, Innovation and Welfare //http://www.econstor.eu/bitstream/10419/79778/1/VfS_2013_pid_58.pdf
23. 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, pp. 361–404.
24. Tandon, P. (1982). Optimal patents with compulsory licensing // *Journal of Political Economy,* 90 (3), pp. 470–486.
25. Tirole, J. (1994). *The theory of industrial organization*. The MIT Press.
26. 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, pp. 467–473.