Journal of Theoretical and Applied Information Technology
31st July 2023. Vol.101. No 14

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

STUDY OF OPEN INNOVATION AND INTELLECTUAL PROPERTY EFFECT ON FIRM PROFIT IN THE FRAME DUOPOLISTIC MARKETS

ELMIRE AZIZ[1], AIT BASSOU AZIZ[2], HLAYAL MUSTAPHA[3] , EL ALAMI JAMILA[4]

[1]LASTIMI laboratory, University Med V of Rabat, Mohammadia School of Engineering Rabat, Morocco
[2]LASTIMI laboratory, University Med V of Rabat, Mohammadia School of Engineering Rabat, Morocco
[3]LASTIMI laboratory, University Med V of Rabat, Mohammadia School of Engineering Rabat, Morocco
[4]LASTIMI laboratory, University Med V of Rabat, Mohammadia School of Engineering Rabat, Morocco

E-mail: [1]aziz.elmire412@gmail.com, [2]aziz.bassou123@gmail.com, [3]mustaphahlyal@gmail.com, [4]jamilaaalami@gmail.com

ABSTRACT

In this research paper, we will probe the influence of open, closed innovation and intellectual property rights protection on competitive advantage by implementing the Cournot duopoly model. The study is set up in two phases: firstly, assessing the effects of the open innovation strategy rate on the competitive landscape, and secondly, proposing a novel model for intellectual property profit based on exponential function. The findings have indicated that embracing open innovation can result in greater profits and market share for both firms, exceeding the outcomes of closed innovation approaches. Also, we demonstrated that they are a link between the open innovation adoption and intellectual property. These results carry important implications for companies operating in innovation-intensive sectors and emphasize the potential advantages of adopting collaborative innovation strategies.
Keywords: *Open innovation; Close innovation; Duopoly market; Games theory.*

1. INTRODUCTION

Open innovation introduces a comprehensive approach to innovation by leveraging both internal and external resources, therefore it enhances the innovation process. It offers a revamped method to enhance business performance through effective resource distribution meanwhile it addresses environmental concerns. By channeling internal resources, companies initiate a flow of valuable assets to their partners, generating tangible value externally.

According to the literature, open innovation can be categorized into three dimensions based on the direction of knowledge flows. The first dimension is known as "outside-in," where a company acquires knowledge from external sources (such as through crowdsourcing). The second dimension is termed "inside-out," in which a company shares its internally developed knowledge with external entities (such as by licensing patents to other firms). The third dimension is referred to as "coupled," where knowledge flows in both directions, encompassing both the inflow of external knowledge and the outflow of internal knowledge [1].

In line with the principles of open innovation (OI), companies are encouraged to actively engage in the acquisition and sale of intellectual property (IP) assets [2].

Intellectual property encompasses the exclusive rights granted to various intellectual creations. It can be categorized into two main branches:

1. Literary and artistic property, which are related to works of the mind such as author's rights, copyright, and related rights, which are relevant in industries such as software development and cinema.
2. Industrial property, which covers utilitarian creations such as patents for inventions and certificates for plant varieties, as well as distinctive signs like trademarks, domain names, and appellations of origin.

According to Chesbrough (2003b), the term "intellectual property" pertains to a specific set of ideas which possess three key characteristics: novelty, usefulness, and tangible embodiment. These ideas must be authentic and innovative, which offer practical value or utility, and have been transformed into a tangible form or expression. Moreover, the management of these ideas must align with legal frameworks and regulations governing intellectual property rights. Chesbrough emphasizes that this definition encompasses the core elements which distinguish intellectual property within a broader realm of ideas.

For a company, striking the right balance of openness is crucial. This allows the company to ensure ownership of IP rights while seizing opportunities to support their innovation endeavors. Open innovation relies on careful management of the relationship between intellectual property (IP) and the openness of the innovation process. Initially considered negatively, according to Chesbrough, it can also be perceived as positive based on specific conditions and in particular contexts.

Game theory has demonstrated its utility as an effective tool for examining intellectual property rights. In particular, the Cournot duopoly model has gained prominence as a favored game theory approach for simulating intellectual property licensing strategies in the context of duopoly competition.

Duopoly games have garnered considerable attention from researchers. This market configuration revolves around the dominant presence of two major companies, and these firms meticulously engage in fully rational decision-making processes to pursue their respective goals. The prevailing methods employed to address the duopoly game primarily revolve around the Cournot model (introduced by Cournot in 1838) and the Bertrand model (proposed by Bertrand in 1883). These two models constitute the most extensively utilized approaches in the field.

Da Silva explores the analytical aspects of a specific mechanism within the realm of open innovation (OI), which involves managing the non-monetary exchange of information. The study also examines the connection between intellectual property rights (IPRs), specifically patent rights, and OI within the context of research and development (R&D) competition, employing a static game-theoretic framework [3].

In our recently published paper [4], we introduced an approach based on game theory and the duopoly model to examine the effect of the open innovation integration rate on the profit of a firm. However, intellectual property is not taken into account and studied in the same model.

There are several representative types of research that study intellectual property modeling and others in the frame of a duopoly market.

Yang et al. employ evolutionary game theory to examine the cooperative behavior of intellectual property cooperation among the Government-Industry-University-Research (GIUR) entities while considering the factors that influence such behavior, including the market mechanism and administrative supervision mechanism [5].

In their study, Nwobodo and Inyiama suggest employing a Dynamic Bayesian Network as a valuable modeling tool for predicting the distribution of Research and Development (R&D) investment efficiency. The proposed approach aims to facilitate the strategic management of intellectual property by providing insights into future investment trends [6].

A recent work published by Nie et al [7] has studied the effect of intellectual property and patent price of the firms' position, therefore they have concluded that the firm with higher marginal cost prices patent is higher under Stackelberg situation than the one under Cournot cases.

Chen et al. present in their work an analysis of IP licencing strategy in the frame of duopoly competition [8].

In their study, Ikeda et al. (2019) conducted a comparison of welfare in two scenarios: Cournot duopoly with an innovator and an imitator, and innovator monopoly. Their findings revealed that when there is a significant spillover effect and low innovation costs, the welfare under a monopoly surpasses the one which is under a duopoly. This suggests that, under these conditions, a monopoly structure tends to generate higher welfare levels compared to a duopoly market structure [9].

A proposal has been made to create a two-stage game (R&D-Production) which is characterized by being asymmetric and non-cooperative. This game aims to represent a developing market scenario where two local firms engage in competition with a foreign firm which is more innovative [10].

Chu et al. examine the intricate dynamic patterns exhibited in a mixed duopoly game with quadratic cost by considering the principles of oligopoly game theory and intellectual property rights protection policy [11]. Another work of Chu and Zhou focuses on analyzing R&D competition with one-way spillover effects, considering the influence of intellectual property protection. Specifically, it examines a R&D-Cournot duopoly game scenario involving a foreign-invested enterprise and a domestic-invested enterprise. The study aims to understand how intellectual property protection impacts the competitive dynamics between these two types of enterprises in the context of research and development activities [12].

The research of Žigić et al. [13] aims to investigate the interplay between two forms of intellectual property rights (IPR) protection: public (copyright) and private protection. The study delves into how these two types of protection mechanisms interact and influence each other in the context of safeguarding intellectual property.

As far as our understanding goes, there is a limited body of research on the correlation between intellectual property (IP) strategies and Open Innovation (OI). Moreover, no study has comprehensively explored how various IP strategies influence a firm's ability to harness and gain advantages from OI initiatives. To bridge this gap, we conduct an analysis that examines the impact of open innovation integration rates within the context of duopoly game theory. By doing so, we aim to shed light on the intricate relationship between IP strategies and OI and uncover their effects on firms' overall competitive capabilities.

2. MODEL

The goal is to comprehensively grasp the workings of open innovation systems and investigate how various market structures, levels of investment in open innovation, and intellectual property rights influence both firm performance and market outcomes.

The model assumes the presence of two companies, labeled i (i=1,2), in a market which offers identical products. The inverse demand function of two firms can be obtained by the maximization of utility function, as:

$$p_i = a - b(q_1 + q_1) \qquad (1)$$

Where,

a>0 and b∈[0,1], q_1 and q_2 are the output of the products produced by the firm 1 and firm 2 respectively.

In our analysis, we have taken into account that both firms are making decisions to incorporate innovation into their strategies. To model Open Innovation (OI) and Closed Innovation (CI), we introduce the parameter $\sigma_i \in [0,1]$, as a key factor, which corresponds to the OI integration rate.

In this case, the effective marginal cost of firm *i* can be represented as

$$C_i(\sigma_i) = A + c(1-\sigma_i), \quad i = 1,2 \qquad (2)$$

The values of the cost function depend on the OI integration rate. If a firm *i* decides to outsource the innovation the marginal cost will be *A*, since the rate σ_i will be equal to one. However, if firm *i* decides to internalize, completely, the innovation, the marginal cost will be high since it will be equal to *A+c*.

If we consider the gains which a firm can obtain from CI, in terms of high-powered incentives, firm-owned property rights and reuse cost, we can imagine that as the firm believes its rate of Open innovation, it loses these gains. Therefore, it represents losses generated by the massive use of Open innovation. We are considering them as charges for the firm and an additional cost as well.

Furthermore, based on several works of duopolistic models, the expressions of a quadratic cost equation, loss of a firm *i* can be expressed as:

$$L(\sigma_i) = \gamma\sigma_i^2 / 2 \quad i = 1,2 \,, \qquad (3)$$

Where γ is a spillover parameter.

Also considering the IP profit that can be modelled by an exponential function of the integration rate of OI σ as follows:

$$\eta(\sigma_i, q_i) = q_i \exp(-\sigma_i) \quad i = 1,2 \qquad (4)$$

The quantity of goods or services produced by a firm can be influenced by its intellectual property rights (IPRs). However, the nature of this influence may vary based on the type of IPR and the industry in which the firm operates. For example, patents grant exclusive rights to inventors or firms to produce and sell their inventions for a limited period, in addition, with patent protection, a firm can have a temporary monopoly over a new and innovative product or technology. Consequently, the firm may choose to produce a higher quantity of the patented product to capitalize on its exclusive rights and maximize profits during the patent's validity.

The proposed model for IP profit can be plotted as shown by figure 1. Since a firm adopt more and more the OI, the IP profit decrease because in this case the firm buy patent.

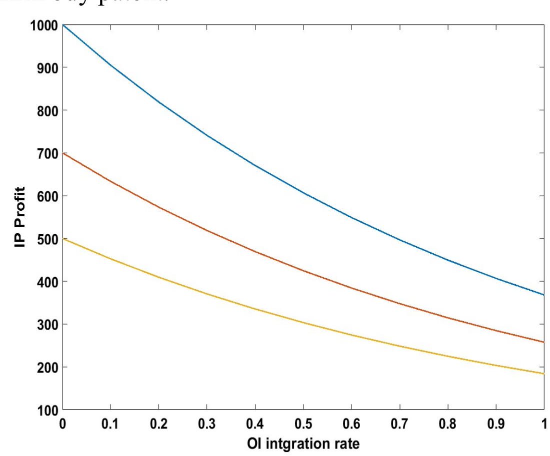

Fig.1: plot of IP profit for tree different quantities

If a firm decides to internalize, completely, the innovation, the profit of IP will be qi, however, if a firm *i* decides to outsource the innovation, it will be $0.36q_i$. This can be explained by the policy of the firm towards the research and development, which means that the closed firms develop their patent and sell them, whereas the opened firm buy the patent.

A. Profit of each firm

According to the propositions given above, we can write the profit equations for the two firms

$$\begin{cases}\pi_1(q_1,q_2,\sigma_1,\sigma_2)=[p_1(q_1,q_2)-C_1(\sigma_1,\sigma_2)]q_1+\eta(\sigma_1,q_1)-L(\sigma_1)\\ \pi_2(q_1,q_2,\sigma_1,\sigma_2)=[p_1(q_1,q_2)-C_1(\sigma_1,\sigma_2)]q_1+\eta(\sigma_2,q_2)-L(\sigma_2)\end{cases} \quad (5)$$

Substituting equations (1), (2), (3) and (4) into equation (5), we get the expression of the profit function for each firm

$$\begin{cases}\pi_1(q_1,q_2,\sigma_1,\sigma_2)=-bq_1^2+(a-bq_2-A-c(1-\sigma_1)+\exp(-\sigma_1))q_1-\gamma\frac{1}{2}\sigma_1^2\\ \pi_2(q_1,q_2,\sigma_1,\sigma_2)=-bq_2^2+(a-bq_1-A-c(1-\sigma_2)+\exp(-\sigma_2))q_2-\gamma\frac{1}{2}\sigma_2^2\end{cases} \quad (6)$$

Now, we can get the marginal profits of these two firms

$$\begin{cases}\frac{\partial\pi_1}{\partial q_1}=-2bq_1+(a-bq_2-A-c(1-\sigma_1)+\exp(-\sigma_1))\\ \frac{\partial\pi_2}{\partial q_2}=-2bq_2+(a-bq_1-A-c(1-\sigma_2)+\exp(-\sigma_2))\end{cases} \quad (7)$$

The second-order conditions are met because.

$$\frac{\partial^2\pi_1}{\partial^2 q_1}=\frac{\partial^2\pi_2}{\partial^2 q_2}=-2<0$$

Letting $\partial\pi_i/\partial q_i=0$ (i=1,2), the reaction function of the firm 1 and firm is obtained as follow:

$$\begin{cases}R1(q_1,\sigma_1)=q_2^*=\frac{(a-bq_1-A-c(1-\sigma_1)+\exp(-\sigma_1))}{2b}\\ R2(q_2,\sigma_1)=q_1^*=\frac{(a-bq_2-A-c(1-\sigma_2)+\exp(-\sigma_2))}{2b}\end{cases} \quad (8)$$

Let $U=\frac{(a-A-c)}{2b}$

we obtain the equilibrium solution for the firms I as following:

$$\begin{cases}q_1^*=\frac{U(1+2b)-c(\sigma_2-2\sigma_1)-(\exp(-\sigma_2)-2\exp(-\sigma_1))}{3b}\\ q_2^*=\frac{U(1+2b)-c(\sigma_1-2\sigma_2)-(\exp(-\sigma_1)-2\exp(-\sigma_2))}{3b}\end{cases} \quad (9)$$

Also, by subtracting q_1^* from q_2^*, we obtain:

$$\Delta Q=q_1^*-q_2^*=\frac{2}{3b}\left[\frac{2}{3}c(\sigma_1-\sigma_2)-(\exp(-\sigma_1)-\exp(-\sigma_2))\right] \quad (10)$$

According to ΔQ value, we can easily find that the equilibrium quantities depend on the innovation integration rates for each firm. Thus, assuming firm 1 chooses an OI approach (σ_1=1) and firm 2 chooses CI as an opposite approach (σ_2=0), $\Delta Q>0$. Firm 1 must always deliver quantities greater than those of firm 2.

According to literature Intellectual property (IP) holds a significant and distinctive significance in the realm of Open Innovation (OI) [14], particularly in the context of outbound OI. Outbound OI refers to the knowledge and technology transfer from one organization to another, exemplified by patent licensing. The relationship between IP protection and Open Innovation (OI) is often seen as paradoxical, as highlighted by Bogers [15]. On one hand, IP protection mechanisms (IPPMs) can enable OI by providing a secure environment for knowledge sharing and collaboration. On the other hand, IPPMs can also act as disablers of OI, creating barriers that hinder the free flow of knowledge and innovation among organizations. Thus, the interplay between IP protection and OI is complex, with IPPMs having the potential to either facilitate or impede the open exchange of ideas and technologies.

Now we define the player's relative profit is determined by subtracting the average of the absolute profits of other players from its own absolute profit. Let $\prod_1=\pi_1-\pi_2$ represent the relative profit of player 1, and $\prod_2=\pi_2-\pi_1$ denote the relative profit of player 2. Thus, the relative profits of the two players can be expressed as follows:

$$\begin{cases}\prod_1=(U-c\sigma_1)-b(q_1+q_2)-\exp(-\sigma_2))\Delta Q+(\exp(-\sigma_1)-\exp(-\sigma_2))q_1\\ \prod_2=(U-c\sigma_1)-b(q_1+q_2)-\exp(-\sigma_1))\Delta Q+(\exp(-\sigma_2)-\exp(-\sigma_1))q_2\end{cases}$$

The pursuit of relative profit maximization aligns with human nature. People tend to compare their wealth or achievements with those of others, and their satisfaction is often influenced by their relative standing rather than their absolute gains. In the competitive market, this behavior is mirrored in enterprises, which not only strive for absolute profits but also pay keen attention to how their profits compare to their competitors'. Enterprises closely monitor their competitors' performance to formulate effective strategies for the next period. Collecting market information requires significant investments in resources like human efforts, materials, and finances, which can deter some from engaging in such activities despite their importance. Thus, enterprises must strike a balance between gathering crucial market insights and the costs involved.

CONCLUSION

This study highlights the importance of choosing and pursuing an IP strategy to achieve better results in

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

terms of outbound OI and performance. We presented a static analysis of Cournot model by considering the integration rate of the Open innovation and the Intellectual property rights. Given the circumstances described earlier, it is reasonable to assume that the two competing enterprises in the market lack complete information about the market and their rivals. Their decision-making process is constrained by bounded rationality, leading to imperfect knowledge when formulating competitive strategies. To address this limitation, the gradient adjustment mechanism becomes essential as it aids in adjusting strategies incrementally, considering the available information and making more informed decisions despite the incomplete knowledge**.**

REFERENCES

[1] E. Aziz, H. Mustapha, and E. A. Jamila, "A bibliometric study of the recent advances in open innovation concept," *Procedia Comput Sci*, vol. 175, pp. 683–688, Jan. 2020, doi: 10.1016/J.PROCS.2020.07.100.

[2] H. Chesbrough, "The Logic of Open Innovation," *Calif Manage Rev*, vol. 45, no. 3, pp. 33–58, Apr. 2003, doi: 10.1177/000812560304500301.

[3] M. A. P. M. Da Silva, "Open innovation and IPRs: Mutually incompatible or complementary institutions?," *Journal of Innovation & Knowledge*, vol. 4, no. 4, pp. 248–252, Oct. 2019, doi: 10.1016/J.JIK.2018.03.010.

[4] A. Elmire, A. A. Bassou, M. Hlyal, and J. El Alami, "Game Theory Approach for Open Innovation Systems Analysis in Duopolistic Market," *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 5, pp. 557–565, 2023, doi: 10.14569/IJACSA.2023.0140559.

[5] Z. Yang, Y. Shi, and Y. Li, "Analysis of intellectual property cooperation behavior and its simulation under two types of scenarios using evolutionary game theory," *Comput Ind Eng*, vol. 125, pp. 739–750, Nov. 2018, doi: 10.1016/J.CIE.2018.02.040.

[6] L. O. Nwobodo and H. C. Inyiama, "Strategic Management of Intellectual Property: R&D Investment Appraisal Using Dynamic Bayesian Network," *International Journal of Computer Applications Technology and Research*, vol. 4, no. 9, pp. 640–647, 2015, Accessed: Jul. 17, 2023. [Online]. Available: www.ijcat.com640

[7] P. yan NIE, H. xing WEN, and C. WANG, "R & D competition and patent values," *Journal of Innovation & Knowledge*, vol. 8, no. 1, p. 100308, Jan. 2023, doi: 10.1016/J.JIK.2023.100308.

[8] J. Chen, L. Liang, and D. qing Yao, "An analysis of intellectual property licensing strategy under duopoly competition: Component or product-based?," *Int J Prod Econ*, vol. 193, pp. 502–513, Nov. 2017, doi: 10.1016/J.IJPE.2017.08.016.

[9] C. K. Ikeda, S. H. Kamai, and M. T. Hayes, "Kuahuokalā: Reflections on Space and Transformative Education Conversations," *Ethnographic Edge*, vol. 3, pp. 29–37, Dec. 2019, doi: 10.15663/TEE.V3I1.45.

[10] M. A. El-Aroui, S. Dellagi, and F. Ben Abdelaziz, "The Dilemma of Intellectual Property Agreements and R&D in Developing Economies: A Game Theory Approach," *Journal of Quantitative Economics*, vol. 19, no. 3, p. 427, Sep. 2021, doi: 10.1007/S40953-021-00243-1.

[11] T. Chu, Y. Yu, and X. Wang, "Complex dynamical behaviors of a mixed duopoly game based on intellectual property rights protection," *Complexity*, vol. 2020, 2020, doi: 10.1155/2020/4601510.

[12] T. Chu and W. Zhou, "Complex dynamics of R&D competition with one-way spillover based on intellectual property protection," *Chaos Solitons Fractals*, vol. 163, p. 112491, Oct. 2022, doi: 10.1016/J.CHAOS.2022.112491.

[13] K. Žigić, J. Střelický, and M. Kúnin, "Copyright and firms' own IPR protection in a software market: Monopoly versus duopoly," *Econ Model*, vol. 123, p. 106282, Jun. 2023, doi: 10.1016/J.ECONMOD.2023.106282.

[14] M. Grimaldi, M. Greco, and L. Cricelli, "A framework of intellectual property protection strategies and open innovation," *J Bus Res*, vol. 123, pp. 156–164, Feb. 2021, doi: 10.1016/J.JBUSRES.2020.09.043.

[15] M. Bogers, "The open innovation paradox: Knowledge sharing and protection in R&D collaborations," *European Journal of Innovation Management*, vol. 14, no. 1, pp. 93–117, Jan. 2011, doi: 10.1108/14601061111104715/FULL/XML.