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Master's Final Work
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South Korean Universities' patenting activity analysis: evolution and technological specialization trends

Beatriz da Silva Costeira

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Supervision:
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ABSTRACT

Universities have been playing an increasingly active role in worldwide patenting. South Korea, as a fast technologically developing country, is home to multiple well distinguished universities marking their position in patenting. This study investigates the patenting trends of South Korean universities, analising how these activities align with national industrial strengths and comparing them with leading universities internationally. Specifically, patent applications filed by South Korean universities at the Korean Intellectual Property Office (KIPO) from 2003 to 2021 were examined, focusing on the top 30 universities ranked in the Academic Ranking of World Universities (ARWU).

Analysis of over 27,000 patent applications filed reveals that South Korean universities experienced approximately a 45.5% increase in patent filings, and the International Patent Classification (IPC) subclass most often given to patent applications was the A61, which belongs to the "Medical or veterinary science; hygiene" class. Followed by Physics (G) and Electricity (H) as dominant fields of patent application classes, fields closely aligned with South Korean's national industrial priorities. South Korean universities demonstrate a technological advantage over the country's industry in almost all the fields requested for protection, and results show an increase in proximity between industry and academia technological trends, highlighting a foundation for collaborative innovation.

In a global context, South Korean universities show a rapid growth rate in patenting activities, mirroring that of Chinese institutions, although total patent volumes remain lower than those of United States institutions. A comparative analysis with universities from the United States, China, Japan, and Taiwan, using data from the United States Patent and Trademark Office (USPTO), highlights similarities and divergences in technological focus across these economies. The findings underscore South Korea's competitive positioning within the global innovation landscape, suggesting potential areas for policy support, industry partnerships, and international collaborations to further strengthen South Korean universities' role in technological advancement.

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1. INTRODUCTION

Innovation is considered one of the central processes driving countries' economic growth (Hu & Mathews, 2005). The success of these innovation processes depends heavily on the participation of many different actors and inputs, both from the private and public sectors. Studies on National Innovation Systems focus on these interactions and the roles that each player—from industry to government and academia—contributes to fostering innovation at a national level (Fagerberg, 2015). Among them, universities have gained a lot of attention. "As knowledge becomes an increasingly important part of innovation, the university as a knowledge-producing and disseminating institution plays a larger role in industrial innovation" (Etzkowitz et al., 2000).

Following the first academic revolution of the late 19th and early 20th century, where universities incorporated research as an academic mission alongside education, the university's role is undergoing what academics call the second academic revolution (Etzkowitz, 2001). In the post-war era, driven by shifts in public funding and rising competition, universities have expanded their linkages with industry as part of their "third mission"—engagement that contributes directly to innovation and economic growth (Mowery, 2009). In this light, universities have been reconceptualised as crucial actors in National and Regional Innovation Systems.

The concept of technological specialisation of a country has a significant role on its innovative performance, which corroborates with the concept of Smart Specialization to build comparative advantage on distinctive technological capabilities. Since universities are key sources of knowledge, they have a crucial role in understanding how regions can sustain their competitive advantage, through technological specialisation dynamics. Studies have shown a positive relationship between academic research and the innovative activities that occur within a geographical area, confirming the importance of proximity between firms and universities (Colombelli et al., 2021).

The Triple-Helix model introduced by Etzkowitz and Leydesdorff (1997) emphasises the interaction industry-university-government as a key driver for innovation and argues that a university needs to be directly linked to the industry to maximise the industrialisation of knowledge, and Eun et al. (2006) suggested a "contingent or context-specific" perspective on industry-university relationships, in which the industry-university linkages (IUL) can take various forms and assume different functions as each country has its own National Innovation System (NIS) (Eom & Lee, 2010, p.626). Joint research centres, technology-licensing offices, science parks, incubating centres, academy-run enterprises and technology markets are examples of channels that mediate the knowledge flow between academia and industry (Lee & Kang, 2010, p.154).

This study focuses on patenting activity as a measure of technological specialization and explores the technological trends emerging from South Korean universities' patent filings. Specifically, it examines patent applications filed at the Korean Intellectual Property Office (KIPO) from 2003 to 2021, with a particular focus on the top 30 universities in the Academic Ranking of World Universities (ARWU). The study aims to identify dominant technological fields in South Korean university patenting, assess how these align with South Korea's industrial technological trends, and compare them with universities in Japan, China-Taiwan (from now forward designated as Taiwan), China, and the United States (U.S). These economies were selected for their shared prominence in technological innovation: South Korea and Taiwan, as "Asian Tigers," have achieved rapid industrialization and now lead in electronic device production. Japan's established industrial base, China's recent economic transformation, and the U.S.'s leadership in university-driven patenting make them suitable benchmarks for international comparison.

The motivation to focus on South Korea is both academic and personal. South Korea's technology leadership makes it an ideal case study, and my incline towards Asian Studies and experience studying in the country sparked a deeper interest in its development path and technological progress.

This dissertation is structured as follows: Section 2 explores the beginnings of academic patent activity, the role of universities in national innovation systems, and provides a literature review. It also presents South Korea's specific case and offers a brief overview of the comparative countries' academic innovation systems. Section 3 outlines the data collection and analysis methods used in the study. Section 4 presents the findings and discussion, and Section 5 concludes with key insights and potential directions for future research.

1. LITERATURE REVIEW

Universities play an increasingly central role in national innovation systems, driving economic growth through knowledge production and collaboration with industry and government. The National Innovation System framework and the Triple-Helix model illustrate how universities contribute to industrial innovation by connecting with other key actors. This chapter reviews the literature on these roles and explores the importance of technological specialization in shaping a country's competitive edge, with a focus on how these dynamics apply to South Korea's innovation landscape.

1.1. Economic Growth Theories

The initial theories of economic growth can be traced back to classical economics, spearheaded by early economists like Adam Smith, David Ricardo, and Thomas Malthus. Adam Smith emphasised the importance of division of labour, productivity, and capital accumulation, arguing that economic growth is driven by the invisible hand of the market, where self-interested individuals contribute to the overall wealth through productive activities. David Ricardo introduced the concept of comparative advantage and focused on income distribution between landowners, capitalists, and labour. He acknowledged that economic growth would eventually slow down due to diminishing returns to capital and land (Ricardo's Law of Diminishing Returns). Thomas Malthus proposed that population growth would outstrip food production, leading to a cycle of famine, disease, and mortality, assuming a pessimistic view which stressed that population growth could impede economic progress (Antonelli, 2009).

These classical growth theories were further formalised and developed into what is known as the Neoclassical Growth Theory, primarily through the work of Robert Solow (Solow, 1956).

In his 1956 article, Solow proposes that the study of economic growth should begin by assuming a standard neoclassical production function with decreasing returns to capital (Mankiw et al., 1992). He introduced a model where economic growth is driven by capital accumulation, labour growth, and technological progress.

The Solow-Swan Model distinguishes between short-term growth achieved through capital investment and long-term growth sustained by technological advancements, although treating technological progress as an exogenous factor, which is not explained within the model. It is typically represented by an aggregate production function which describes how inputs (capital and labour) produce output (goods and services). It reflects the overall productivity of an economy and how efficiently it uses its resources. (Kasun, 2019)

Since a substantial part of economic growth could not be attributed merely to increases in capital and labour, Solow introduced the *Solow Residual*, which essentially captures the effects of technological progress (improvements in technology that allow more output to be produced from the same number of inputs) and efficiency improvements (better allocation and utilisation of resources, managerial innovations, enhanced skills of the workforce, and organisational improvements). (McCombie, 2000)

Built on neoclassical economics, the Endogenous Economic Growth Theory emerged in the 1980s and 1990s with contributions from scholars like Paul Romer, addressing some of its limitations, particularly the treatment of technological progress. It explains technological progress and innovation as results of economic activities and decisions made within the model, emphasising the role of education, skills, and knowledge as drivers of productivity.

Romer (1990) argues that technological change is the result of intentional investments in Research and Development (R&D) by firms and is a primary driver of economic growth. He also emphasises non-rival ideas and knowledge spillovers as essential elements of growth. (Antonelli, 2009)

Joseph Schumpeter, "founding father of the economics of innovation" (Antonelli, 2009, p. 619), is also one of the "key contributors to an economics of complexity where agents are credited with the actual competence to generate new knowledge and change their technologies." (Antonelli, 2009, p. 619). In other words, he treats innovation as endogenous, driven by entrepreneurial activity and competitive pressures. Technological change and economic change are inherently intertwined, as they are both integral aspects of the process of creative destruction that defines economic development. Schumpeter's concept of "creative destruction" describes the dynamic process through which new industries and technologies replace old ones, driving progress and economic growth.

While both the Endogenous Growth Theory and the Schumpeterian Theory seek to explain economic growth through innovation and technological progress, the first focuses on internal, incremental improvements facilitated by human capital and knowledge spillovers and sees innovation as a gradual and continuous process influenced by investments in R&D and education, whereas the last one highlights the disruptive role of entrepreneurial innovation and the dynamic process of creative destruction, understanding innovation as disruptive and often occurring in waves, leading to cycles of boom and bust.

In the 1990s, a model that contributes to the Endogenous Growth Theory literature was developed by the economists Philippe Aghion and Peter Howitt. The Aghion-Howitt Model, also known as the Schumpeterian Growth Model, emphasises the role of innovation and technological progress as core drivers of economic growth. It builds on "Schumpeter's idea that productivity growth at the macroeconomic level stems from a process of creative destruction in which the continuous entry of new firms and technologies renders the incumbents obsolete" (BBVA, 2020).

The model posits that firms invest in R&D to innovate, motivated by the prospect of obtaining temporary monopoly profits from new technologies. The balance between competition and innovation is critical, as it influences firms' incentives to invest in R&D (Wolf, 2021). This dynamic interplay creates a continuous process of growth, marked by periods of rapid advancement and subsequent economic adjustments. The model highlights the importance of policies that foster education, training, and R&D investment, as well as the need for regulatory frameworks that balance competition and innovation incentives, providing a comprehensive understanding of innovation as an economic growth-driving mechanism (Aghion and Howitt, 2009).

1.2. Technological growth in the context of economic development

Two distinct concepts brought up by Cho (2014) can help explain the technological growth and progress in nations, in the context of economic development.

On the one hand, the Innovation Paradigm focuses on the creation of new technologies, products, and processes through significant investments in research and development and fostering a culture of innovation (Cho, 2014). One key feature is being a Knowledge-Based Economy, and a major example is the USA and several European countries, having strong innovation ecosystems, robust R&D infrastructures, and a culture that encourages experimentation and creativity.

The Catch-up Paradigm refers to the process by which less developed or emerging economies narrow the technological gap with more advanced economies by adopting, adapting, and improving existing technologies (Cho, 2014). "The process of technological change in developing countries is one of acquiring and improving on technological capabilities rather than of innovating at frontiers of knowledge." (Lall, 2000, p. 13). For example, East Asian economies, such as Japan, South Korea, and Taiwan, are often cited as successful examples of nations focused on rapid industrialisation through the adoption and adaptation of technologies pioneered by more advanced economies. Mastering, adapting, and enhancing imported knowledge is challenging as technological knowledge is hard to identify, price, and assess. It requires a longer process that necessitates local learning. (Lall, 2000)

The importance of institutions, such as education and training, that back industrial technology is emphasised in the literature on technology for aiding enterprises to enhance their knowledge and skills. Education is not equal to capabilities, but it provides the base on which learning takes place (Lall, 2000). Fagerberg and Godinho (2006) focus on the variables skills (education), R&D, and innovation for their discussion on the performance differences of "potential catching up countries" and confirm that, like established industrialised countries, such as the US, some catching up economies also place a strong emphasis on higher (third level) education. Economies like Korea and Taiwan focus heavily on higher education overall, and more so than many other countries, they channel their educational investments into fields that are crucial for technological catch-up (Fagerberg and Godinho, 2006).

Education's impact on long-term growth relies on how well it is utilised. Without sufficient employment opportunities for highly educated workers, the potential benefits of higher education investments might be hindered. The rapid growth of higher technical education in Asian Newly Industrialized Countries (NICs) was matched by increased job opportunities for engineers and scientists in R&D, highlighting the synergy between industrial, technological, and educational policies. Currently, Japan leads in R&D expenditure, with South Korea and Taiwan also becoming major R&D investors (Fagerberg and Godinho, 2006).

Fagerberg and Godinho's (2006) findings confirm that the countries most successful in catching up, such as South Korea and Taiwan (following Japan), have shifted from traditional activities to focusing on the most cutting-edge industries, where they are now key players. This economic shift involved substantial investments in higher education, especially in engineering and sciences, along with significant increases in R&D and innovation funding. The role of government actions and policies was crucial in these developments, though they varied according to each country's history and circumstances.

1.3. University Patenting

Traditionally, universities are considered to have the sole purpose of teaching and conducting basic research (Etzkowitz, H., Leydesdorff, L., 2000).

However, in the most recent decades, there has been a shift in universities' aim toward a more direct contribution to economic development (O. Fisch et al., 2015), as the arrival of the knowledge-based economy (Etzkowitz et al., 2000) and the fast-paced global competition and technological change brought the linkages between universities and firms to the spotlight.

With the emergence of the new Knowledge Economy, endogenous growth theories address the importance of endogenous forces to economic growth through innovation and investment in knowledge production. This idea is associated with the non-competitive nature and unlimited access to knowledge that allows for positive externalities in its production and diffusion. The rising of concerns around the economic competitiveness at national and international levels during the 1990s led governments to strengthen their efforts towards the increase of the nation's innovation levels. After recognising the universities' role as powerful drivers of innovation and economic change, policy initiatives started focusing on stimulating academic research and knowledge transfer from universities to the industry (Kitagawa, 2004). The renovated focus of universities on innovation, transfer activities and entrepreneurship can also be understood from the perspective of the Schumpeterian and endogenous growth theories, which emphasise the dynamics of creative destruction and incorporate technological change as a force for economic growth.

University patenting started in the United States of America (USA) to ensure public health and safety, safeguarding the universities' reputation. Universities also aimed to counter external "free riders", who used inventions from institutes like Massachusetts Institute of Technology (MIT) without offering compensation. By the early 20th century, universities recognised the financial benefits of leveraging their knowledge for both the institution and its inventors. This led to a new academic role merging science and business, which quickly expanded from merely protecting intellectual property to actively participating in creating new products and enterprises (Leydesdorff et al., 2016).

Within the innovation studies literature, two contrasting views can be drawn on the interaction between universities' second and third missions (academic research and their direct contribution to the economy, respectively). Firstly, a group of theoretical frameworks positively explain this relationship (Kwon, K., 2011). Among them, we can highlight the Triple Helix Framework, Mode 2, and the National Innovation System Framework.

The Triple Helix Model takes the interactions among government, industry, and universities as key elements for innovation (Etzkowitz and Leydesdorff, 1997), therefore emphasising the role of universities in economic development. Etzkowitz (2008) even regards universities that actively capitalise their academic knowledge as "entrepreneurial universities".

The "Mode 2 science" or "new production of knowledge" put forward by Gibbons et al. (1994) "assumes a shift from an academic, disciplinary, and autonomous university-based organisation of primarily fundamental knowledge - described as Mode 1 - to a more diverse, transdisciplinary, applied, and reflexive kind (Mode 2)" (Zapp and Powell, 2017, p.645). In other words, knowledge is produced not only in the academic sphere but also in the networks between academic institutions, research institutes, industry and the government.

The concept of "national innovation system" (NIS) is widely defined as the institutions and actors that affect the creation, development, and diffusion of innovations, emphasising the importance of strong linkages among them (Mowery & Sampat, 2004). Lundvall (1992) defines the "structure of production" and "the institutional set-up" as being the two most important dimensions that "jointly define a system of innovation". In the NIS literature, one of the roles of universities is to be "knowledge diffuser" by producing quality students and by interacting with firms through cooperative programs (Eom and Lee, 2010).

On the other side, "a group of scholars in the "new economics of science", as well as other researchers, have raised concerns that the identity of academia may be undermined by its direct exposure to industrial influences." (Kwon, 2011, p.495). To gain priority and promote further advances in investigation, researchers disseminate information via publications freely. However, patenting requires secrecy prior to filing dates to preserve the necessary novelty for the patent being granted. These different incentives challenge both the access to research results and the dissemination of information.

In order to stimulate university patenting, government policy initiatives can be launched to further develop Industry-University linkages (IUL).

The Bayh-Dole Patent and Trademark Amendments Act promulgated in 1980 is often "indicated as the principal law that regulates the technology commercialisation of intellectual property resulting from federal funds in the United States" (Destro, 2012, p.11). To promote the commercialisation of university science, this legislation allowed universities, small businesses, and non-profit institutions to retain invention's property rights even when their inventions were developed with the support of federal funds. By doing so, researchers were allowed to file for patents and grant licenses to other organisations, encouraging universities to develop Technology Transfer Offices (TTO) to market and manage their patentable inventions (Destro, 2012). "The share of patents in the USA won by universities grew exponentially for more than two decades (1976-1998)" (Leidesdorff et al., 2016, p.258) but entered a period of relative decline in the decade 1998-2008. It is presumable that the exponential growth in the first period may be due to the Bayh-Dole Act, but its linear growth is more likely the result of an external driver, such as the patenting by non-USA universities at the USPTO (Leidesdorff et al., 2016).

Following Bayh-Dole's rationale, other countries started to implement similar legislation in the years after. These initiatives, together with various established partnerships, financial pressures, and the culture within universities, have played a significant role in transforming the mission of universities, aiming at positioning universities at the forefront of innovation and economic growth (Dundas, 2012; Fisch et al, 2015; Wang & Guan, 2010).

The increase in the prioritisation of technology transfer activities by universities can be explained by the need to attract industrial funding or generate income, where licensing patents and establishing innovation centres played an important role (Fisch O. et al., 2014). However, given the high costs involved in patenting, it can be assumed that universities, academic researchers, or technology transfer offices (TTOs) need compelling reasons to undertake the commercial risk associated with filing for a patent. The rationale for university patenting goes far beyond just financial incentives (Leidesdorff et al., 2016).

Japan

In the past decades, Japan's position as a major industrial and technological power has been established.

In 1868, Japan's Meiji Restoration launched a significant push to modernise the nation's economy and military in response to Western threats. The ruling elite at the time saw strengthening these areas as crucial. Since Japan did not have other means to modernise, the government took the lead—it overhauled the legal system, revamped infrastructure, and reformed education. They even started new businesses in key industries, later turning them over to the private sector. The focus was on engineering and applied sciences. Gradually, private enterprises and partnerships between government and businesses took on more weight, especially as family-operated business groups grew influential.

World War II's defeat drastically changed things, giving the bureaucracy more clout in reshaping the economy. In the early post-war years, the Ministry of Trade and Industry (MITI) played a vital role, but as Japan's economy regained strength, private business groups became more prominent. These groups often had strong connections to banks instead of being controlled by individual families.

There is a lot of debate about just how much the government versus private sectors contributed to Japan's economic success. However, government actions – through various economic, industrial, and trade policies – were crucial, particularly in the beginning. The government successfully directed private businesses towards modernisation. Over the years, Japan smoothly transitioned from older industries to more advanced and tech-focused ones. By focusing on innovations in production processes and efficient management practices, Japan quickly caught up with Western countries in fields like steel production, shipbuilding, automobiles, and electronics. Their ability to balance large-scale production with flexibility and high quality was key to their success (Fagerberg & Godinho, 2006).

Universities play a pivotal role in Japan's economic development as they not only are key in the development of human capital through education and training programs but also serve as hubs for research and innovation, driving the development of new technologies and processes, and enhancing productivity and competitiveness. Collaboration between universities and industry is a cornerstone of Japan's economic strategy.

Moreover, universities serve as knowledge hubs, disseminating research findings and fostering knowledge spillovers that stimulate innovation in the wider economy. They also play a key role in regional development by attracting talent, investment, and businesses to their surrounding areas, creating innovation clusters, and enhancing quality of life.

Additionally, universities engage in policy research and advisory roles, influencing decision-making and policy formulation to support innovation and economic growth.

Being one of the main global patent applicants, universities started being seen as not only a source of innovation but also as drivers of economic growth (Walsh & Huang, 2014), so various measures were taken that led to the revision of their science and technology policies, notably the "Act on the Promotion of Technology Transfer from Universities to Private Business Operators (Act No. 52 of May 6, 1998, as amended by Act No. 87 of July 26, 2005)" (WIPO, 2024), which aims to promote the transfer of technologies from universities and other research institutions to the private sector, providing a framework for the establishment of technology licensing offices and the management of intellectual property rights, contributing to the facilitation of the transformation of the State's industrial structure, development of national economy and the advancement of learning (WIPO).

China

The first policy to give the credits of scientific research to the project undertaking organisation was the Opinions on Strengthening the Protection and Management of Intellectual Property Rights Related to Science and Technology of China, promulgated in 2000. "Since it has been promulgated, the growth rate of inventions in Chinese universities has accelerated significantly." (Gong and Peng, 2018, p.688).

According to Gong and Peng (2018), Chinese universities have not met expectations regarding their role in commercialisation and technology transfer, which are critical for sustainable economic development. Despite policy changes, scholars attribute this issue to the absence of systematic policies, which hampers the translation of valuable service invention patents into practical applications. Moreover, the motivation of researchers significantly impacts patent outputs, with university activities being particularly sensitive to policy changes compared to those in enterprises.

According to Zhao and Wu (2017), most types of patent research and technology transfer activities are conducted under the government's guidance.

The conclusions from these studies, primarily Gong and Peng (2018), show that while the policy has improved patent outputs by defining ownership and providing economic benefits to inventors, it has not fostered the commercialisation of patents. In fact, over time, it may dampen universities' enthusiasm for commercialisation. The findings suggest that policymakers should tailor incentive strategies for different patent types and shift focus from quantity to quality in evaluating patent success.

Taiwan

Taiwan has made significant strides in catching up to Western economic levels through rapid industrialisation and structural change. Unlike other Asian nations, Taiwan's economy is primarily driven by small and medium-sized private enterprises, especially in the electronics sector. The Taiwanese government's role was pivotal, initially through policies such as tariff protection and financial support for specific industries. Unlike Japan and South Korea, which relied heavily on state-directed credit, Taiwan focused on early financial liberalisation and utilised state-owned enterprises along with public-private partnerships to support industrialisation. Taiwan's export-oriented strategy was essential due to its limited domestic market, a move that was bolstered by the reduction in global trade barriers after World War II. Recently, Taiwan has emphasised research, development, and innovation, strengthening its position in the global electronics industry (Fagerberg & Godinho, 2006).

Universities in Taiwan play a crucial role in economic growth through their research and innovation activities by creating and diffusing innovation knowledge for the industry. They enhanced the national innovative capacity by acquiring external knowledge from advanced countries like the United States and Japan, internalising it, and establishing their own innovation capability. Additionally, universities in Taiwan have seen a dramatic increase in the number of patents after certain legislative acts were implemented, like Taiwan's "Statute for Industrial Innovation" enacted in 2010, which provided a legal basis for the transfer of technology and intellectual property from academic and research institution to industry (Laws and Regulations Database of the Republic of China (Taiwan)), indicating their importance in building the country's innovative capacity. The universities tend to focus on technological fields that respond to industrial demands, particularly in the ICT and biotechnology industries. Furthermore, the university patenting activity reflects the development and demands of the electronics and biotechnology industries in Taiwan (Hsu and Yuan, 2013).

South Korea

In the catch-up process, the education system is important because education enables countries to absorb external knowledge and diffuse it through the national system (Kwon, 2011). But one of the most important characteristics of the Korean NIS is the "twin dominance" of big businesses (Chaebols) and the government, and a relatively weaker role of the universities and small and medium enterprises (SMEs) (Eom & Lee, 2010b).

The university-industry relationship in South Korea needs to be seen as an evolving process, dependent on the country's level of economic development. Three different stages can be distinguished: the beginning of the catch-up process (1960s and 1970s), where universities' main concern was education activities, and the Government Research Institutes were responsible for conducting demand-oriented R&D activities and transferring the results to private firms; in the mid-1980s, private firms began performing in-house R&D, whereas universities and GRIs started conducting joint or contract R&D with firms; and from the mid-1990s onwards, universities became more entrepreneurial (Lee & Kang, 2010b). The government played a crucial role by shifting its policy agenda towards the entrepreneurial role of universities. South Korea's "Act on the Promotion of Technology Transfer", promulgated in 2001, symbolises the transition of interests towards knowledge industrialisation, which prescribed that "public universities should establish units or institutions, such as Technology Licensing Offices (TLOs), which are in charge of technology transfer and training of specialists" (Eom & Lee, 2010b, p. 626). After this mark, South Korea witnessed an increase in both universities' patenting and publishing activities.

Korean industrial structure has changed rapidly in just a few decades, which might affect the activities and missions of Korean universities. The disciplines of Korea's patents were highly concentrated in certain fields during the catch-up period and changed over a short period of time (Kwon, 2011).

If, ultimately, Korean universities have been focusing on the same fields as the country is itself in the past two decades, it will be assessed further through the comparison of both technological specialisations.

2.4. Patents and statistics

A patent is a right of industrial property, valid in a specific territory and for a certain period, up to a maximum of 20 years. This gives its holder the right to prevent third parties from using their invention without their authorization in the territories where protection has been obtained, but in return, the holder must disclose the invention.

Patent applications are classified according to a specific classification system, aiming to group patents by technical areas. The classification used by most patent offices is the International Patent Classification (IPC), originated from the Strasbourg Agreement in 1971. It is divided into eight sections: A - human necessities, B - transport and operations, C - chemistry and metallurgy, D - textiles and paper, E - constructions, F - mechanical engineering, lighting, heating, weapons, G - physics, and H - electricity. Each of these sections is broken down into different levels, which are classes, subclasses, groups, and subgroups. (Lages, 2016).

According to Abbas et al (2014), patent analysis plays an ever-increasing role in defining business strategies and supporting decision making in and across organizations. Tseng et al (2011) says that patent analysis also helps identify industry trends and the competitive strength of companies or countries. As patent data has a broad coverage and high reliability, it offers a valuable perspective on technological developments and is increasingly accessible through online platforms.

Arrow (1962) stated that patents are traditionally used to solve market failures, by encouraging companies to invest in Research and Development. However, in the case of universities, which are entities that do not manufacture products, the justification is different, that is, to generate funds and the commercialization argument which argues that what matters is the act of turning inventions into marketable products requiring investment and excluding competition (Lemley, 2007). Lemley (2007) also refers that research has disclosed that university patents increase commercialization, and therefore, the Bayh-Dole Act has been a success, despite some critics saying that there were already technology transfer activities flowing besides patenting from universities to enterprises.

In conclusion, the literature highlights the crucial role of universities within National Innovation Systems, especially through their contributions to technological specialization and their collaborative interactions with industry and government. Theoretical models like the Triple-Helix emphasize how universities have evolved to engage directly in industrial innovation, supporting economic growth through knowledge creation and technology transfer. Research on technological specialization shows that countries can enhance their competitive advantage by developing distinct technological strengths, and universities play a key role in nurturing and advancing these capabilities.

However, there remains a noticeable gap in the literature when it comes to a detailed examination of South Korean universities' technological specialization and how these align with national industrial priorities, especially in comparison with international peers. Much of the existing research has focused on broader innovation metrics, often overlooking the specific patenting activities and specialization dynamics within academic institutions. This study seeks to address this gap by analyzing the patenting trends of South Korean universities, exploring their focus in technological fields, and comparing these patterns with universities in Japan, Taiwan, China, and the United States. Through this exploration, the study aims to enhance our understanding of the positioning of South Korean universities in the global innovation landscape and their growing role in advancing South Korea's technological and economic development goals.

2. METHODOLOGY

The main practical goal of this paper is to characterise the technological tendencies of South Korean universities' patenting activity. For this purpose, I relied mainly on patent statistics to answer the research questions adopting both quantitative and descriptive approaches.

The first question is related to universities' technological trends and whether those trends are aligned with the country's own technological trends. To answer, the sample was defined as the South Korean universities listed within the Top 1000 of the *Academic Ranking of World Universities* (ARWU) in 2023. Both universities and total number of applications' statistics were based on patent applications made to the Korean Intellectual Property Office (KIPO). The statistics were extracted through the online platform ORBIS-IP, which links global patent data to companies and corporate groups. For each university, it was determined the total number of patent fillings, between 2003 and 2021, excluding the year of 2022 as the data is not complete yet. The total values of filed patents by the country for the same period were retrieved from the same platform.

The first problem was related to the identification of the applicants' name as, sometimes, the universities' patents are not all filed under the names they are commonly known but under entities which belong to them with different names. In this way, it was considered not only the universities' name, but also their TTOs and other entities associated with the university, as well as other variations of the applicants' name, including abbreviations, word order and different languages. It was made through research on the possible entities related to each university.

It was then possible to verify and analyse their technological tendencies and in which technological areas they are focused on, and which ones have seen a bigger growth rate, allowing for the comparison with the country's own technological trends, answering the first question.

The second question focused on the comparison between South Korean universities' technological tendencies and worldwide universities considered among the most active in patenting activity, being considered the United States, Japan, Taiwan, South Korea, and China's universities ranked on the top 500 of the ARWU. This included 131 American universities, 4 Taiwanese universities, 13 Japanese universities, 11 South Korean universities, and 74 Chinese universities. In addition to the problem of the correct identification of the applicants' name, another problem arose with regard to the American universities to be observed. Although many of the US universities in the top 500 register their patents under the same designation as those universities are publicly known, there are many cases in which the filed patents are registered by a single entity, despite those individual campus being ranked separately in the top 500 of the ARWU. In these cases, the patents are filed under a single applicant's name, not being evident which belong to each campus. One example is the University of California, which has 8 campuses but whose patents are filed under "The Regents of the University of California". Following the approach of Vanessa Fatal (2019), the university's campuses acting as independents were considered as a single entity as it does not affect the main goal of the study. This logic was followed for the University Texas System, the University of Colorado and the University of Illinois. Following the same problem, some campuses showed a low number of patent applications on their own, most of them being under the system of the university. In the cases where the number of campuses was too high compared to number of campuses belonging to the TOP500 in the ARWU, it was decided to exclude those universities from the study. These were the University of Maryland at Baltimore and at College Park; the Indiana University at Bloomington and Indianapolis; the University of Hawaii at Manoa; the State University of New York at Buffalo; the University of Alabama at Birmingham; CUNY Graduate School and University Centre; and the City College of New York, leaving us with a total of 102 American universities. The statistics were gathered from the ORBIS-IP platform as well, following the total number of patent applications of the universities near the USPTO; it is one of the most important institutes with the biggest patent activity rates worldwide.

To analyse the technological tendencies of both the South Korean universities and South Korea, I used the IPC-Technology Table of the WIPO (World Intellectual Property Organization), a classification based on IPC which distributes patents into five sectors and 35 technological fields. Since a patent can receive more than one IPC classification, the main one was considered. To analyse the proximity in distribution I used the R-squared values. When R-squared equals one, the distribution is the same for both. The furthest from one, the less similar is the distribution.

I used the Coefficient of Variation indicator to determine the technological diversification of the universities and the country under study. The furthest it is from zero, the higher the specialisation in specific technological fields.

As for the analysis of specialisation, I used the Revealed Technology Advantage (RTA) index to evaluate the relative specialisation of South Korean universities in certain technological fields in order to assimilate its technological advantages over South Korean industry. In our case, the RTA is defined as the ratio between: (i) the share of patent applications by a group of entities (South Korean universities) located in a country (South Korea) in a certain technology (IPC class);

and (ii) the share of patent applications from all the entities with patent activity in the country in the same IPC class. The indicator is: a) equal to zero when universities have no patents in the observed technology (IPC class); b) equal to one when the technological specialisation of the universities in a technology class is the same as its country; and c) above one when the universities are more specialised in a certain technology class than its country.

For the comparative study between universities at the USPTO, I selected statistical data for their dominant IPC classes and computed the growth rates throughout the period of study to assess the technological tendencies.

3. RESULTS

This chapter analysis the patenting activities of South Korean universities, examining the trends in technological specialisation and comparing them with national and international benchmarks. Through a detailed exploration of patent data, key areas of focus and growth, implications for industry collaboration, and alignment with global technological advancements were identified.

3.1. South Korean Universities vs South Korea

The analysis comparing the technological specialisation of South Korean universities with that of South Korea reveals distinct trends in patent applications across the two periods under review. For South Korea as a country, the annual mean of patent applications decreased slightly from 183,615 during 2003-2018 (t_0) to 181,273 in 2019-2020 (t_F), with an average annual growth rate of -0.13%.[1] This decline may suggest a marginal reduction in the overall pace of technological innovation at the national level, though one may not exclude that this trend also reflects the impact of the Covid epidemic. Additionally, the coefficient of variation increased from 2.1 to 2.2, indicating a slight rise in specialisation within certain International Patent Classification (IPC) fields.

In contrast, South Korean universities exhibited a significant increase in the annual mean of patent applications, rising from 5,310 in 2003-2018 to 7,724 in 2019-2020. This growth reflects a

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[1] Average annual applications were estimated for each of the two periods observed (2003-2018 and 2019-2021) and then a compound annual growth rate was estimated as if for the average year of each of those periods. This calculus was applied to the annual growth rates mentioned in this paragraph and in the next paragraph.

robust average annual growth rate of 4.02% and around 45.5% increase in patent fillings, underscoring the universities' expanding role in the national innovation landscape. Furthermore, the coefficient of variation for universities increased from 2.9 to 3.2, indicating not only that specialisation within specific IPC fields is increasing but also it is significantly higher than for the country. These results indicate that while the national trend points reveal mostly a stabilisation in patent activity, South Korean universities are increasingly focusing and advancing in specialised technological areas.

As observed above, the values computed for the universities' coefficients of variation (closer to 3) are higher than those computed for the country (closer to 2), thus indicating a higher concentration of universities in certain technological areas. Such higher concentration is confirmed by the cumulative share of the top 15 IPC classes, that account for 75% of the overall universities' patent applications in t_0, while at the national level the top 15 classes account for a little less than 60% of the total applications in the same period (see table 1).

Table 1. TOP15 IPC classes for both Korean universities and total national applications at the KIPO

Ranking TOP 15 IPC classes (t_F)	Universities (t_F, 2019-2021)	% change (2019-2021 vs. 2003-2018)	RTA t_0 (2003-2018)	RTA t_F (2019-2021)	South Korea (t_F, 2019-2021)	% change (2019-2021 vs. 2003-2018)
1	A61 (19.6%)	6.96%	3	2.5	H01 (8.9%)	-12.89%
2	G06 (13%)	5.54%	1.4	1.1	H04 (5.4%)	-18.10%
3	H01 (9.7%)	3.14%	1	1.1	G06 (12.1%)	-12.05%
4	G01 (8%)	4.62%	2.1	1.6	A61 (8%)	-21.36%
5	C12 (7.2%)	3.71%	5.8	4.2	B60 (3.5%)	-13.47%
6	H04 (5%)	-3.47%	1	0.9	G01 (4.9%)	-16.44%
7	B01 (3.7%)	9.21%	1.6	2.1	G02 (1.1%)	-13.70%
8	C07 (3.5%)	3.20%	4	2.4	A47 (2.3%)	-17.98%
9	G16 (2.8)	30.47%	4.9	3.1	H02 (2.8%)	-14.55%
10	H02 (2.4%)	8.05%	0.8	0.8	A23 (2.2%)	-15.02%
11	A01 (2%)	7.15%	0.8	0.9	E04 (1.8%)	-15.58%
12	C08 (1.7%)	2.95%	1.5	1.1	B01 (1.8%)	-14.76%
13	C01 (1.5%)	4.26%	3.6	2.8	B65 (1.7%)	-15.99%
14	A23 (1.4%)	2.66%	0.8	0.6	C12 (1.7%)	-13.61%
15	C09 (1.2%)	3.71%	1.2	1	C08 (1.6%)	-14.48%
Top 15	75%				59.80%	

Table 1 allows for a better understanding of both the universities and the country's technological specialization. By analyzing this table focusing on the universities first, we observe that their TOP 15 IPC classes account for 75% of the total number of patent applications for universities, with almost all these 15 classes displaying a positive average annual growth rate. One also observes that 5 out of the top 6 classes (A61, G06, H01, G01 and H04) are the same both for the universities and the country. For the remaining 10 classes there is still a certain alignment, with an extra 5 classes (B01, H02, C08, A23 and C12) coinciding on the top 15. Despite that, there are still significant differences. For the first group, applications in class A61 (medical or veterinary science; hygiene) account for almost 1/5 of the universities' applications, while for the country that class accounts only for 8% of the total applications. For the second group, it is possible to see that class C12 (biochemistry; beer; spirits; wine; vinegar; microbiology; enzymology; mutation or genetic engineering) has a much higher relative importance for the universities (7,2%) than for the country. Interestingly, for the remaining classes not mentioned before, universities display a higher concentration in IPC Section C ("chemistry; metallurgy") classes, including C07 (organic chemistry), C08 (organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon), C01 (inorganic chemistry) and C09 (dyes; paints; polishes; natural resins; adhesives; compositions not otherwise provided for; applications of materials not otherwise provided for).

Focusing on the RTA values, we see that universities have a high comparative advantage in almost all fields, highlighting C12, A61, and G01 as the ones with higher RTA values. Classes such as H01, H04, G06, C08 and C07 show an RTA of 1 or very close, indicating that the total share of patent applications is very similar for universities and the country. Classes B60, A47, E04 and B65, which integrate only the country's top 15 classes, we observed that after calculations (not displayed in table 1) their RTA values vary up to a maximum of 1, with several values even close to 0, evidencing that universities don't have a reasonable degree of technological advantage in those fields.

For three top classes in South Korea's top 15 (H01, H04, G06), universities' RTA values for those same classes in the universities are quite close to 1, while for the A61 class, ranked fourth in the country's top 15, the respective RTA values are much higher (2,5 to 3), revealing that universities have a higher comparative advantage in these A61 technologies. The alignment between

South Korean universities' technological specialisation and the country's industrial priorities suggests strong potential for technology transfer and industry partnerships. The advantage shown by the RTA values indicates that universities are specialising in fields with strong application potential, which can enhance knowledge transfer opportunities. Furthermore, the technological proximity – especially in electricity – implies a robust foundation for collaborative innovation. For instance, if universities are advancing research in energy-efficient electrical systems, industries focusing on electronics or power distribution (both areas encompassed by IPC H) can adopt and commercialise these innovations, benefiting both academia and industry through enhanced national competitiveness.

Regarding the (di)similarity of the specialization patterns, the R-squared value between t_0 and t_F for the universities was 0.91, indicating that the distribution of patent applications is very close in both periods for all the top 15 IPC categories. For the Republic of Korea, the R-squared value is 0.84, indicating that there was some change in the distribution, though the specialization patterns are not that different between both periods under analysis. When comparing distributions between universities and the country itself, we can assess whether both technological specializations is close and, on the contrary, quite apart. In t_0, we got an R-squared of 0.69, while in t_F, it increased to 0.75. These figures indicate a degree of proximity of the technological specialization of the universities vis-à-vis that of the Republic of Korea over the two periods we observed, though the distance between both specializations seems to be decreasing.

We can verify that universities have shown a strong and increasing focus in three main IPC classes: Medical Sciences (A61), Physics (G), and Electricity (H). Over the study period, these fields have seen consistent growth, underscoring a strategic alignment with high-impact sectors. Specifically, the A61 category represents nearly 20% of the universities' patent applications, highlighting a substantial focus on medical devices and health sciences, aligning with national healthcare priorities and South Korea's advanced biotechnology sector. Accounting for a significant proportion of patent applications, Physics demonstrates the universities' focus on scientific research with applications in electronics, optics, and information technology. This class's steady growth, particularly in G06 (computing) and G01 (measuring/testing) is indicative of robust academic contributions to South Korea's ICT and semiconductor industries. Approximately 40% of patent applications fall under Electricity, reflecting South Korea's established industry in electronics and electrical engineering. This category's growth underscores the universities' alignment with South Korea's industrial strengths, particularly in fields related to power generation, distribution, and electrical systems. By examining these subfields, we observe that universities are not only specialising in these broad fields but also targeting high-demand, application-specific areas that have strong industry relevance.

3.2. Universities' patenting performance at the USPTO

South Korean universities filed a total of 12,506 patents from 2003 to 2021, with an average annual growth rate of 9.4%, demonstrating steady growth in academic patenting. In comparison, Chinese universities filed 22,143 patents during the same period, with a higher growth rate of 13.1%, reflecting significant expansion in university-driven innovation. Japanese universities, with 13,964 patents filed, showed minimal growth at 0.3%, indicating a stable yet modest increase in activity. Taiwanese universities contributed 3,293 patents, with a growth rate of 2.9%, highlighting focused but limited growth. U.S. universities led with 400,318 patents filed and an average annual growth rate of 14.6%, indicating a mature and robust patenting landscape. These comparisons underscore South Korea's competitive positioning, reflecting its steady advancement in academic patenting relative to other major economies in the global innovation landscape.

Table 2. Shares and Annual Growth Rates of Universities' TOP15 IPC classes in 2003-2018 at USPTO

USA		South Korea		China		Japan		Taiwan	
Share	**% change**	**Share**	**% change**	**Share**	**% change**	**Share**	**% change**	**Share**	**% change**
A61 (29.8%)	1.93%	**H04 (17.3%)**	8.10%	**H01 (16.5%)**	4.71%	**A61 (18.7%)**	-0.12%	**A61 (28.1%)**	4.09%
C12 (11.3%)	2.30%	**H01 (15.7%)**	11.72%	**G01 (12.5%)**	15.83%	**H01 (14.2%)**	-2.82%	**H01 (11.8%)**	6.40%
G01 (10.3%)	0.47%	**A61 (12.2%)**	7.20%	**G06 (10.7%)**	15.26%	**G01 (11.0%)**	1.72%	**G06 (9.1%)**	9.34%
C07 (8.8%)	4.29%	**G06 (11.7%)**	12.15%	**H04 (6.3%)**	10.14%	**C12 (10.7%)**	1.22%	**G01 (9.0%)**	8.40%
H01 (7.6%)	-0.51%	**G01 (7.2%)**	8.11%	**A61 (5.6%)**	14.03%	**C07 (8.3%)**	1.17%	**C07 (6.4%)**	1.39%
G06 (5.5%)	3.79%	**C12 (4.4%)**	6.65%	**C07 (4.4%)**	12.02%	**G06 (4.9%)**	2.12%	**H04 (5.2%)**	5.89%
G02 (3.5%)	2.17%	**C07 (3.6%)**	6.31%	**C12 (4.4%)**	13.91%	**G02 (2.9%)**	-7.45%	**C12 (4.7%)**	7.60%
H04 (2.5%)	2.64%	**H03 (3.6%)**	7.57%	**B01 (3.0%)**	13.40%	**C08 (2.8%)**	3.30%	**H02 (2.4%)**	10.68%
B01 (2.4%)	3.97%	**H02 (2.9%)**	6.64%	**H02 (2.4%)**	17.93%	**H04 (2.7%)**	-4.74%	**H03 (2.3%)**	-0.88%
A01 (2.4%)	-2.51%	**B01 (2.6%)**	11.23%	**G02 (2.3%)**	11.10%	**B01 (2.6%)**	1.36%	**G02 (1.8%)**	8.92%
C08 (1.5%)	3.00%	**G02 (1.8%)**	9.97%	**C08 (2.2%)**	12.41%	**A01 (1.7%)**	-8.77%	**B01 (1.7%)**	12.23%
H03 (0.9%)	-0.31%	**G11 (1.2%)**	14.89%	**E21 (1.6%)**	15.93%	**C01 (1.5%)**	3.90%	**G09 (1.3%)**	-1.90%
H02 (0.8%)	6.04%	**C08 (1.2%)**	7.06%	**C01 (1.5%)**	11.09%	**G11 (1.4%)**	5.00%	**C08 (1.2%)**	2.33%
C09 (0.7%)	4.69%	**C09 (0.9%)**	13.91%	**C02 (1.4%)**	14.77%	**C09 (1.2%)**	7.08%	**G05 (1.1%)**	4.53%
B32 (0.7%)	-12.99%	**G09 (0.9%)**	11.61%	**A01 (1.1%)**	13.13%	**C23 (1.0%)**	-9.35%	**C25 (1.0%)**	-4.98%
Next row displays for the TOP 15 classes and each of the economies the cumulative shares and average annual growth rates respectively.									

88.7%	1,3%	**87.2%**	9,5%	**75.9%**	13,0%	**85.6%**	-0,4%	**87.1%**	4,9%

Table 3. Shares and Annual Growth Rates of Universities' TOP 15 IPC classes in 2018-2021 at USPTO

USA		South Korea		China		Japan		Taiwan	
Share	**% change**	**Share**	**% change**	**Share**	**% change**	**Share**	**% change**	**Share**	**% change**
A61 (29.4%)	1.93%	**H01 (19.1%)**	11.72%	**G01 (15.6%)**	15.83%	**A61 (17.9%)**	-0.12%	**A61 (23.5%)**	4.09%
C12 (11.5%)	2.30%	**H04 (15.3%)**	8.10%	**G06 (12.8%)**	15.26%	**G01 (12.5%)**	1.72%	**H01 (12.2%)**	6.40%
C07 (10.8%)	4.29%	**G06 (14.7%)**	12.15%	**H01 (7.9%)**	4.71%	**C12 (11.6%)**	1.22%	**G06 (12.2%)**	9.34%
G01 (8.9%)	0.47%	**A61 (10.0%)**	7.20%	**A61 (6.0%)**	14.03%	**H01 (10.5%)**	-2.82%	**G01 (11.1%)**	8.40%
G06 (6.4%)	3.79%	**G01 (6.4%)**	8.11%	**H04 (4.9%)**	10.14%	**C07 (9.0%)**	1.17%	**C12 (5.4%)**	7.60%
H01 (5.9%)	-0.51%	**C12 (3.4%)**	6.65%	**C12 (4.7%)**	13.91%	**G06 (5.7%)**	2.12%	**H04 (5.2%)**	5.89%
G02 (3.5%)	2.17%	**H03 (3.0%)**	7.57%	**C07 (4.0%)**	12.02%	**C08 (3.7%)**	3.30%	**C07 (4.2%)**	1.39%
B01 (2.8%)	3.97%	**B01 (3.0%)**	11.23%	**H02 (3.6%)**	17.93%	**B01 (2.9%)**	1.36%	**H02 (3.6%)**	10.68%
H04 (2.7%)	2.64%	**C07 (2.8%)**	6.31%	**B01 (3.1%)**	13.40%	**C09 (2.3%)**	7.08%	**B01 (2.8%)**	12.23%
C08 (1.6%)	3.00%	**H02 (2.3%)**	6.64%	**C08 (2.1%)**	12.41%	**C01 (2.1%)**	3.90%	**G16 (2.7%)**	31.03%
A01 (1.5%)	-2.51%	**G11 (2.0%)**	14.89%	**E21 (2.0%)**	15.93%	**G11 (2.1%)**	5.00%	**G02 (2.3%)**	8.92%
G16 (1.3%)	18.54%	**G02 (1.9%)**	9.97%	**G02 (1.9%)**	11.10%	**H04 (1.6%)**	-4.74%	**G10 (1.7%)**	22.34%
H02 (1.2%)	6.04%	**C09 (1.4%)**	13.91%	**G05 (1.6%)**	21.19%	**H02 (1.6%)**	6.24%	**H03 (1.2%)**	-0.88%
C09 (0.9%)	4.69%	**G09 (1.1%)**	11.61%	**C02 (1.6%)**	14.77%	**G02 (1.3%)**	-7.45%	**G05 (1.0%)**	4.53%
B29 (0.7%)	5.67%	**C01 (1.1%)**	13.08%	**B23 (1.6%)**	21.25%	**G16 (0.9%)**	20.60%	**B29 (1.0%)**	16.50%
Next row displays for the TOP 15 classes and each of the economies the cumulative shares and average annual growth rates respectively.									
89.1%	3,8%	**87.5%**	9,9%	**73.4%**	14,3%	**85.7%**	2,6%	**90.1%**	9,9%

Tables 2 and 3 display, respectively for the first period and the second period of analysis, information for the TOP15 IPC classes with most patent applications filed by ARWU universities located in South Korea vis-à-vis those in the USA, China, Japan and Taiwan. These tables show a high degree of concentration in the top 15 patent classes in both periods, with a cumulative share above 80% in period 1 and raising to values closer to 90% in period 2 the cases of South Korea, US, Japan and Taiwan. In contrast, those values are closer to 75% in both periods in China, indicating a slightly smaller degree of concentration in the top 15. We can also confirm in the two periods covered by tables 2 and 3 a large number of common classes among the TOP 15 for each of the economies observed. This suggests that universities from these five economies tend to follow similar paths of technological specialization, namely with a high concentration in classes belonging to fields G and H, and generally displaying a solid performance on A61. Chinese universities show the most impressive average annual growth rates, well above 10% in each of the two periods, confirming a significant increase in USPTO patent applications by them over the years. Focusing on South Korean universities, significant growth was observed in both periods, with average annual growth rates quite close to 10% per year. This increase in patent applications provide further evidence towards confirming a positive trend in connection with the first research question. With China and South Korea, Taiwanese universities come next in patent applications at the USPTO, with their average annual growth rate increasing from the first to the second period. Similar acceleration trends between period 1 and period 2 verify both for the US and Japan, though at much lower levels when compared with the remaining economies. This is specially so for Japan that even experienced a negative average annual growth rate in the first period.

The comparative analysis of technological fields shows distinct specializations among universities in different economies. South Korean universities excel in **basic electronics (H01), electrical communication (H04), and computing (G06),** reflecting a focused alignment with national priorities in electronics, telecommunications, and digital technologies. Specifically, around 10% of patents from South Korean universities are in the medical sciences (A61), underscoring a notable emphasis on biochemistry, medical devices, and health sciences.

U.S. universities demonstrate a broader distribution with strong representation in **medical sciences (A61), organic chemistry (C07), and biotechnology (C12)**, aligning with the United States' extensive focus on life sciences and pharmaceuticals. Chinese universities prioritize **basic electronics (H01), computing (G06), and measurement (G01),** showcasing a strategic focus on industrial applications and digital innovation. Japanese universities maintain strength in **medical sciences (A61), basic electronics (H01), and computing (G06)**, key areas in Japan's high-tech sectors, with an increase in the importance of patent filings in **biotechnology (C12)**. Taiwanese universities, though smaller in patent volume, emphasize **semiconductors and electronics (H01), computing (G06), and medical sciences (A61)**, consistent with Taiwan's global leadership in the semiconductor industry. This overview highlights each country's strategic focus areas within the broader global innovation landscape.

Table 4. Proximity between universities' specializations with estimates of R-squared values, each cell displaying values for both t_0 and t_F

R^2 $t0_{-}t_F$	USA	South Korea	China	Japan	Taiwan (China)

USA	1	0.78 – 0.82	0.87 – 0.88	0.87 – 0.86	0.99 – 0.96
South Korea	-	1	0.93 – 0.91	0.98 – 0.94	0.79 – 0.92
China	-	-	1	0.95 – 0.89	0.88 – 0.91
Japan	-	-	-	1	0.87 – 0.93
Taiwan (China)	-	-	.	-	1

Note: The closest to 1, the more similar are the technological specialisations of universities in the two observed periods.

Table 5. Proximity between universities’ specializations with estimates of R-squared values, between period t_0 and period t_F, for each one of the five economies

USA	South Korea	China	Japan	Taiwan (China)
1	0.97	0.97	0.99	0.95

Note: The closest to 1 lesser the changes in specialization from the first period of analysis to the second

After calculating the R-squared values presented in table 4, the overall indication is that the ARWU universities from the five economies show very close technological specialisations, particularly in high-tech areas common to global innovation leaders. Specially, one notices that Taiwanese universities’ technological specialization is closer to that that exists in American universities, while a not so high proximity exists between Chinese universities and their US counterparts. At the same time, South Korean universities show a closer proximity with Japan, although from t_0 to t_F a slight decrease in that proximity is observed. South Korean and Japanese universities share a strong emphasis on Electronics (H01), while the U.S. focuses more broadly on Medical Sciences (A61), Computing (G06), and Biotechnology (C12). China and Taiwan exhibit regional strengths in Electronics (H01) and Computing (G06). However, China’s rapid growth across key fields like Measurement (G01) and Computing (G06) highlights its broader innovation strategy, while Taiwan’s focus remains narrower, driven by its leadership in semiconductors.

South Korean universities show a concentrated focus on a few key technology fields, mentioned above (Physics and Electricity). This high degree of specialisation contrasts with the broader patenting portfolios observed in U.S. and Chinese universities, which often cover a wider range of technological fields. This concentrated focus could be a strategic advantage, as it allows South Korea to develop niche expertise within the global innovation ecosystem.

While South Korean universities have lower overall patent volumes than U.S. and China's institutions, their growth rate closely mirrors that of Chinese universities, indicating a competitive trajectory in high-demand sectors and an active narrowing of the gap with major patent-producing countries, particularly in Asia. This alignment with global trends reinforces South Korea's position within the international innovation landscape and points to potential areas for cross-border collaborations.

When considering each of the five economies separately, the comparison between their technological specialization in periods t_0 to t_F, allows to draw the conclusion that those specializations remained quite steady.

The analysis in this chapter illustrates that South Korean universities are strategically focused on high-impact, industry-aligned fields, nationally, with strong growth in Medical Science, Physics, and Electricity. Their technological concentration and rapid growth rates indicate a focused approach to innovation, supported by government policies aimed at promoting university-driven economic contributions. Compared to global peers, South Korean universities are building competitive edge, particularly in areas with high commercialisation potential, paving the way for continued growth in patenting activities and collaborative opportunities in the national and international innovation ecosystem.

4. CONCLUSIONS

This study examined the technological specialisation and patenting activities of South Korean universities, focusing on how these activities align with national technological trends and how they compare with the technological specialisation and patenting activities of universities in United States, Japan, China, and Taiwan (China). By analysing patent data and technological fields, this research aimed to answer several key questions regarding nature, growth, and impact of university patenting in South Korea.

First, and responding to the first research question of what South Korean universities patenting trends are and how do these align with the country's technological priorities, this study found that South Korean universities have developed a strong specialisation in patenting fields aligned with the country's national technological focus, particularly in Medical and Veterinary Science (IPC A61), Physics (IPC G), and Electricity (IPC H). These areas reflect South Korea's industrial strengths in high-tech sectors, including electronics, biochemistry, and medical sciences. Over the study period, universities exhibited an increasing degree of specialisation, particularly in Physics and Electricity. This trend aligns with national industrial priorities, underscoring a synergy between academia and industry and suggesting that universities are effectively contributing to South Korea's broader innovation goals.

The research also shows a high degree of technological concentration among South Korean universities, with nearly 40% of patent applications in IPC classes belonging to sections G (Physics) and H (Electricity) and another 20% in the top IPC class, which is Medical and Veterinary Science (A61). This concentration, reflected in an increasing coefficient of variation, points to a focused and strategic approach to innovation that strengthens South Korea's competitive positioning. The similarity between university and industrial specialisations in fields such as Electricity further indicates a solid foundation for technology transfer and collaboration, which can enhance national competitiveness and stimulate economic growth through knowledge diffusion and partnerships.

As for the second research question, which focused on how South Korean universities' technological trends compare with chosen benchmarks, the study reveals that while South Korean universities' patenting trend stays below that of US universities, they have a growth rate similar to that of Chinese universities, indicating a strong momentum in patent generation. This comparative trend highlights that while South Korean universities are still building their patenting footprint, the rate of increase is substantial, signaling a deepening focus on technological innovation and a shift toward more active contributions to global patenting efforts.

Government policies and institutional initiatives have played a pivotal role in shaping university activities in South Korea. Policies like the "Act on the Promotion of Technology Transfer" have driven the development of an "entrepreneurial university" model, promoting patenting, commercialisation, and collaboration with industry. Such government support has been essential in establishing technology licensing offices and creating infrastructure that facilitates the transfer of university innovations to the market. This policy alignment with institutional patenting activity has positioned South Korean universities as increasingly entrepreneurial and vital to the country's innovation ecosystem.

Compared to their global peers, South Korean universities may benefit from further enhancement of their technology transfer and commercialization infrastructure to translate patenting activity into economic impact. While U.S. and Japanese institutions often have established networks for bringing university research to market (Tassey, 2018), South Korean universities are still building this capacity. According to a report by the Korea Development Institute (KDI, 2017), while efforts to improve technology transfer offices in South Korea are underway, their effectiveness remains limited, highlighting the need for further development. Strengthening these pathways could improve the real-world impact of South Korean patents and better position the country's universities in the global commercialization landscape.

This study provides valuable insights into the technological specialisation and patenting trends of South Korean universities, yet several limitations highlight areas for further exploration. The reliance on patent filings at the South Korean and US patent offices was the approach favoured by this study, but further research could expand the study to include data from other major offices, or PCT applications or yet consider data on patent families. Just as it is made a comparison between South Korean universities and the country South Korea, also the universities from the benchmark group could be compared with the respective economies.

Additionally, the study focuses on quantitative metrics such as patent volumes and growth rates, which, while informative, do not necessarily reflect the quality or commercial impact of these patents. Future research could incorporate qualitative metrics, including patent citation counts or commercialisation outcomes, to assess quality and knowledge flow of university-generated patents.

While the study compares South Korean universities with those in the United States, China, Japan, and Taiwan (China), differences in national innovation policies, economic contexts, and cultural approaches to academia-industry collaboration may limit the direct comparability of these results.

Future studies could focus on more detailed subclasses – IPC (>3) to better assess technological paths, as IPC classifications have subclasses up to 8 digits, further specifying the category, technologies are being protected.

For this study, we focus on patent filings, but future research could compare patent grants with patent applications potentially offering insights into both process efficiency and the economic and technological impact of patents.

Addressing these limitations could provide a more nuanced view of the impact and direction of university patenting activities in South Korea.

Based on the analysis of South Korean universities' patenting trends, several public policy recommendations and strategic initiatives can further strengthen their role in innovation. Enhanced government support, particularly for high-impact fields like medical science and electronics, could prioritise funding for patents with strong economic and societal benefits, aligning with the fields in which universities already demonstrate specialisation. Strengthening university-industry collaboration through incentives and regional innovation clusters would promote knowledge transfer and commercialisation, while policies encouraging diversification into emerging sectors such as AI and renewable energy would ensure adaptability to global shifts in innovation. Universities can complement these policies by focusing on patent quality and interdisciplinary research, expanding industry partnerships, and enhancing technology transfer infrastructure to drive commercialisation success. Increased international networking would also boost the global reach of South Korean innovations, reinforcing the country's competitive position in the knowledge economy. Together these recommendations offer a pathway for South Korean universities and policymakers to maximise the impact of academic research on economic growth and technological advancement.

In summary, this study highlights the expanding role of South Korean universities in advancing national technological and economic objectives. Through targeted specialisation and strategic alignment with industrial goals, these universities are bolstering South Korea's position in the global innovation landscape. Continued policy support, university-industry partnerships, and an entrepreneurial focus will be essential for maintaining this growth trajectory and enhancing the practical impact of university-driven innovation in the years to come.

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