

Patent rights in a duopoly with price leadership

Research Article

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Received 28 August 2024; Accepted 08 June 2025

Abstract: This study analyzes the impact of patent rights on duopolistic competition with price leadership. The willingness of companies with significant patent rights to form a cartel was assessed. The main aim of the analysis was to determine the role of patents in maintaining the stability of the cartel. It has been shown that the existence of patent rights eliminates the prisoner's dilemma and strengthens cartel agreements. This leads to the conclusion that patent rights may significantly limit competition between enterprises and therefore should be within the scope of interest of antitrust offices.

Keywords: *Patent rights • Duopoly • Price leadership • Cartel stability*

JEL: *L13 • L41 • O34*

1. Introduction

Ensuring market competition is one of the important goals of the state's economic policy. To secure free market competition, government agencies make efforts to eliminate all types of corporate collusion. Oligopolistic markets in particular, where a small number of companies operate, create opportunities to limit competition by creating cartels. Collusion or cartels enable companies to achieve monopoly profits at the expense of buyers and contribute to general social losses, so combating them is of significant economic importance.

In the context of antitrust activities of government agencies, an important issue is the level of stability of cartel agreements. Instability occurs when colluding participants can achieve higher profits after unilaterally breaking the contract. The argument is usually made that a prisoner's dilemma occurs between the colluding companies, which contributes to the breakdown of the cartel. This type of instability gives hope that even the lack of interference by government agencies does not pose a major threat to competition.

Levenstein and Suslow (2006) noted that the average period of operation of a cartel collusion is not very long precisely due to the lack of stability caused by the prisoner's

dilemma.¹ However, this does not stop companies from forming cartels and thus restricting competition.²

Cartel agreements cannot be legally enforced, so only non-legal measures can ensure their durability. Therefore, to combat cartelization of markets and ensure free competition, it is important to know the factors affecting the stability of collusion.

The main factors influencing the stability of cartel agreements have been described many times in the literature on the subject.³ However, there are still mechanisms among them that require further investigation. These include patent rights.

In this study, we will focus on the impact of patents on the stability of cartel agreements. Analogously to the work of Prokop (2021, 2023), we will focus on a duopoly in which each company has the patent rights to a different component of the final good. This means that for the final production, each of these firms must acquire the patent rights of the other company. Unlike previous works, when the duopolists compete, we will assume the price-leadership behavior.⁴

¹ See also Harrington and Wei (2017).

² See, e.g., European Commission (2021).

³ See, e.g., Levenstein and Suslow (2011), Lipczynski et al. (2017, pp. 222–233), or Paha (2017).

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The situation discussed here often occurs in highly innovative industries,⁵ where technologies are protected by many different patents, and no company has the full set of technologies needed to manufacture the final product.⁶ In pharmaceuticals, companies often hold patents for various stages of the drug production process (e.g., active substance synthesis, tablet formulation, etc.). For example, company A may have a patent on the active ingredient, but company B has a proprietary method of administering or distributing it in the body. To bring a drug to market, both companies must use competitors' patents and sign cross-licensing agreements. While companies A and B might be fierce competitors in the consumer market, they could also collaborate through cross-licensing agreements related to patent rights.

Should the companies decide to pool their patents, it will not automatically mean collective ownership of the rights to produce the final good. Instead, we assume that the companies enter a collusive agreement to manufacture a certain quantity of the final product without having to pay for the patent rights owned by the other firm. A firm neglecting the quota will be responsible for payment of the extra costs of the patent rights. We show that such an arrangement helps maintain the cartel stability, and therefore, contributes to increased durability of the collusion. Patent rights by themselves often create a monopoly position for the companies that own such rights; thus, it is not a typical focus of the antitrust agencies to look for collusive agreements enforced by the patent rights.

In the next section, we will provide a brief overview of the factors influencing the stability of cartels, with particular emphasis on the role of patents. Then, we will describe models that will allow us to analyze the situation and draw conclusions. First, we will present a duopoly model with a price leader in the end-product market, and then we will compare it with a full cartel model in a given industry. The comparison results are discussed in Section 4. The work ends with a description of the conclusions.

2. Literature review

Considerations on the prisoner's dilemma, which explain the lack of internal stability of the cartels, were limited to a static view of the functioning of the agreements. The

analysis of oligopolistic competition from a dynamic perspective allows to justify the close cooperation of enterprises forming a cartel.⁷

The arguments for the stability of cartels, presented through supergames, are true, provided that the behavior of companies in the market is observable. In the absence of complete information about the pricing decisions of colluding participants, cartels may periodically break up, especially when there are fluctuations in demand on the market that are difficult to identify immediately. Green and Porter (1984) presented a model analysis of such a situation where cartel participants may be uncertain whether low profits are due to a sudden drop in demand or a secret price reduction by one of the colluding members, which weakens cartel cooperation.⁸

The impact of demand fluctuations on the stability of collusion was also examined by Rotemberg and Saloner (1986) and Harrington and Skrzypacz (2007). Their research showed that an increase in demand strengthens cooperation between cartel participants, while a decrease, even fluctuations, lead to the breakdown of agreements.

The number of companies in a market and differences in production capacity are key factors influencing the durability of cartels. A small number of companies in a given industry facilitates the formation of a cartel and prolongs its existence.⁹

Compte et al. (2002) and Vasconelos (2005) noted that firms with large production capacities tend to break cartels because of the weakness of smaller firms to retaliate. Symmetry in production capacity promotes cartel stability, although Prokop (1999) pointed out that establishing a stable cartel may be difficult, even for identical companies.

Research on the impact of antitrust policy on market cartelization has focused on government leniency programs. Aubert et al. (2006), Harrington (2008) and Spagnolo (2008) confirmed that such programs can destabilize cartel arrangements. Optimal competition policy is discussed in the study by Harrington (2017).

The beginning of the debate on the impact of patents on cartel stability can be found in the study by Wu (2019). The author argues that creating a pool of patents can stabilize cartels of producers of final goods, and vertical licensing agreements help monitor compliance with cartel agreements. Unlike previous concepts, Karbowski (2020)

⁴ See, e.g., Baranowska-Prokop and Sikora (2014).

⁵ See, e.g., Karbowski (2016).

⁶ See, e.g., Alsharkas (2014).

⁷ Compare, e.g., Church and Ware (2000, pp. 331–340), or Tirole (1997, pp. 245–247).

⁸ See, e.g., Tirole (1997, pp. 251–253 and pp. 262–265).

⁹ See, e.g., Hay and Kelly (1974), Prokop (1999), or Pepall et al. (2014, pp. 375–376).

presented a formal model of the relationship between patents and market collusion, pointing out that patents can contribute to the destabilization of cartels by enabling avoidance of retaliation for leaving the cartel.

3. Method of analysis

In this article, we will analyze an industry consisting of two companies, each of which holds patent rights to part of the production process of the final good.

First, we consider competition among duopolists who hold patent rights. We will look at the case of a duopoly with a price leader.¹⁰ We will describe the behavior of enterprises in the framework of a non-cooperative game for which we will find a Nash equilibrium.

We will then move on to examining the cartel created by the two companies that agreed to pool their patents and use them jointly (patent pool). We will analyze the benefits of duopolists from participating in cartel collusion. In order to examine the stability of their cooperation, we will consider enterprises' incentives to reduce prices. Finally, we will compare the benefits of companies cooperating in a cartel with their profits in the absence of collusion, taking into account patent rights.

3.1 Price leadership under the existence of patent rights

We will analyze a branch consisting of two enterprises, which we will denote L and F . The enterprises produce a homogeneous product for the end user. The market demand function in inverted form is as follows:

$$p = a - q_L - q_F, \quad (1)$$

where p is the price of the final product, q_i is the production volume of enterprise i ($i = L, F$), and a is a constant and positive parameter.

We assume that the production of the final good consists of two necessary parts, which we will mark as A and B. The components of the production process are mutually complementary and their substitution is impossible. Company L owns the patent rights to part A, while company F owns the patent rights to part B.

The total costs of delivering the product to the end buyer by enterprise i consist of manufacturing costs and the costs of patent rights. We assume that manufacturing costs have a form of a quadratic function $\frac{q_i^2}{2}$, and patent rights fees are linear. So, the total costs are:

$$C(q_i) = \frac{q_i^2}{2} + w_j q_i, \quad (2)$$

where w_j is a unit fee paid by enterprise i ($i \neq j$) for the patent rights owned by company j . In this model, we assume that entry barriers to this industry prevent the emergence of additional competitors.

The game under consideration consists of two stages. In the first stage, enterprise i sells the patent rights to another enterprise in this industry at a price w_i . In the second stage, enterprises compete on the final product market according to the price leader model, in which enterprise L takes the role of leader and enterprise F is a follower, i.e., first enterprise L chooses the price level and then, enterprise F decides on the volume of its own production at this price.

The company i 's profit can be written as follows:

$$\pi_i = (p - w_j)q_i - \frac{q_i^2}{2} + w_i q_j. \quad (3)$$

We will apply the concept of subgame perfect Nash equilibrium to this game. Therefore, the equilibrium point will be determined by the use of backward induction. First, we will analyze the behavior of enterprises in the second stage of the game. The follower determines the amount of its production q_F that maximizes its profit at the price p set by the leader

$$\pi_F = (p - w_L)q_F - \frac{q_F^2}{2} + w_F q_L. \quad (3a)$$

From (1), we have

$$q_L = a - p - q_F. \quad (4)$$

Substituting (4) in (3a), we obtain

$$\pi_F = (p - w_L)q_F - \frac{q_F^2}{2} + w_F(a - p - q_F). \quad (5)$$

From the first-order conditions for maximizing the follower's profit relative to the production level q_F given by

$$\frac{\partial \pi_F}{\partial q_F} = p - w_L - q_F - w_F = 0, \quad (6)$$

¹⁰ Competition models of this type were considered, for example, by Diamantoudi (2005). Another model that can be used to analyze cartel stability is Cournot competition (Prokop, 2021) or the Stackelberg quantity leader model (Prokop, 2023).

we obtain the supply of enterprise F as a function of the price level set by the leader

$$q_F = p - w_L - w_F. \quad (7)$$

In turn, the leader sets the price p that maximizes its profit, which is

$$\pi_L = (p - w_F)q_L - \frac{q_L^2}{2} + w_L q_F. \quad (8)$$

Substituting (7) in (4), we have

$$q_L = a - 2p + w_L + w_F. \quad (9)$$

Then, substituting (7) and (9) in expression (8), we obtain

$$\pi_L = (p - w_F)(a - 2p + w_L + w_F) - \frac{(a - 2p + w_L + w_F)^2}{2} + w_L(p - w_L - w_F). \quad (10)$$

From the first-order conditions for maximizing the leader's profit relative to the price level p

$$\frac{\partial \pi_L}{\partial p} = 3a - 8p + 4w_L + 5w_F = 0, \quad (11)$$

we obtain the price that maximizes the leader's profit as a function of the patent fee for the follower

$$p = \frac{1}{8}(3a + 4w_L + 5w_F). \quad (12)$$

Substituting (12) in expressions (9) and (7), we obtain the optimal production levels of the leader and the follower as functions of patent fees

$$q_L = \frac{1}{4}(a - w_F), \quad (13)$$

$$q_F = \frac{1}{8}(3a - 4w_L - 3w_F). \quad (14)$$

The price level p and the production level q_F described by expressions (12) and (14) constitute the Nash equilibrium for a given level of prices charged by enterprises for patent rights, w_L and w_F .

Substituting (12) and (14) in (5) and (10), we obtain the profits of each company as a function of patent fees w_L and w_F

$$\pi_L(w_L, w_F) = \frac{1}{16}(-8w_L^2 + (a - w_F)(a + 8w_L - w_F)), \quad (15)$$

$$\pi_F(w_L, w_F) = \frac{1}{128}((3a - 4w_L)^2 + 62aw_F - 71w_F^2 + 40w_L w_F). \quad (16)$$

In the first stage, when enterprises simultaneously and independently set the prices of their patent rights, Nash equilibrium strategies are obtained as a solution to the following system of equations with unknowns w_L and w_F

$$\frac{\partial \pi_L}{\partial w_L} = \frac{1}{2}(a - 2w_L - w_F) = 0, \quad (17a)$$

$$\frac{\partial \pi_F}{\partial w_F} = \frac{1}{64}(31a - 20w_L - 71w_F) = 0. \quad (17b)$$

From the above system of equations, we have

$$w_L^* = \frac{20}{61}a, \quad (18a)$$

$$w_F^* = \frac{21}{61}a. \quad (18b)$$

Substituting w_i^* given by (18a) and (18b) in expressions (13) and (14), we obtain the production volumes of each enterprise at the equilibrium point

$$q_L^* = \frac{10}{61}a, \quad (19a)$$

$$q_F^* = \frac{5}{61}a, \quad (19b)$$

and from functions (15) and (16), we determine the profit levels of these enterprises

$$\pi_L^* = \frac{300}{3,721}a^2, \quad (20a)$$

$$\pi_F^* = \frac{655}{7,442}a^2. \quad (20b)$$

Substituting (18a) and (18b) in expression (12), we obtain the equilibrium price at which enterprises sell the final product

$$p^* = \frac{46}{61}a. \quad (21)$$

In Section 3.2, we will consider the behavior of companies that entered into a cartel agreement.

3.2 Cartel agreement

We will now look at the situation of cartel formation in the analyzed industry. We will assume the same production conditions and an unchanged demand function. The companies operating within the cartel jointly use their patents, which exempts them from paying fees for patent rights,

but only up to a fixed production level not exceeding $\frac{a}{5}$ and provided that the supply of each company is positive.¹¹ If the supply of enterprise i exceeds the established level, it will be necessary to incur costs in the amount w_j^* specified in (18a) and (18b) for each unit of its excess production. Moreover, the company will be obliged to pay an identical fee for each unit produced if the demand for its competitor's production is zero.

The decisions of enterprises in the final product market concern the production volumes q_L and q_F that maximize the total profit of the cartel

$$\pi = \pi_L + \pi_F = (a - q_L - q_F)q_L - q_L^2/2 + (a - q_F - q_L)q_F - q_F^2/2. \quad (22)$$

In a cartelized industry, we can assume that identical companies behave symmetrically, and therefore $q_L = q_F$. Hence, equation (22) can be written as

$$\pi = 2(a - 2q_L)q_L - q_L^2. \quad (22a)$$

The first-order condition for profit maximization has the following form:

$$\frac{\partial \pi}{\partial q_L} = 2a - 10q_L = 0. \quad (23)$$

Equation (23) then shows that the production volume of each cartel participant at the equilibrium point is

$$\bar{q}_L = \bar{q}_F = \frac{a}{5}. \quad (24)$$

Substituting (24) for q_L and q_F in the inverted demand function defined by equation (1), we obtain the equilibrium price of the final good determined by the cartel

$$\bar{p} = \frac{3}{5}a. \quad (25)$$

The total profit of the cartel at the equilibrium point is calculated by applying formula (24) in equation (22a), and it will then be

$$\bar{\pi} = \frac{a^2}{5}. \quad (26)$$

Hence, the profit of each of the companies forming the cartel is equal to

$$\bar{\pi}_L = \bar{\pi}_F = \frac{1}{2}\bar{\pi} = \frac{a^2}{10}. \quad (27)$$

Comparing the above cartel profits of each company with their expected profits in competition with the price leader, given by expressions (20a) and (20b), we note that

$$\pi_L^* = \frac{300}{3,721}a^2 < \bar{\pi}_L = \frac{1}{2}\bar{\pi} = \frac{a^2}{10}, \quad (28a)$$

$$\pi_F^* = \frac{655}{7,442}a^2 < \bar{\pi}_F = \frac{1}{2}\bar{\pi} = \frac{a^2}{10}. \quad (28b)$$

This means that each company will achieve higher profits by forming a cartel compared to a non-cartelized industry with price leadership. Let us assume that a cartel has been established and examine its stability in the absence of patent rights and in the presence of such rights. If patent rights did not exist, then firm i , being convinced that its competitor j is sticking to the cartel arrangement by producing $\bar{q}_j = \frac{a}{5}$, should maximize the following profit function:

$$\begin{aligned} \pi_i &= (a - q_i - \bar{q}_j)q_i - \frac{q_i^2}{2} = \left(a - q_i - \frac{a}{5}\right)q_i - \frac{q_i^2}{2} \\ &= \left(\frac{4}{5}a - \frac{3}{2}q_i\right)q_i. \end{aligned} \quad (29)$$

From the first-order condition for the maximization of the above profit function

$$\frac{\partial \pi_i}{\partial q_i} = \frac{4}{5}a - 3q_i = 0, \quad (30)$$

we obtain the optimal production volume of enterprise i

$$q_i = \frac{4}{15}a > \bar{q}_i = \frac{a}{5}, \quad (31)$$

and the profit

$$\pi_i = \frac{8}{75}a^2 > \bar{\pi}_i = \frac{a^2}{10}. \quad (32)$$

Therefore, it would be beneficial for the company to not honor the cartel agreement. This means that in the absence of patent rights, the cartel is not stable.

Let us now turn to the consideration of a cartel formed by both companies L and F when patent rights exist and may be enforceable. First, we will analyze the case of a

¹¹ This upper threshold of production levels set at $\frac{a}{5}$ in the collusive scenario follows from the optimal supply levels of cartel members. It is worth stressing that it is an important arrangement helping enforce the collusive agreement. Ownership of the individual patent rights allows the execution of severe punishment for deviations from the collusive agreement by making the miscreant pay for the patent rights of excessive supply.

slight price reduction by company L . After offering a price $\tilde{p}_L = \bar{p} - \varepsilon = \frac{3}{5}a - \varepsilon$, where ε is a small positive number, company L will take over the entire market demand, i.e., $\tilde{q}_L \approx \frac{2}{5}a$, that is, the demand for the products of company F would be $\tilde{q}_F = 0$. In this situation, company L will have to pay for the patent rights to competitor F . Hence, the net profit of company L will be

$$\tilde{\pi}_L = (p - w_F^*)\tilde{q}_L - \frac{\tilde{q}_L^2}{2} \approx \left(\frac{3}{5}a - \frac{21}{61}a\right)\frac{2}{5}a - \frac{4}{50}a^2 = \frac{34}{1,525}a^2. \quad (33)$$

Comparing the profit of enterprise L from failure to comply with the cartel agreement given by expression (33) with the profit of this enterprise from participation in the cartel given by expression (27), we see that it is lower

$$\tilde{\pi}_L = \frac{34}{1,525}a^2 < \pi_L = \frac{a^2}{10}. \quad (34)$$

Therefore, we concluded that it is not profitable for company L to break the cartel agreement by lowering the price. This conclusion is different than in the absence of patent rights.

Similarly, let us consider the case of a small price reduction by company F . If it offers a price $\tilde{p}_F = \bar{p} - \varepsilon = \frac{3}{5}a - \varepsilon$, where ε is again a small positive number, it will take over the entire market demand, i.e., $\tilde{q}_F \approx \frac{2a}{5}$ and $\tilde{q}_L = 0$. In turn, failure to comply with the cartel agreement will result in the need for company F to pay a fee for patent rights to competitor L . Then, the net profit of company F will be

$$\tilde{\pi}_F = (p - w_L^*)\tilde{q}_F - \frac{\tilde{q}_F^2}{2} \approx \left(\frac{3}{5}a - \frac{20}{61}a\right)\frac{2}{5}a - \frac{4}{50}a^2 = \frac{44}{1,525}a^2. \quad (35)$$

Comparing the above profit of company F from failing to comply with the cartel agreement with the profit of the company adhering to the cartel agreements, defined by expression (27), we find that it is lower

$$\tilde{\pi}_F = \frac{44}{1,525}a^2 < \pi_F = \frac{a^2}{10}. \quad (36)$$

Therefore, it is not profitable for any company to break the cartel agreement by changing the price level.

4. Results

The presented considerations lead to the conclusion that in the case of a duopoly with a price leader, it is profitable for all companies to join the cartel. A cartel established in such a market would be unstable in the absence of patent rights. However, if patent rights existed, such a cartel

would be stable and its functioning would not be disturbed. This is a very important difference in the operating conditions of enterprises.

5. Summary and conclusion

This article demonstrates that the existence of patent rights relevant to the production of the final good contributes to the elimination of the prisoner's dilemma between companies forming a cartel that previously participated in a duopoly with the price leader and supports the stability of the collusion. Therefore, patent rights may have a significant impact on limiting market competition and should therefore be subjected to careful analysis by antitrust agencies and competition protection offices.

This conclusion adds additional arguments to the important debate on the economic justifications for patent protection. Karbowski and Prokop (2013) reviewed the discussion about patents and showed the weaknesses of many arguments for patent protection. The analysis provided in the current work shows another adverse effect of patent protection and makes a strong argument for limiting patent laws.

The conclusions obtained in this article are consistent with the results of research by Wu (2019) and Prokop (2021, 2023) conducted under slightly different assumptions. Nevertheless, it is worth emphasizing that these conclusions are different than in the absence of patent rights. They also indicate that cartel participants with significant patent rights may behave differently than in the study by Karbowski (2020). Further research is therefore necessary on the impact of patents on cartel stability.

The results presented in this study are based on a simple duopoly model with a homogenous product. In the next step, it would be beneficial to consider product differentiation in the oligopolistic competition. Industries with significant patent activities are often characterized by product diversity.

Among the additional directions for future research regarding the impact of patent rights on industry cartelization, the effects of more complex cross-licensing schemes among firms should be considered.

Funding information

Author states no funding involved.

Author contributions

The author confirms the sole responsibility for the conception of the study, presented results and manuscript preparation.

Conflict of interest statement

Author states no conflict of interest.

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