경영학석사 학위논문

Innovation in the Korean Pharmaceutical Industry:
Divergent Impacts of Technological Licensing-In

2023년 8월

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이 논문을 경영학 석사 학위논문으로 제출함
2023년 5월

서울대학교 대학원
경영학과 경영학 전공
홍 신 기

홍신기의 경영학 석사 학위논문을 인준함
2023년 7월

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ABSTRACT

This study examines the impact of external knowledge sourcing through technological licensing-in on the innovation performance of Korean pharmaceutical firms, with particular attention paid to the types of innovation, whether incremental or radical. Moreover, I focus on how internal R&D investments and University-Industry Collaboration (UIC) affect these relationships. Using a panel dataset spanning 13 years (2009-2021) consisting of 58 Korean pharmaceutical firms listed on the Korean stock market, I analyze the effects of technological licensing-in activities on innovation performance. The results of this study contribute to understanding the interplay between external knowledge sourcing and various types of innovation in the pharmaceutical industry, offering insights for firms and policymakers seeking to boost pharmaceutical innovation performance.

Keyword : Korean pharmaceutical industry, technological licensing-in, external knowledge sourcing, organizational learning, innovation.
Student Number : 2020-27784

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I. INTRODUCTION

External knowledge sourcing is becoming essential to facilitate the search for innovation (Helfat, 1994; Ahuja & Lampert, 2001). In the pharmaceutical industry, external knowledge sourcing became common since the development of new drugs became expensive, and the complexity and intensity of research activities have increased, deterring firms from bearing all of research themselves (Simonet, 2002). By acquiring external technologies, a firm can improve its innovation performance by broadening its knowledge base, enhancing its technological capabilities, and tapping into advanced technologies (Wang et al., 2012). It can also combine the knowledge and technologies invented in internal R&D activities with those developed by licensors (Kim, 1997; Fleming & Sorenson, 2004; Tsai & Wang, 2008).

Licensing-in agreement refers to a kind of knowledge-seeking activities to access knowledge and technologies developed outside a focal firm's organizational boundaries (Anand & Khanna, 2000; Arora et al., 2013). Previous literature showed that firms engage in licensing-in agreements to overcome innovation challenges and keep up with the pace of developing new products (Wang et al., 2012). Through licensing-in firms increase their

capabilities to improve innovation performance. In particularly, Korean pharmaceutical firms often use technological licensing-in agreements to catch up global leaders and to develop their own drugs (Lee et al., 2016). For example, as of 2023, *Hanmi Pharm* is engaged in the development of a novel treatment for dry age-related macular degeneration through a licensing-in agreement that allows for joint development and exclusive sales rights for *Allegro*'s '*Luminate*' in Korea and China. Additionally, *Hanmi Pharm* has introduced an oral immune antagonist, '*CCR4*', from *RAPT Therapeutics*, which has successfully passed Phase 2 clinical trials in Korea.

However, previous studies did not explain the mechanism that external knowledge sourcing activities differently affect a firm's capabilities of developing new products, lead a firm to focus on a specific type of organizational learning, and influence on a firm's innovation on a different direction. To fill this gap, I focus on technological licensing-in activities of Korean pharmaceutical firms and their effects on the types of a firm's innovation, whether radical or incremental. In the Korean pharmaceutical industry, most technological licensing-in agreements involve transferring existing technologies that fit a firm's knowledge (Min, 2021). A firm's

absorptive capacity is also accumulated in finding technologies and substances that can be adjusted with existing technologies rather than finding completely new ones. This situation causes path dependence in organizations, highly valuing knowledge close to existing technological areas while devaluing more distant knowledge. Such in-depth learning has a positive effect on incremental innovation but a detrimental impact on radical innovation that requires various knowledge sourcing (Kim et al., 2012).

I will try to identify what factors affect the relationship between technological licensing-in and a firm's incremental and radical innovation. First, previous literature showed that internal R&D investments influence on a firm's innovation performance. I propose that internal R&D investments would help firms to enforce the positive relationship between technological licensing-in and firms' incremental innovation. In terms of radical innovation, internal R&D investments will mitigate the negative relationship between technological licensing-in and firms' radical innovation.

Moreover, to mitigate the negative effect of technological licensing-in on radical innovation performance, firms can take advantage of University-Industry Collaboration (UIC). They will have the opportunity to gain knowledge different from the existing

knowledge base (Bellucci & Pennacchio, 2016; Perkmann & Walsh, 2007). In the pharmaceutical industry, UIC provides firms the opportunity to search new knowledge domains that they never enter and then find new sources of innovation, accumulating a new type of absorptive capacity. Through UIC, pharmaceutical firms will obtain more fundamental knowledge, learn about utterly new knowledge, and increase the diversity of external knowledge sources.

In order to examine the proposed hypotheses, a panel dataset was assembled, spanning 13 years (2009 to 2021), and consisting of 58 Korean pharmaceutical firms listed on the Korean stock market. Since the 1990s, these firms have been successfully developing creative imitation products through the process of licensing-in global leader's original technologies and carrying out substantive internal R&D activities (Min, 2021). Toward the end of the 1990s, a few firms even managed to achieve both incremental and radical innovation using their own capabilities and have successfully licensed-out their developments internationally. Recently, Korean pharmaceutical firms strategically employ open innovation strategies, including licensing-in, co-development, and university-industry collaboration, in their pursuit of developing new drugs (Lee et al. 2016). Therefore, the Korean pharmaceutical industry presents an appropriate context to

study the effects of licensing-in activities on innovation performance, and to test my hypotheses related to other open innovation activities.

The remaining sections of this paper are organized as follows: The first section discusses the theoretical backgrounds of this study, focusing on external knowledge sourcing and innovation in the Korean pharmaceutical industry. The second section presents a series of hypotheses for empirical analysis. Following that, the third section provides a detailed description of the databases used for our empirical analysis and outlines the specific research methods deployed to test the hypotheses. Lastly, I show the results of our empirical tests and conclude with a discussion on key findings and insights.

II. THEORETICAL BACKGROUND

2.1. External Knowledge Sourcing in Korean Pharmaceutical Industry

In the past, Korean pharmaceutical firms frequently use various ways to increase R&D capabilities through reverse engineering, licensing-in, OEM, and ODM (Min et al., 2017). Among them, licensing-in agreements became common since the development of new drugs became expensive, and the complexity and intensity of research activities have increased (Simonet, 2002). Licensing-in refers to a kind of knowledge-seeking activities to access knowledge and technologies developed outside a focal firm's organizational boundaries (Anand & Khanna, 2000; Arora et al., 2013). Licensing-in enables firms to face new opportunities to learn new knowledge and technology and integrate acquired technology with their internal R&D activity (Wang et al., 2012).

Given their relatively small size compared to global pharmaceutical firms, Korean pharmaceutical firms face significant challenges in independently undertaking the entire process of new drug development. Thus, Korean pharmaceutical firms are focusing on open innovation as a strategy to develop new drugs. According to

Lee et al. (2016), licensing-in (40.7%) and research collaboration (28.5%) constitute the largest segments of their open innovation efforts. Moreover, the landscape of open innovation in the pharmaceutical industry has evolved significantly. Historically, collaboration with other organizations was largely bilateral, involving just two entities. However, recent trends have seen the model evolve into a network structure, involving the participation of three or more entities such as government research institutions, pharmaceutical firms, universities, and non-profit organizations.

Emerging trends in open innovation have led to the formation of public-private consortiums in the pre-competition stage, providing a platform to share new ideas and technologies with a wider range of actors beyond the boundaries of a single organization. This approach facilitates the active utilization of external R&D resources, as well as technologies and experiences of external partners. Moreover, open innovation is no longer restricted to collaboration via organization alone but has further evolved to encompass novel methods such as open access, data sharing, and crowdsourcing. These developments signify a broadening of the scope and inclusivity of knowledge sharing in the pharmaceutical industry (Kim, 2018).

The general characteristics of open innovation in Korean

innovative pharmaceutical firms can be observed, particularly the in-bound open innovation related to firm performance and technological capabilities. Large and medium-sized pharmaceutical firms often import and utilize external knowledge, predominantly through licensing-in strategies. The key business strategy for most large and medium-sized pharmaceutical firms in Korea involves introducing foreign technologies via licensing-in during the clinical trial and marketing stages for domestic market sales.

Among licensing-in agreements, Korean pharmaceutical firms often use technological licensing-in to develop their new drugs. Technology licensing-in refers to a contractual agreement wherein a firm acquires the rights to materials, technology, or patents from an external organization, as opposed to merely purchasing a product's copyright for sales, co-promotion, or marketing (Johnson, 2002). Primarily, in Korean Pharmaceutical industry, technological licensing-in serves as a method of external knowledge sourcing for clinical trials and marketing phases (Lee et al., 2016).

For instance, *Ildong Pharmaceutical* introduced a new Hepatitis B treatment drug developed by *LG Life Sciences*. Following the completion of Phase 2 clinical trials, *Ildong* exclusively contracted for Phase 3 trials and sales to develop *'Besivo'* Tab.

Similarly, *Yuhan Corporation* co-developed '*Recomid* SR' Tab, a novel sustained-release drug for treating infections, with *GC Biopharma*. Additionally, *Korea United Pharm* concluded the development of '*Levotics CR' Tab*, a sustained-release tablet, by adopting the technology of *Kwangdong Pharmaceutical* and *JW Pharmaceutical*.

As illustrated, technological licensing-in is a frequently employed strategy by Korean pharmaceutical firms to compete with global industry leaders, and it continues to play a critical role in new drug development. Furthermore, it influences the mechanism of organizational learning, as it transcends simple imitation and merges with the development capabilities inherent to each firm. Therefore, this study will focus on technological licensing-in and try to analyze how this activity influences a firm's innovation performance.

2.2. Innovation in the pharmaceutical industry

In the pharmaceutical industry, innovation can be distinguished into incremental and radical innovation (Cardinal, 2001). Incremental innovation requires an internal source of information related to a firm's specific production line, while radical innovation requires a source of knowledge outside the firm. In addition, while

incremental innovation is related to an in-depth analysis of existing and related technologies, the search for a new domain, such as basic knowledge, is essential for radical innovation (Norman & Verganti, 2014). Incremental innovation involves a slight change in a product, such as lowering the cost or improving product quality and emphasizes short-term performance. In contrast, radical innovation is associated with developing new products with significant changes over existing products and can expect long-term performance improvements.

In the pharmaceutical industry, Food and Drug Administration (FDA) shows the two dimensions of product innovation (Sorescu et al., 2003). According to Sorescu et al. (2003), *standard review* drugs in Therapeutical Potential and *update* drugs in Chemical Composition reflect incremental innovation in pharmaceutical industry, while priority review drugs and new molecular entities (NMEs) are classified in radical innovation. Incremental innovation involves developing incrementally modified drugs that enhance the effectiveness of existing drugs, or that apply other substances to produce different effects. On the contrary, radical innovation can be classified into developing drugs that are more effective than existing drugs, such as discovering new drug substances or developing new

chemical structures (Cardinal, 2001).

In conclusion, pharmaceutical firms search for external technologies that can be used in combination with existing knowledge and technologies for incremental innovation. To improve radical innovation, they invest in basic research or search for a new domain they have yet to enter. As a result, firms that focus on exploitative learning will accumulate absorptive capacity relevant to external knowledge that can be combined with their existing knowledge and be more effective in developing incrementally modified drugs. However, they will not be able to pursue radical innovation since the in-depth learning process constrains them from searching for utterly novel knowledge. Exploitation-oriented firms need to accumulate absorptive capacity in another direction to transfer utterly novel knowledge to their organization.

I will focus on how an effort to source external knowledge, especially in technological licensing-in experience, triggers organizations to pursue exploitative or exploratory learning, affecting incremental and radical innovation performance, respectively. Therefore, it is necessary to understand which kinds of absorptive capacity will be improved depending on external knowledge sourcing and to analyze how external knowledge sourcing will influence on

learning mechanism of a firm, causing different effects on a firm's innovation performance. Also, I will investigate how search for new domain knowledge, such as collaborating with universities can increase radical innovation performance.

III. THEORY AND HYPOTHESES

3.1. The Relationship between Technological Licensing-in Experience and Innovation

Firms in the Korean pharmaceutical industry frequently engage in technological licensing-in agreements to overcome innovation challenges and keep up with the pace of developing new drugs (Min, 2021). It enables firms to acquire global leaders' knowledge and technology for their internal drug development capability (Tian & Siebert, 2020). Since most firms cannot develop new drugs alone, they must search for suitable technologies to incorporate into their ongoing R&D tasks. Moreover, combining licensed technologies with their ongoing R&D tasks allows firms to save time and resources that would otherwise have to be committed to the trial-and-error process of developing technology (Chesbrough et al., 2006). Firms can utilize readymade technologies to improve the existing drug's quality.

Moreover, the process of analyzing and leveraging licensed technology can serve to enhance a firm's internal knowledge base. This process not only brings in new knowledge and technologies but also stimulates organizational learning system, thereby contributing

to the overall growth and dynamism of the organization's knowledge base (Arora et al., 2013). As the technological routines and competencies of firms became standardized and specialized, the efficiency of the development new drugs would increase. They find the relevant substances or technologies, integrate them with internal technology, and finally commercialize them to make new incrementally modified drugs. Therefore, licensing-in helps firms to improve their knowledge base and allows them to pursue exploitative learning for incremental innovation, improving firms' incremental innovation performance.

However, Technology acquisition through technological licensing-in involves the transfer of existing technologies (Moreira et al., 2020). Firms can predetermine the characteristics of target knowledge related to existing technology in their firm. Through technological licensing-in, firms can improve existing drugs' quality and develop incrementally modified drugs. However, because of limited time and cost, a firm highly devoted to technological licensing-in activities cannot pay attention to identifying novel knowledge different from the existing knowledge base (Kim et al., 2012). Focusing on technological licensing-in implies that a firm's absorptive capacity will be deeply related to existing technology for

incrementally modified drugs rather than original drugs.

Repeatedly sourcing knowledge similar to a firm's knowledge base causes a firm to pursue exploitation activities. A firm that emphasizes exploitation-oriented activities tends to constrain the search for innovations within its current technologies (Levinthal, 1997; Uotila et al., 2009). This tendency triggers the firm to accumulate absorptive capacity in the direction of exploitative learning, such as finding technologies that can be adjusted with existing technologies, causing path dependence in organizations, and resulting in lock-in to current technology (Kim et al., 2012). As a result, it is difficult for an exploitation-oriented firm to pursue exploratory learning.

Instead of recognizing and developing new substances and technology for radical innovation, they put most of their resources into improving their current drug pipelines. Even if an R&D organization in a firm tries to find novel substance or technology for radical innovation, these efforts will be minimal due to limited resources (Colombelli & Tunzelmann, 2011). Hence, absorptive capacity relevant to incremental innovation will be enforced. Firms are likely to identify new technology relevant to existing drugs, mainly for incrementally modified drugs, and assimilate the

technology acquired from other firms with their knowledge base.

Moreover, since the purpose of technological licensing-in is to integrate the new technology with their internal capabilities to develop incrementally modified drugs, their learning process will emphasize combining new technology with their existing technology. Such in-depth learning has a positive effect only on incremental innovation, so it can have a negative effect on radical innovations that require various knowledge sourcing (Xu, 2015). In addition, the organization does not recognize itself as an organization that develops new original drugs even if they try to find new substances or technologies to improve the quality of existing drugs (Min, 2021). The intense competition is also likely for firms to immerse in existing products so that they will focus on the current drug pipeline (Moreira et al., 2020). This situation causes path dependence in organizations, myopia of learning, and reluctance to change the status quo, resulting in lock-in to current technology (Sorescu et al., 2003).

As a result, through external knowledge sourcing activities, firms can improve their absorptive capacity. As the technological routines and competencies of firms became standardized and specialized, the efficiency of the development new drugs would increase. They find the relevant substances or technologies,

integrate them with internal technology, and finally commercialize them to make new incrementally modified drugs. Therefore, technological licensing-in helps firms to improve their absorptive capacity and allows them to pursue exploitative learning for incremental innovation, improving firms' incremental innovation performance. In contrast, knowledge sourcing through technological licensing-in improves absorptive capacity only relevant to the existing knowledge base. It moves away from the utterly new knowledge and technology that never existed in the organization. In addition, repeated technological licensing-in experience will force them to pursue exploitative learning for incremental innovation, which is stronger deterrents of radical innovation.

Hypothesis 1.a. Technological licensing-in experience positively affects a firm's incremental innovation.

Hypothesis 1.b. Technological licensing-in experience negatively affects a firm's radical innovation.

3.2. The Role of Accumulated Internal R&D Investment

Internal R&D investments refer to the resources that a firm allocates to its research and development activities. These investments can influence both incremental and radical innovation

within the firm (Min et al., 2017). Previous studies showed that the relationship between internal R&D investments and a firm's innovation is generally positive (Becheik et al., 2006). For example, they proposed that internal R&D investments would bring out such outcomes as enhanced absorptive capacity (Cohen & Levinthal, 1990) and increased employee skills and expertise (Polder et al., 2010).

In terms of incremental innovation, Internal R&D investments help firms develop and strengthen their technological capabilities, enabling them to better identify and integrate external technologies and knowledge through technological licensing-in. Higher internal R&D investments equip firms with the necessary knowledge to understand and utilize external technologies effectively (Kim, 1997). Continuous investment in internal R&D helps firms build and maintain a robust technical infrastructure and foster a team of skilled researchers. This not only strengthens the firms' capacity for continuous innovation but also enhances their ability to understand and assimilate externally sourced technologies (Jin et al., 2022). It is particularly important in the pharmaceutical industry, where a deep understanding of existing technologies and knowledge is essential for successful innovation.

Higher internal R&D investments can lead to more resources being allocated for high-risk, high-reward projects, which can potentially result in radical innovations (Robbins & O'Gorman, 2015). Internal R&D investment propels the discovery of new pharmaceutical compounds and the development of innovative therapeutic solutions. This can lead to the development of new drugs that meet unaddressed medical needs or that are more effective or have fewer side effects than existing treatments. Additionally, increased R&D investments can enhance the firm's overall knowledge base, expertise, and capabilities, which can contribute to the development of breakthrough innovations (Chamsuk et al., 2017). Moreover, increased internal R&D investment can lead to exploitative learning as well as exploratory learning by giving Korean pharmaceutical firms the opportunity to explore basic knowledge. The firms can acquire basic knowledge and more fundamental understanding, which in turn can increase radical innovation performance.

Overall, internal R&D investments have positive impact on a firm's incremental and radical innovation. While external knowledge sourcing is beneficial, excessive dependence on it can be risky, as it can lead to a loss of control over key technologies and increase

vulnerability to changes in external partners' strategies or business conditions. Investment in internal R&D can mitigate such risks by ensuring a steady supply of internally generated knowledge and technologies. Therefore, higher internal R&D investment can strengthen the positive relationship between technological licensing-in and incremental innovation, and thus can also mitigate the negative relationship between technological licensing-in and radical practices.

Hypothesis 2.a. Internal R&D investment will positively moderate the relationship between technological licensing-in and incremental innovation.

Hypothesis 2.b. Internal R&D investment will mitigate the negative relationship between technological licensing-in experience and a firm's radical innovation.

3.3. The Role of University-Industry Collaboration

Pharmaceutical firms aim to develop their own original drug for their long-term success. An intense exploitative learning process does not guarantee further success in such a situation. Although firms successfully integrate external knowledge with their knowledge base to enhance absorptive capacity, especially capabilities to develop incrementally modified drugs, creating new original drugs,

radical innovation is another mission. They should delve into the fundamental basic research phenomena and enhance relevant absorptive capacity for radical innovation, developing new original drugs.

Research-intensive industries often utilize collaboration with public research institutions such as universities to draw on novel knowledge and technology (Bellucci & Pennacchio, 2016; Perkmann & Walsh, 2007). Especially collaboration with the university, so-called University-Industry Collaboration, give firms a better understanding of the fundamental basic research phenomena (George et al., 2002). Many studies also provide empirical evidence to support the proposition that UIC provides the foundation for utterly novel inventions, even radical innovation, and has a long-term positive impact on innovation (Jong & Slavova, 2014; Un et al., 2010).

Moreover, Melnychuk et al. (2021) also shed light on the importance of UIC in improving R&D performance, measured by the number of new patents. Although this paper does not pay attention to specific kinds of innovation, it gives insight into the UIC's role in improving absorptive capacity and increasing innovation performance. In the pharmaceutical industry, UIC provides firms the opportunity to search new knowledge domains that they never enter and to find new

sources of innovation. Through UIC, pharmaceutical firms will increase the diversity of external knowledge sources, learn about utterly new knowledge, and obtain more fundamental knowledge.

In the Korean pharmaceutical industry, according to the Science and Technology Policy Institute, domestic pharmaceutical firms are actively engaging in joint ventures with universities and public research institutions to identify and develop drug candidate substances. The UIC in Korea fosters joint research from the inception stage, with academic and research institutions spearheading the discovery of initial drug candidate substances. Firms then play their role in optimizing these candidate substances and advancing their development through the preclinical and early clinical stages.

Examining past instances demonstrates the efficacy of this approach. Korea's first new original drug, '*Sunpla Injection*', was successfully developed by *SK Chemicals* through a collaborative research effort led by *Seoul National University Hospital*. This multi-institutional collaborative method continues to be employed in the present day. For example, *Hanmi Pharm* is currently advancing the development of innovative anti-cancer drugs in collaboration with *Ajou University's Industry-University Cooperation Foundation*.

Similarly, *Korea United Pharm* is developing new anti-cancer drug candidates in partnership with *UNS Bio of Seoul National University*. Furthermore, *Daewoong Pharmaceutical* is advancing the development of '*Fexuclue*' with the *Korea Research Institute of Bioscience and Biotechnology*, supported by scientific evidence published in relevant journals.

Hence, these cases highlight the integral role of UIC in pursuing innovation in Korea pharmaceutical industry. By sharing roles and responsibilities in each step of the drug development process, these partnerships effectively combine the strengths of each participating entity and drive the progression of novel therapeutics. UIC gives firms a chance to tap into novel knowledge they never face, so Korean pharmaceutical firms will have the opportunity to gain knowledge different from the knowledge base and then to accumulate new aspects of absorptive capacity (Ma et al., 2022). Access to novel knowledge helps firms overcome tendencies to constrain the search for innovations within their current technologies, improving their radical innovation (Helfat, 1994).

Hypothesis 3. The experience of UIC will mitigate the negative relationship between Technological licensing-in experience and a firm's radical innovation.

IV. EMPIRICAL SETTING AND METHODS

4.1. Research Setting

The empirical analyses in this study were conducted within the Korean pharmaceutical industry, which provides an ideal context to test my hypotheses. In the 1960s and 1970s, Korean pharmaceutical firms, driven by government initiatives for domestic drug production, made their entry into the industry through imitation (Min, 2021). To fulfill the objectives set by the Korean government, these firms reverse-engineered, in-licensed, or manufactured original products that had been invented by industry leaders in advanced countries like the US, Japan, and the EU (Kim, 1997). The resultant 'imitation' products were then marketed and sold within the Korean domestic market.

Beginning in the 1990s, while maintaining their imitation strategy, some Korean pharmaceutical firms began developing new original drugs and incrementally modified drugs based on their own capabilities. They launched these into the domestic market, and by the late 1990s, these firms started to enter foreign markets through licensing out technologies and products. Beginning with SK Chemicals, which developed *'Heptaplatin'* in 1990, a variety of firms

have been investing in the development of new drugs. As of 2022, a total of 36 original drugs have been developed. In 2008, the Ministry of Food and Drug Safety introduced the Incrementally Modified Drug (IMD) system. This move aimed to shift the pharmaceutical industry towards research and development, with the goal of improving public health and quality of life. Consequently, numerous Korean pharmaceutical firms have invested in the development of IMDs, which are now designated and approved under the new system. As of 2021, a total of 125 IMDs have been approved.

To test the hypotheses, I constructed a panel data set of 58 Korean pharmaceutical firms over 13 years (2009-2021), all of which were listed on the Korea Stock Exchange as of December 31, 2022. I gathered licensing information of Korean pharmaceutical firms using several resources, including, DART (a web-based database of Korean firms' business and financial information managed by Financial Supervisory Service of the Korean government), Korea Pharmaceutical Industry R&D White Papers published by Korea Drug Research Association, firms' websites, and press releases by Ministry of Food and Drug Safety. I collected financial and business information and data on R&D activities of the sample firms through DART, KIND (a database of Korean firms' disclosure information

managed by KRX (Korea Exchange)), TS-2000 (a web-based database of Korean firms' business information managed by Korea Listed Firms Association), and Pharmaceutical Industry Reports published by the Korea Health Industry Development Institute.

On the Korea Stock Exchange, there were a total of 164 firms listed as belonging to the pharmaceutical manufacturing industry. Using annual reports disclosed in DART, I categorized these 164 firms into six types: general pharmaceutical firms, animal pharmaceutical specialists, raw material specialists, medical device specialists, biopharmaceutical specialists, and therapy specialists. To select the most relevant sample firms for this study, I decided to focus exclusively on general pharmaceutical firms. However, due to constraints related to data availability, I could only include 58 of these firms for testing the hypotheses.

4.2. Variables

Dependent Variables. The number of new Incrementally Modified Drugs and new Original Drugs in each year. I will focus on incremental and radical innovation related to a firm's drug development. Cardinal (2001) defined incremental and radical innovation in the pharmaceutical industry using data from the FDC

Reports, classifying innovation outcomes into drug enhancements (incremental innovation) or new drugs (radical innovation). According to the FDA, incremental innovation in the pharmaceutical industry is reflected by *standard review drugs* (in terms of therapeutic potential) and *updated drugs* (in terms of chemical composition). On the other hand, radical innovation is represented by *priority review drugs* and *new molecular entities* (NMEs) (Sorescu et al., 2003).

In research examining innovation performance in the Korean pharmaceutical industry, Min et al. (2017) categorized innovation performance in a way that aligns with previous studies. In their work, they considered incremental innovation performance as being represented by Incrementally Modified Drugs (IMD), and they measured radical innovation performance by the development of new original drugs. Following their categorization, in this study, I will also measure incremental innovation as the number of new incrementally modified drugs produced each year, and I will assess radical innovation using the number of new original drugs each year as an indicator.

Independent Variable. The total number of publicly disclosed technological licensing-in contracts signed by the focal firm within 3-year and 9-year windows before the observation year for

incremental and radical innovation respectively. On average, Korean pharmaceutical firms spend about 38 billion won and take 9.1 years to develop a new original drug. However, it only costs about 2.7 billion won and takes 3.1 years to develop an incrementally modified drug (Min et al., 2017). Therefore, in this study, I set the evaluation period for moderators (the level of accumulated internal R&D investment and University-Industry Collaboration) and independent variable (licensing in experience) to 3 years when incremental innovation is the dependent variable. When radical innovation is the dependent variable, I set the evaluation period to 9 years.

In this research, I have divided licensing in activities into five categories: *Product Licensing, Technology Licensing, Intellectual Property Licensing, Co-Development Agreements, and Research Collaborations*. Out of these categories, I assumed that '*Technology Licensing*' and '*Intellectual Property Licensing*' can trigger to organizational learning in the firms. Thus, I have measured these two categories as '*Technological Licensing-in*' in this study. Following Moreira et al. (2020) 's measurement, I will calculate the total number of licensing-in deals that a firm i had engaged in year t-3 for incremental innovation and in year t-9 for radical innovation. Technological licensing-in is a count variable that takes value 0 if a

focal firm did no licensing-in in a given year and the corresponding number of deals otherwise.

Moderating Variables. Accumulated internal R&D investment and Joint co-authored publication with universities. The level of a firm's accumulated internal R&D investment was measured by calculating the natural logarithm of total R&D expenditure in the 3-year preceding the year of observation for incremental innovation and in the 9-year for radical innovation. For the measurement of UIC frequency, I followed Melnychuk et al. (2021)'s approach. They measured UIC frequency in preclinical research as the number of joint co-authored publications of a focal firm with universities. I will measure the total number of joint co-authored publications in the 9-year preceding the year of observation for radical innovation.

Control Variables. The lagged number of incrementally modified drugs and original drugs, the number of research collaboration with other firms, firm size, a firm's prior performance, firm age, and year dummy. I controlled for several firm-level factors that could influence on a firm's incremental innovation and radical innovation. In light of a firm's innovation capabilities, a control variable was included to account for the firm's drug development capability. These were measured by counting the total number of

new original drugs and incrementally modified drugs before the observation year. This accounts for the firm's historical experience and capability in executing and managing drug development projects and is expected to provide a more accurate analysis. A firm's research collaboration experience as another type of external knowledge sourcing might significantly confound the effects of licensing in activities on the dependent variable. I calculated the number of research collaboration by counting the total number of publicly disclosed research collaboration with other firms and strategic alliances contracts signed by a focal firm within the five-year window before the observation year. I also controlled for firm size by accounting for the total number of employees in a focal firm before the observation year. I controlled for a firm's prior performance, measured by return on assets: the ratio of total income divided by total assets before the observation year. Firm age was measured by subtracting the year of establishment from the observation year. Lastly, I accounted for year-specific unobserved heterogeneity by including year dummies in the regression models.

4.3. Model

In this study, the dependent variables are the number of new

incrementally modified drugs and the number of new original drugs, both of which are count variables. To accommodate the overdispersion present in the data, a negative binomial (NB) model will be employed for the analysis of the panel count data, as suggested by Wooldridge (2013).

When analyzing panel data at the firm level, the choice between fixed effects or random effects models is contingent on the significance of firm heterogeneity between panels. Breusch and Pagan (1980) proposed an LM test statistic that can identify the presence or absence of a random effect using the residuals of the pooled model. Moreover, the Hausman (1978) model-setting test method can be applied to decide which of the two models is more suitable. Park (2012) suggested that by comparing the estimates of the pooled model, fixed effects model, and random effects model, a more suitable model could be chosen between the fixed effects and random effects models. If the coefficient estimate from the pooled model is significantly different from the estimates of the within-group model or the random effects model, this could indicate the existence of a fixed or random effect within the analysis data.

4.3.1. Incremental Innovation Model

The analysis of the fixed-effect model test produced a F-test statistic value of 2.2492. At a 5% significance level, the null hypothesis that all δ are equal to 0 is rejected, implying a statistically significant fixed effect in the panel data.

The LM test results reject the null hypothesis that there's no random effect at a 5% significance level, indicating a statistically significant random effect in the panel data. Based on the Hausman test results, the chi-square test statistic is 45.986, which rejects the null hypothesis that the fixed-effect model and random-effect model are identical at a 1% significance level. This suggests that the fixed effects model could be more appropriate than the random effect model for the panel data. Therefore, for the incremental innovation model, the fixed effects model is statistically superior.

4.3.2. Radical Innovation Model

In the analysis of the fixed-effects model test, the value of the F-test statistic is 33.952. At a significance level of 1%, the null hypothesis that all δ are equal to 0 is rejected, suggesting the presence of a statistically significant fixed effect in the panel data.

According to the LM test results, the null hypothesis that there is

no random effect is rejected at a 1% significance level, suggesting a statistically significant random effect in the panel data. The results of the Hausman test show that the chi-square test statistic is 19.755 which rejects the null hypothesis that the fixed-effect model and the random-effect model are identical at a 5% significance level. Therefore, it can be concluded that the fixed-effects model is more suitable for the radical innovation model.

V. RESULTS

Table 1 presents the descriptive statistics and the correlation matrix for all variables. Potential collinearity among variables was assessed through the correlation matrix, which indicated no major concerns, except for a correlation between firm size and accumulated internal R&D investment. To address this potential multicollinearity, I calculated the variance inflation factors (VIFs) for the model covariates. The VIFs for firm size and accumulated internal R&D were 3.0225 and 2.9657 in incremental innovation model and 5.4318 and 6.0302 in radical innovation model, which were below 10, while the average of VIFs for two models were 1.6804 and 2.664. These results suggest that there is no significant bias due to multicollinearity in these models.

Insert Table 1 about here

Table 2 shows the results from the fixed effect panel negative binomial regression analyses for incremental innovation model (Models 1 to 3). Model 1, a base model, displays only the effects of

the control variables. In Models 2 and 3, I added technological licensing-in experience as independent variables and accumulated internal R&D investment as moderating variable. Model 3 tests an interaction term of technological licensing-in experience and accumulated internal R&D investment. All models exhibited high explanatory power ($p < 0.001$).

Insert Table 2 about here

Hypothesis 1a proposed a positive relationship between technological licensing-in experience and incremental innovation performance. In Models 2, the coefficient of technological licensing-in experience was positive and significant ($p < 0.01$), supporting Hypothesis 1.

Hypotheses 2a suggested accumulated internal R&D investment will positively moderate the relationship between technological licensing-in experience and incremental innovation performance. The coefficients of the interaction term of licensing-in experience and accumulated internal R&D investment in Model 3 were positive and significant ($p < 0.01$), supporting Hypothesis 2a.

Table 3 shows the results from the fixed effect panel negative binomial regression analyses for radical innovation model (Models 4 to 6). Model 4, a base model for radical innovation performance, shows only the effects of the control variables. In Models 5, I added technological licensing-in experience as independent variables and accumulated internal R&D investment and UIC as moderating variables. Model 6 tests an interaction term of technological licensing-in experience and accumulated internal R&D investment for radical innovation and an interaction term of technological licensing-in experience and UIC for radical innovation. All models exhibited high explanatory power ($p < .001$).

Insert Table 3 about here

Hypothesis 1b proposed a negative relationship between technological licensing-in experience and radical innovation performance. In Models 5, the coefficient of technological licensing-in experience was negative but not significant, not supporting Hypothesis 1b. Hypotheses 2b suggested accumulated internal R&D investment will mitigate the relationship between technological

licensing-in experience and radical innovation performance. The coefficients of the interaction term of licensing-in experience and accumulated internal R&D investment in was not statistically significant in Model 5.

Hypotheses 3 suggested UIC will mitigate the negative relationship between technological licensing-in experience and radical innovation performance. The coefficients of the interaction term of licensing-in experience and UIC in Model 5 was statistically significant ($p < 0.05$). However, this does not mean that Hypotheses 3 was supported. However, this is an interesting result because it implies that the mere presence of technology licensing in experience does not drive radical innovation performance, but the interplay between licensing in and UIC leads to radical innovation.

To elaborate, it appears that technology licensing in experience alone doesn't yield significant radical innovation performance. However, when these two factors interact—meaning when a Korean pharmaceutical firm invests in its own R&D while simultaneously diversifying its basic knowledge from university—the synergy can lead to innovation.

VI. DISCUSSION AND CONCLUSION

Korean pharmaceutical firms have historically pursued growth and innovation through imitation, a strategy that poses considerable challenges, particularly in knowledge-intensive industries characterized by fierce competition (Chung et al., 2015). Simply replicating existing drugs does not guarantee future success, pushing these firms to explore alternative paths. They have adopted strategies such as reverse-engineering, in-licensing, and manufacturing original products, following the lead of global industry leaders (Kim, 1997).

Recent trends in the industry highlight the potential for new drug development through licensing-in (Lee et al. 2016). Firms are now moving beyond merely licensing and selling products. They are licensing more complex knowledge forms, such as substances, technologies, and patents, to foster their drug development. This shift prompts an examination of the strategic actions needed for these latecomer firms, with their inherent resource disadvantage compared to global leaders, to transition from imitation to true innovation.

This research examines how the effects of external knowledge sourcing, specifically technological licensing-in agreements, vary

with incremental and radical innovation in the Korean pharmaceutical industry context. The study focuses on the types of external knowledge sourcing, organizational learning, and innovation. This study reveals how repeated licensing-in experience may have a positive effect on incremental innovation but a negative impact on radical innovation. Moreover, internal R&D investments can reinforce the positive effect of licensing-in experience on incremental innovation. To weaken the potential negative impact, firms can take advantage of University-Industry Collaboration (UIC), offering an opportunity for radical innovation.

I found that the positive effect of technological licensing-in experience on incremental innovation. Simultaneously, accumulated internal R&D investment can positively moderate the relationship between technological licensing-in experience and incremental innovation. These results suggest an effective strategy for Korean pharmaceutical firms seeking to develop new incrementally modified drugs: accelerating the development process and lowering costs by licensing technology and patents from other organizations. This process of continuous technological licensing-in can enhance the efficiency of new incrementally modified drug development, reinforcing firms' exploitative learning capabilities.

Furthermore, by consistently investing in their own R&D, Korean pharmaceutical firms can amplify the positive impact of technological licensing-in. For incremental innovation, firms can facilitate new drug development by boosting internal R&D investments and complementing them with external knowledge sourced through technological licensing-in. This not only fortifies the firms' ability for sustained innovation but also amplifies their capacity to comprehend and integrate technologies acquired externally (Jin et al., 2022). Such competencies are of paramount importance in the pharmaceutical industry, where an in-depth grasp of pre-existing technologies and knowledge is a crucial determinant of successful innovation.

However, the impact of technological licensing-in on radical innovation diverges from its effect on incremental innovation. Although not statistically significant, licensing-in might have a negative effect on radical innovation performance. This indicates that Korean pharmaceutical firms need a distinct development mechanism for new original drugs, separate from the incremental modification of existing drugs. As mentioned in Kim (2018), in accordance with the swift pace of technological advancement, firms might need to reconsider their traditional open innovation practices. Instead, they should shift towards more progressive forms of open innovation,

such as open access, data sharing, and crowdsourcing. This suggests that firms need to diversify both the methods and partners of their knowledge sourcing strategies.

Interestingly, I found that the interaction between technological licensing in experience and University-Industry Collaboration (UIC) positively influence radical innovation. To drive new original drug development, firms need to access basic knowledge alongside sourcing knowledge from global leaders or other Korean pharmaceutical firms through technological licensing-in. This process involves investment in the process of drug development with high-risk, which could lead to significant rewards if successful. This strategy underscores the need for a nuanced approach, combining diverse knowledge sourcing with robust internal R&D, to propel both incremental and radical innovation.

These findings offer critical insights for latecomers in the industry, suggesting they cannot rely solely on technological licensing-in or imitation strategies to developing new original drugs. Instead, they can stimulate innovation and potentially improve performance by diversifying the knowledge they acquire. In summary, this research highlights the importance of a balanced and integrated approach, incorporating both technological licensing-in and UIC to

drive innovation. These findings may have practical implications for business strategy formulation and policy-making in innovation management.

However, this study has several limitations. First, the generalization of empirical analysis results is limited because I used Korean pharmaceutical industry as an empirical context for research. It would be empirically and theoretically meaningful to expand the context of this research to other emerging countries, including China, India, and Brazil.

Second, in measuring innovation performance, this study, following previous studies, has used incrementally modified drugs (IMD) as a proxy of incremental innovation performance, and original drugs as a proxy of radical innovation performance. However, it would be precipitous to assert that this is the most precise measurement approach. The reason for this uncertainty lies in the ongoing debate surrounding how best to classify incremental and radical innovation performance, and the recognition that results may vary depending on the measurement employed.

Third, this research analyses the impact of licensing-in on innovation performance at the firm level. Nonetheless, when scrutinizing its impact on innovation performance, a team-level

analysis might yield more precise insights than a firm level analysis. The decision to use company-level data was determined by the data accessibility, but future studies should consider examining the issue at a team level, as internal organizational structure responsible for external knowledge sourcing vary across firms, and teams within a firm might adopt different approaches to external knowledge sourcing.

Finally, this study did not identify any factors that directly influence radical innovation. This implies that improving radical innovation performance might require a multifactorial analysis or an investigation of different innovative mechanisms. It's possible that radical innovation necessitates more intricate technological capabilities, and the effects of various knowledge sourcing methods may intersect. Consequently, future studies could aim to unravel the intricate interaction of various factors by analyzing multiple types of external knowledge sourcing methods simultaneously.

Table 1: Descriptive Statistics and Correlations

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) Incremental Innovation Performance	1.00												
(2) Radical Innovation Performance	0.31	1.00											
(3) Technological Licensing-in (3)	0.14	0.06	1.00										
(4) Technological Licensing-in (9)	0.13	0.08	0.70	1.00									
(5) Accumulated Internal R&D investment (3)	0.25	0.10	0.22	0.38	1.00								
(6) Accumulated Internal R&D investment (9)	0.26	0.11	0.21	0.37	0.97	1.00							
(7) University-Industry Collaboration	0.20	0.34	0.12	0.23	0.38	0.39	1.00						
(8) Project Capability for Incremental Innovation	0.26	0.05	0.07	0.12	0.45	0.48	0.21	1.00					
(9) Project Capability for Radical Innovation	0.19	0.16	0.11	0.23	0.47	0.49	0.39	0.34	1.00				
(10) Collaboration Experience	0.05	0.02	0.08	0.11	0.45	0.47	0.22	0.31	0.46	1.00			
(11) Firm Size	0.29	0.11	0.26	0.41	0.82	0.84	0.31	0.49	0.48	0.40	1.00		
(12) Prior Performance	0.05	0.00	0.00	0.05	0.20	0.18	0.04	0.06	0.03	0.05	0.15	1.00	
(13) Firm Age	-0.01	0.05	0.14	0.19	0.10	0.11	0.13	-0.14	0.24	0.14	0.01	-0.05	1.00
Mean	0.13	0.01	0.53	1.42	9.68	10.71	0.88	0.64	0.23	0.41	620.53	0.02	44.96
Std. dev.	0.51	0.10	0.98	1.77	1.50	1.42	1.47	1.50	0.57	1.05	482.49	0.07	22.65

Table 2: Negative Binomial Regression (Fixed Effect Model)

– Incremental Innovation Model –

Variables	Model 1	Model 2	Model 3
Project capability	0.032 (0.022)	0.031 (0.022)	0.033 (0.022)
Collaboration Experience	-0.040 (0.024)	-0.041 (0.024)	-0.042 (0.024)
Firm Size	0.001 *** (0.000)	0.001 *** (0.000)	0.001 *** (0.000)
Prior Performance	0.009 (0.314)	0.057 (0.315)	-0.028 (0.314)
Firm Age	-0.007 * (0.003)	-0.008 ** (0.003)	-0.008 ** (0.003)
Technological Licensing-in (3)		0.064 ** (0.023)	-0.426 * (0.172)
Accumulated Internal R&D investment (3)		0.001 (0.039)	-0.017 (0.039)
Technological Licensing-in (3) X Accumulated Internal R&D investment (3)			0.047 ** (0.017)
Unit fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Observations	717	717	717
R^2 / R^2 adjusted	0.133 / 0.033	0.143 / 0.041	0.154 / 0.052

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001

Table 3: Negative Binomial Regression (Fixed Effect Model)

- Radical Innovation Model -

Variables	Model 4	Model 5	Model 6
Project capability	0.066 *** (0.015)	0.046 ** (0.015)	0.047 ** (0.015)
Collaboration Experience	-0.006 (0.005)	-0.006 (0.005)	-0.005 (0.005)
Firm Size	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Prior Performance	-0.040 (0.065)	-0.043 (0.063)	-0.038 (0.063)
Firm Age	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Technological Licensing-in (9)		-0.002 (0.003)	-0.012 (0.033)
Accumulated Internal R&D investment (9)		0.001 (0.012)	0.002 (0.012)
UIC (9)		0.027 *** (0.004)	0.018 ** (0.006)
Technological Licensing-in (9) X Accumulated Internal R&D investment (9)			0.000 (0.003)
Technological Licensing in (9) X UIC (9)			0.004 * (0.002)
Unit fixed effects	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*
Observations	717	717	717
R^2 / R^2 adjusted	0.061 / -0.047	0.114 / 0.007	0.121 / 0.012

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001

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국문초록

한국 제약 산업에서의 혁신:
기술 라이센싱 인의 이질적 영향

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이 연구는 기술 라이센싱 인을 통한 외부 지식 탐색 활동이 한국 제약기업의 혁신 성과에 미치는 영향을 분석하며, 특히 점진적 또는 급진적인 혁신 유형에 주목하여 기술 라이센싱 인의 각각의 혁신 유형에 따라 어떤 여행을 주는 지 분석하고자 한다. 더욱이, 내부 R&D 투자와 대학-산업 협력(UIC)이 기술 라이센싱 인과 혁신 성과의 관계에 어떻게 영향을 미치는지를 분석하였다. 2009년부터 2021년까지 13년 동안의 패널 데이터를 활용해 한국 증권 시장에 상장된 58개의 한국 제약기업을 대상으로 기술 라이센싱 인 활동이 혁신 성과에 미치는 영향을 분석하였다. 이 연구 결과는 외부 지식 획득과 다양한 형태의 혁신 간 상호작용을 이해하는데 기여하며, 제약 혁신 성과를 향상시키고자 하는 기업과 정책 입안자에게 통찰력을 제공한다.

주요어: 한국 제약산업, 기술 라이센싱 인, 외부 지식 탐색 활동, 조직학습, 혁신
학 번: 2020-27784