COMILLAS
UNIVERSIDAD PONTIFICIA

ICAI

BACHELOR'S DEGREE IN ENGINEERING FOR INDUSTRIAL TECHNOLOGIES

UNDERGRADUATE THESIS

ANALYSIS OF PATENT CROSS-LICENSING FROM A GAME-THEORY PERSPECTIVE

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CHAPTER 1: INTRODUCTION AND OBJECTIVES OF THE THESIS

This section discusses the contextual framework of the Undergraduate Thesis, explaining both the previous background and the thesis's purpose, motivation, and structure. Furthermore, it introduces one of the applications of this thesis: the negotiation of patent cross-licenses.

1.1. CONTEXT

Throughout the last decades, patenting behavior in firms has changed in several industrial sectors ranging from smartphones to semiconductors and pharmaceuticals. Most of these sectors rely on high-complexity technologies with modular design, which means that final products incorporate several patented technological advances[1]. As a result, competition in these industries is likely to develop. Businesses can block competitors, so they will engage in more strategic patent system interaction than in other technology-related fields.

Figure 1 shows the growth of European patent applications in the digital communication field. This field encompasses basic electronic circuitry and electronic communication, e.g., amplifiers, decoders, and telegraphic communication. The figure shows a nearly steady increase in EPO patent filings over the last decade, with China, USA, Korea, Japan, and Sweden leading the picture. In 2021, top applicants in the field were Huawei (1840 applications), Ericsson (1382 applications), Qualcomm (1054 applications), Samsung (810 applications), and Oppo (688 applications).

Figure 1. Growth of EPO patent applications, 2012-2021.[2]

Firms in industries based on such complex technologies face a growing "patent thicket": a dense web of overlapping patents in which a firm frequently confronts rivals who hold patents that may prevent its own patents from being used. In such a setting, companies feel compelled to amass

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[1] See Harhoff et al., 2016.

[2] Source: EPO, 2021, retrieved on January 28th, 2023.

sizable patent portfolios to safeguard themselves from litigation and subsequent injunctions, which would hamper production. To avoid patent wars, firms in patent thickets frequently use non-adversarial methods to resolve overlapping claims, such as cross-licensing, broad settlement agreements, and other out-of-court agreements[3].

Cross-licensing emerges as a method to unlock markets. However, this solution raises some concerns. First, cross-licensing creates an almost impenetrable intellectual property legal barrier for newcomers to the industry, as the cost of granting such licenses can be prohibitive for small or start-up companies. Second, licensing rights add a layer of expense to the product and may subtract profit margins within the value of the intellectual property. Third, the company may become dependent on the skills and capabilities of third parties, especially if the license is exclusive. And finally, when many companies find themselves in patent thickets, incentives to challenge the validity of the patent post-grant diminish. This often reduces the quality of the patents on which the agreement is built, slowing down industry development and innovation.

Considering the above, the objective of this thesis is to carry out a study of value trade-offs in patent cross-licensing from a game theory perspective. The study aims to provide a model that optimizes such value exchanges by applying the mathematical approaches of Graph Theory and cooperative Game Theory, to improve the relationships between companies and save costs.

1.2. MOTIVATION

In 2011, Apple first sued Samsung for copying the design of the iPhone, which resulted in a $1 billion ruling in Apple's favor. The dispute centered on several design and utility patents for the primary operation of a smartphone. For seven years, the parties fought to identify which patents had been violated and, more recently, how much money Samsung owed to Apple due to the infringement. On June 27, 2018, a jury decided that Samsung must pay Apple $ 539 million for violating five patents with Android phones it sold in 2010 and 2011, which resolved the case. Although Apple won on paper, it did not gain a competitive advantage over Samsung and other phone manufacturers. After years of court battles, tens of millions of dollars in legal fees, and countless hours of its executives' time, Apple was left with insignificant profits from the cases[4].

The case will most likely serve as a reminder that the courtroom is not always the best place to get ahead. There is always a trade-off between litigation and innovation, and these companies were

[3] See Shapiro, 2001.
[4] See Nicas, 2018.

not innovating while they were in court. Thus, the motivation for this thesis arises from observing the current context of intellectual property and seeing wide gaps in the State of The Art. Despite multiple authors warning about the risks and failures of the current system of licensing negotiations, there is still no method to determine quickly fair and reasonable compensation royalties in patent cross-licensing agreements. By “fair and reasonable”, I mean amounts that do not lead to potentially abusive dominance positions, e.g., quantities that do not prevent start-ups with small patent portfolios from entering the market. I consider optimizing these agreements is vital to ensure a continuous trend towards innovation and economic growth.

1.3. Objectives

The motivation for the thesis leads us to define the following objectives. The main goal of the thesis is to define an algebraic model based on cooperative Game Theory and Graph Theory that optimizes value trade-offs in cross-licensing agreements. Once defined, the aim is to test the model by contrasting it with data obtained from the European Patent Office (EPO) database. The results will be analyzed to extract conclusions on the viability of the model. The following secondary objectives are defined to ensure the achievement of the main goal:

- Update the reader on current issues related to intellectual property registration.
- Inform about the existing regulations in the market.
- Demonstrate the usefulness and need for patent cross-licenses in markets of high technological complexity.
- Elaborate on advanced mathematical concepts, specifically game theory, and apply them to a real-life economic problem.
- Deepen knowledge of the Python programming language and develop a code applicable to a real-life situation.
- Boost innovation, improve business-to-business relations, and optimize transaction costs.

In addition, the study must be aligned with the following Sustainable Development Goals (SDGs):

> *Goal 9: “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.”*

Intellectual property, such as patents, encourages innovation for several reasons. First, they serve as an incentive to invent by recognizing and rewarding inventors for their commercially successful inventions. Second, the income generated by commercially successful patent-protected technologies helps to finance new research and technological development (R&D) activities. Third, patent information can be mapped, which provides policy makers with practical information about where R&D is taking place and who is doing it. This information can be useful in developing policies that allow innovation to flourish[5]. Moreover, patent cross-licensing agreements will accelerate the development of superior products while lowering product development costs. It will also allow companies to reduce time-to-market by leveraging each other's manufacturing capabilities.

Goal 8: "promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all."

Patents promote sustainable economic growth. A patent effectively converts an inventor's know-how into a tradable commercial asset. When this new asset hits the market, society will benefit. According to statistics from the Bertelsmann Stiftung foundation, countries in Europe, North America and Asia show that a 1% increase in key technology patents results in an average increase of 0.108% in GDP per capita income[6].

1.4. Focus and Structure

The first step to developing the value exchange optimization model is to usher in the key concepts and the required technology. In this regard, Chapter 2 of the thesis comprises a study on the various Industrial Property protection models and determine which models are most appropriate for each product type. The patent concept is thoroughly explored, including its requirements, structure, ownership, the scope of protection, and patent limitations. Similarly, this section will comprise the current regulations governing patents, and will provide a brief comparison across jurisdictions.

Chapter 3 provides a literature review of patent licensing. When discussing a patent license, two main questions arise. First, how much must the licensee pay the licensor for his patent? And second, what rights do the patent acquisition entitle the licensee to? To answer these questions, we begin by defining the variables that affect the price of the license. Then, we review the classical models developed so far to optimize patent licensing. Subsequently, we review the existing conflicts within the patent licensing international context and the present regulations. This analysis leads to the proposal of patent cross-licensing and patent pools as a solution to market problems.

[5] See WIPO, 2017.
[6] See Wurster, 2021.

Chapter 4 provides a model that optimizes patent cross-licensing, taking advantage of the gaps in the literature reviewed: "The Sieglinde Game". The main objective of the model is to streamline the process of obtaining a patent cross-license. Therefore, rather than focusing on an algebraic model that exclusively determines the optimal net royalty between two patent owners, a comprehensive two-phase model is developed, which brings together computation and algebra. In the first phase, the identification of patent corrals is automatized through optical character recognition techniques and graph models. In the second and third phases, Game Theory is used to design an optimization problem to determine the utility of each party in the negotiation and optimize the net royalty.

Chapter 5 validates the model developed by applying it to a real scenario within the current context of digitalization, 5G. The chapter describes the conflict derived from Intellectual Property blocking in the 5G market, including the challenges faced, the measures taken to curb them and viable alternatives to these measures. The solutions inspection includes a review of the basic concepts of 5G geopolitics and the trade war between China and the United States, approaching them from the perspective of Industrial Property rights. Subsequently, Chapter 5 introduces the solution of the case study. During the model application, each step is justified. Finally, the game results are analyzed to discover any shortcomings in the execution.

Chapter 6 introduces the economic report, which examines the costs associated with the different patent game strategies for Huawei and Ericsson. Specifically, it explores the ramifications of discontinuing the product line, pursuing legal action for patent infringement, or mutually cooperating through cross-licensing negotiations. By juxtaposing the incurred costs for each company based on their chosen strategy, this chapter seeks to substantiate the efficacy of cross-licensing agreements as cost-saving mechanisms.

Finally, Chapter 7 will include the drawing of conclusions. In this section, it will be assessed the extent to which the objectives defined in the first chapter have been met. The most significant results will be emphasized, as well as the limitations encountered, and the suggestions made for further research. Moreover, conclusions will include further directions.

1.5. RESOURCES

The following resources have been used for the development of the thesis:

- Academic databases, as well as articles and papers from the University Library, are used for the basic bibliography.

- We rely on published materials on patents, licenses, and other legal patents, licenses, and other associated legal documentation to develop the theoretical framework.
- The European Patent Office virtual database is used to collect information about the sample so to apply the model to the case study.
- Computation programs: Python, Excel, and PowerPoint.

CHAPTER 2: INTELLECTUAL PROPERTY

In chapter two, we will examine the various Industrial Property protection models and determine which models are most appropriate for each product type. The concept of the patent will be thoroughly explored, including its requirements, structure, ownership, the scope of protection, and patent limitations. Similarly, this section will comprise the current regulations governing patents, and will provide a brief comparison across jurisdictions.

1.1. INTRODUCTION TO INTELLECTUAL PROPERTY

Intellectual property (IP) is a set of legal rights and protections that give creators and innovators control over their works and creations. Unlike physical property, IP consists of ideas, designs, symbols, and other creative works that are not physical objects. These rights are intended to encourage the development of new ideas and creations, by giving their creators the ability to control how their works are used, and to receive compensation for their efforts.

Intellectual property is a critical component of the modern economy, as it allows inventors and creators to gain a competitive advantage in the marketplace, while also protecting consumers from counterfeit goods and fraudulent services.

IP shows the following characteristics. First, intellectual property rights are granted exclusively, implying that their creators or owners have the sole right to use, sell, or license their creations. Second, IP rights are territorial in nature. Thus, they are given and enforced on a country-by-country basis, which might challenge innovators who want to protect their work in different countries. Third, IP rights depend on limitations and exceptions that balance authors' interests with societal needs. Finally, intellectual property law is a dynamic field constantly changing to keep up with evolving technologies, economic practices, and social norms. Hence, creators and innovators must stay updated on the latest advancements in IP law to secure their works and make educated decisions about how to use and license their ideas.

As the pace of innovation continues to accelerate and as the global economy becomes increasingly knowledge-based, intellectual property is more important than ever. IP plays a critical role in stimulating innovation, supporting economic progress, and improving people's quality of life. This makes intellectual property research a vital and dynamic topic, with a growing demand for professionals who can manage the complexity of IP law and policy.

1.2. TYPES OF INTELLECTUAL PROPERTY

Figure 2 shows there are several types of intellectual property (IP) that are recognized under the law, each with its own set of rules and regulations. The main types of IP are patents, trademarks, copyrights, trade secrets, and industrial designs[7]. These different types of IP are intended to provide legal protection and support for creative and innovative endeavors.

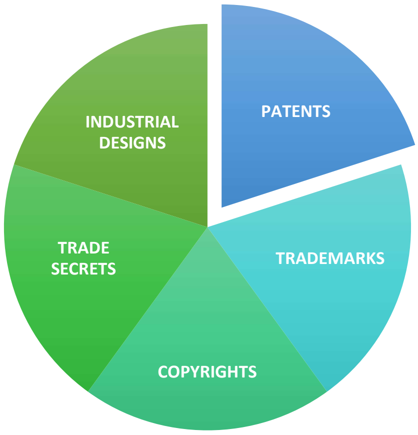


Figure 2. Types of Intellectual Property[8].

Patents: Patents are legal protections granted to inventors, which give them the exclusive right to make, use, and sell their inventions for a certain period of time. Patents are typically granted for new and useful inventions and can include everything from machines and devices to chemical compounds and biological processes.

Trademarks. Trademarks are symbols, words, or phrases that are used to identify and distinguish goods or services in the marketplace. They can include logos, brand names, slogans, and other distinctive features that help consumers recognize and choose specific products.

Copyrights. Copyrights protect original works of authorship, such as books, music, films, and software. They give the creators of these works the exclusive right to reproduce, distribute, and display them, and can last for a set period (often the lifetime of the creator plus certain years).

Trade secrets. Trade secrets refer to confidential business information, such as formulas, processes, and methods, that give a company a competitive advantage in the marketplace. Unlike patents and trademarks, trade secrets do not require registration, but they are protected under law as long as they remain confidential.

[7] Source: WIPO, n.d., retrieved 2023.
[8] Prepared by the author, 2023.

Industrial designs. Industrial designs refer to the visual or ornamental appearance of a product or article and are protected under law as a type of intellectual property. They can include everything from the shape and color of a product to its packaging and graphics.

1.3. PATENTS

Patents are legal rights granted by government agencies to an inventor or assignee to exclude others from making, using, selling, or importing an invention for a limited period of time[9]. The patent is granted in exchange for the public disclosure of the invention, which provides benefits to society by enabling others to learn from the invention and build upon it. A patent typically lasts for a limited period of time, which varies by country and can be subject to renewal fees. In most countries, the duration of a patent is 20 years from the date of filing[10].

Figure 3 shows a simplified representation of the patent process. The patent process stages are very similar across jurisdictions, varying the duration of each step.

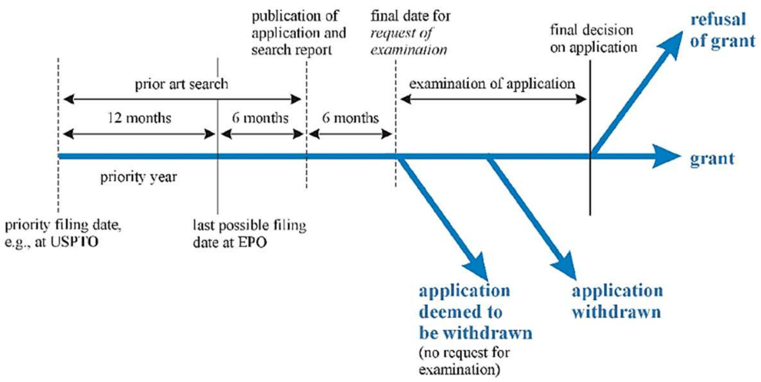


Figure 3. Simplified representation of the patent process[11].

The patenting process begins when an inventor, an assignee, or a legal representative files a patent application after determining that the invention is eligible for a patent and conducting a prior art search. The patent attorney must pay a fee and provide documentation, including a patent request, details of the applicant, a description of the invention, claims, and drawings. The application must enable a person skilled in the relevant field to replicate the invention, and the claims must be

[9] See Bronwyn H. Hall, 2007.
[10] Some of the main organizations that provide patents in the world are the United States Patent and Trademark Office (USPTO), the European Patent Office (EPO), the World Intellectual Property Organization (WIPO), and the Japan Patent Office (JPO). WIPO is a specialized agency of the United Nations that promotes the protection of intellectual property worldwide. In addition, unlike USPTO, both EPO and JPO have a centralized application and examination process (Von Graevenitz, 2007). While each organization has its own characteristics and values, they all aim to promote innovation and protect IP rights.
[11] Source: Harhoff & Wagner, 1984.

supported by the description. If the documents are correct, the application is assigned a filing date, i.e., the priority date[12]. After filing the patent application, an examiner analyzes it to determine if the invention meets the patentability requirements. To do this, the examiner prepares a search report listing all prior art documents relevant to the technology. If the examiner has objections to the application, the applicant can respond and make changes or amendments. Finally, if the examiner approves the application, the patent is issued. If not, the applicant can decide to appeal the decision. After the grant of the patent, third parties can file a notice of opposition during a certain time period, which varies across jurisdictions.

A patent is a form of intellectual property, and as such, it can be bought, sold, licensed, or used as collateral. The patent owner has the exclusive right to exploit the invention and can prevent others from using it without permission. Moreover, patents can be transferred or licensed to others through assignment or licensing agreements. In some countries, the inventor may retain certain rights even if the patent is assigned or licensed to someone else.

Patents can provide significant advantages to inventors and companies by providing legal protection, financial rewards, and incentives for innovation and investment. They promote technological progress and encourage competition, while balancing the interests of inventors with the needs of society. However, it's important to note that the patent system can also have drawbacks, including high costs and complexity associated with obtaining and enforcing patents, as well as the potential for patent trolls and other abuses of the system.

To conclude, concepts defined in this chapter will follow the European Substantive Patent Law, of November 2020. This law has been extracted from the latest amendment to the Patent Law published in the 17th edition of The European Patent Convention, 2020.

1.3.1. Patent requirements

Patent requirements can be broadly divided into two categories: patentability criteria and eligibility requirements. The former determines whether an invention is eligible for patent protection, while the latter determines who can apply for a patent and under what conditions.

An invention is patentable if it is new, it involves an inventive step, and it has a practical utility capable of being used in an industry. These criteria are like patentability criteria in other jurisdictions, although there may be differences in how they are interpreted and applied in practice.

[12] See EPO, n.d., retrieved 2023.

Novelty. The invention must be new, which means it must not be included in the State of the Art[13]. The State of the Art includes all the information that has been made available to the public before the priority date of the patent application, either in written or oral form. It also includes the petitions that have already been filed and that are currently being processed.

Inventive step. The invention must not be obvious to a person skilled in the relevant technical field[14]. In other words, it must involve an inventive step that is not readily deducible from the prior art.

Industrial applicability. The invention must be capable of being made or used in any kind of industry, including agriculture[15].

Non-exclusion. The invention must not fall into any of the categories of excluded inventions listed in EPC. This list contains certain subjects that are not considered to be inventions either or both because they are non-technical, and they do not involve a practical application. Although not patentable, these items may still be protected by other forms of Intellectual Property, such as copyright, industrial designs, or trademarks. The list includes discoveries, scientific theories, and mathematical methods; aesthetic creations, presentations of information, and schemes, rules, and methods for performing mental acts, playing games, or doing business, and programs for computers[16]. Additionally, the law excludes certain inventions from patentability, such as those that would be contrary to public order or morality, methods for surgical or therapeutical treatment of the body, and plant and animal varieties or biological processes for its production of plants or animals. An exception is when use of a substance for a certain use is new and inventive[17].

Sufficiency of disclosure. The patent application must provide a clear and complete description of the invention to enable a person skilled in the art to carry out the invention[18].

Some similarities and differences in patent requirements across jurisdictions are as follows. First, almost all jurisdictions, including the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), and the Japanese Patent Office (JPO), require that an invention be novel or new to be eligible for patent protection. However, there are differences in the rules around what constitutes novelty, e.g., the EPO and JPO have a 12-month grace period for certain public disclosures of the invention, while the USPTO has a one-year grace period[19]. Second, most jurisdictions, including

[13] See The European Patent Convention, art. 54, § 2. Hereinafter EPC, art. 54, § 2.
[14] See EPC, art. 56, § 2.
[15] See EPC, art. 57, § 2.
[16] See EPC, art. 52, § 2.
[17] See EPC, art. 53, § 2.
[18] See EPC, art. 83, § 2.
[19] See Von Graevenitz, 2007.

the EPO, USPTO, and JPO, require that an invention be capable of industrial application, meaning that it can be made or used in some kind of industry or commercial context. However, the types of subject matter that can be patented may vary between them. For instance, the USPTO has traditionally allowed for the patenting of software and business methods, while the EPO has been more restrictive in this area. The USPTO and JPO also allow for the patenting of plants, while the EPO does not. Finally, other differences in patent requirements across jurisdictions include distinct level of inventiveness, different level of detail required for the description of the patent, different exclusions from patentability, and the existence of grace periods.

1.3.2. Patent Structure

A patent application shall contain a request for the grant of the patent, a description of the invention, one or more claims, any drawing referred to in the description or the claims, and an abstract[20]. Moreover, the patent specification shall be written in a clear manner that is understandable to a person skilled in the relevant technical field.

The sections included in the patent document will be explained below. For this purpose, the European patent "Method and device for detecting battery micro-short circuit[21]", filed in 2017 with code **EP 3 550 317 B1**, will be used as a model.

1.3.2.1. Abstract

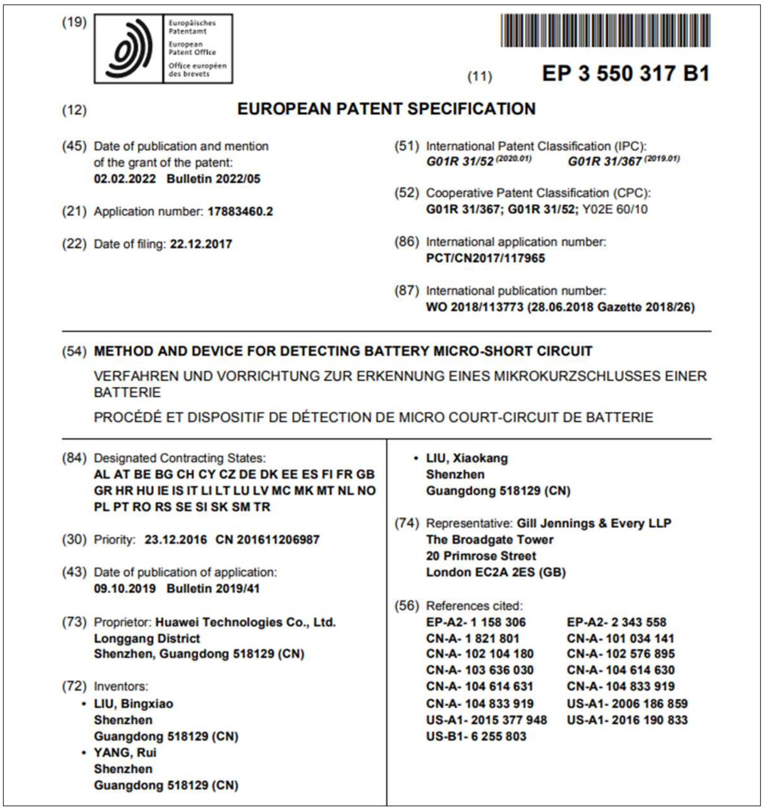
A patent document abstract is a short statement of its technical disclosure. The abstract should allow the reader, regardless of his level of expertise with patent documents, to readily determine the nature of the subject matter covered by the technical disclosure. It may only be used for technical information and not for any other purpose, including interpreting the scope of the protection sought[22]. The abstract provided for patent EP 3 550 317 B1 is cited below:

> A battery micro-short circuit detection method and apparatus are disclosed. The method includes: obtaining a target initial battery parameter value of a target battery at an initial moment, and determining a reference initial battery parameter value of a virtual reference battery at the initial moment, where a response of the virtual reference battery is the same as a response of the target battery when a same excitation condition is given; obtaining a target battery parameter value of the target

[20] See EPC, art. 78, § 2.
[21] See LIU et al., 2022.
[22] See EPC, art. 85, § 2.

battery at a specified moment; determining a reference battery parameter value of the virtual reference battery at the specified moment based on the target battery parameter value and the reference initial battery parameter; and calculating a difference between the target battery parameter value and the reference battery parameter value, and determining, based on the difference, that the target battery is micro-short-circuited. Embodiments of the present invention have advantages of improving accuracy of battery micro-short circuit detection, enhancing applicability of battery micro-short circuit detection, and reducing a battery fault mis-determining rate. (LIU et al., 2022).

1.3.2.2. Patent Specification



(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 3 550 317 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent: **02.02.2022 Bulletin 2022/05**

(21) Application number: **17883460.2**

(22) Date of filing: **22.12.2017**

(51) International Patent Classification (IPC): ***G01R 31/52*** (2020.01) ***G01R 31/367*** (2019.01)

(52) Cooperative Patent Classification (CPC): **G01R 31/367; G01R 31/52;** Y02E 60/10

(86) International application number: **PCT/CN2017/117965**

(87) International publication number: **WO 2018/113773 (28.06.2018 Gazette 2018/26)**

(54) **METHOD AND DEVICE FOR DETECTING BATTERY MICRO-SHORT CIRCUIT**
VERFAHREN UND VORRICHTUNG ZUR ERKENNUNG EINES MIKROKURZSCHLUSSES EINER BATTERIE
PROCÉDÉ ET DISPOSITIF DE DÉTECTION DE MICRO COURT-CIRCUIT DE BATTERIE

(84) Designated Contracting States: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(30) Priority: **23.12.2016 CN 201611206987**

(43) Date of publication of application: **09.10.2019 Bulletin 2019/41**

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(56) References cited:

EP-A2- 1 158 306	**EP-A2- 2 343 558**
CN-A- 1 821 801	**CN-A- 101 034 141**
CN-A- 102 104 180	**CN-A- 102 576 895**
CN-A- 103 636 030	**CN-A- 104 614 630**
CN-A- 104 614 631	**CN-A- 104 833 919**
CN-A- 104 833 919	**US-A1- 2006 186 859**
US-A1- 2015 377 948	**US-A1- 2016 190 833**
US-B1- 6 255 803	

Figure 4. Patent Specification for patent EP 3 550 317 B1[23].

Figure 3 shows the patent specification, which must be structured using numbered paragraphs. These labels are the same across all jurisdictions. This use of numbered paragraphs in is intended to facilitate the search and retrieval of patent information, as well as to enable a quick and efficient evaluation of the patent application by the patent examiner.

[23] Source: LIU et al., 2022, p. 1.

1.3.2.3. Description

Figure 5 shows part of the description of patent EP 3 550 317 B1.

EP 3 550 317 B1

Description

TECHNICAL FIELD

[0001] The present invention relates to the battery management field, and in particular, to a battery micro-short circuit detection method and apparatus.

BACKGROUND

[0002] A secondary battery is also referred to as a rechargeable battery or a storage battery. During use of the secondary battery, a safety problem such as thermal runaway, over-charge, or over-discharge may occur due to impact of a factor such as a raw material of the battery or a manner of using the battery. Thermal runaway is an ultimate manifestation of a battery safety problem. One of main causes of thermal runaway is a battery micro-short circuit. Battery micro-short circuits mainly include a micro-short circuit caused by an external factor, a micro-short circuit caused by an internal structure change of a battery, and the like. The micro-short circuit caused by an internal structure change of a battery has a long evolution process. A phenomenon of the battery micro-short circuit is insignificant at an early stage, and diagnosis of the battery micro-short circuit is easily confused with a problem such as battery bolt looseness, causing high difficulty in identifying the battery micro-short circuit. A micro-short circuit phenomenon of a single battery in a battery pack including a plurality of single batteries occurs occasionally, increasing difficulty in identifying a micro-short-circuited single battery from the battery pack. However, at a later stage, the battery micro-short circuit may cause a severe safety problem such as battery thermal runaway, and battery micro-short circuit detection is one of battery safety issues that urgently need to be resolved.

[0003] In the prior art, an equivalent internal resistance Zi of each single battery in a secondary battery pack is calculated by collecting a terminal voltage Ui of the single battery and an output current I of the single battery, and whether the single battery is micro-short-circuited is determined based on a difference ΔZi between Zi and a reference resistance.

Figure 5. Description of patent EP 3 550 317 B1[24].

The description of the patent must be clear and detailed enough for someone skilled in the relevant technology to be able to put it into practice. The language used must be technical, objective, and neutral, with no promotional or commercial references. Also, the description should provide the basis for and support the claims made in the patent and must be logically ordered. The description must begin on page 2 of the application and include specific headings: technical field, background of the invention, summary of the invention, description of the drawings, detailed description of the invention, example(s), industrial application, and best mode of carrying out the invention (optional)[25].

1.3.2.4. Claims

The claims in a patent refer to the specific and detailed statements that define the precise boundaries of what the inventor considers to be their original contribution to the field. They must define the subject matter for which protection is sought[26]. The claims are typically found at the end of the patent document and are numbered in sequence. They are crucial to the patent application process as they are the basis on which a patent is granted, and they must be specific, clear, and supported by the description and drawings in the patent application. Once a patent is granted, the claims provide the basis for enforcing the patent, as any infringement of the claims can result in legal action.

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[24] Source: LIU et al., 2022, pp. 2-21.

[25] The format of the description is usually consistent across different countries' patent documents, but it can be modified for clarity if the modifications do not affect the substance of the invention.

[26] See EPC, art. 84, § 2.

Figure 4 shows part of the claims of patent EP 3 550 317 B1.

EP 3 550 317 B1

Claims

1. A battery micro-short circuit detection method, comprising:

obtaining (S401) a target initial battery parameter value of a target battery at an initial moment, and determining a reference initial battery parameter value of a virtual reference battery at the initial moment, wherein a response of the virtual reference battery is the same as a response of the target battery when a same excitation condition is given;
obtaining (S402) a target battery parameter value of the target battery at a specified moment;
determining (S403) a reference battery parameter value of the virtual reference battery at the specified moment based on the target battery parameter value and the reference initial battery parameter; and
calculating (S404) a difference between the target battery parameter value and the reference battery parameter value, and determining, based on the difference, that the target battery is micro-short-circuited.

2. The method according to claim 1, wherein the target battery parameter value comprises a target terminal voltage value of the target battery, a current value of the target battery, and a temperature parameter value of the target battery; and the initial battery parameter of the virtual reference battery comprises an initial state-of-charge value of the virtual reference battery;

duration between the specified moment and the initial moment is ΔT0;
the determining a reference battery parameter value of the virtual reference battery at the specified moment based on the target battery parameter value and the reference initial battery parameter comprises:

determining a state-of-charge change value of the virtual reference battery within ΔT0 based on the current value of the target battery and the temperature parameter value of the target battery, and determining a reference remaining battery capacity of the virtual reference battery based on the initial state-of-charge value of the virtual reference battery; and
the calculating a difference between the target battery parameter value and the reference battery parameter value, and determining, based on the difference, that the target battery is micro-short-circuited comprises:

Figure 6. First two claims for patent EP 3 550 317 B1[27].

1.3.2.5. Drawings

Drawings are an important component of a patent document as they provide a visual representation of the invention and help to clarify the written description of the invention. They can help to demonstrate the structure and operation of the invention and can be used to support the claims made in the patent. Drawings also help the examiner to understand the invention more clearly, so to demonstrate the novelty and non-obviousness of the invention. Figure 7 shows the first drawing out of 5 that are associated to patent EP 3 550 317 B1.

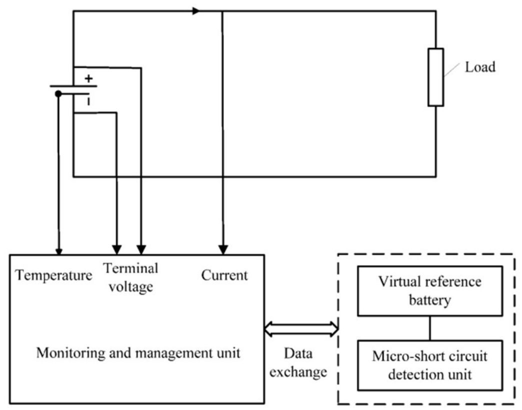

FIG. 1

Figure 7. Drawing 1 of the invention associated to patent EP 3 550 317 B1[28].

[27] See LIU et al., 2022, pp. 22-32.
[28] See LIU et al., 2022, pp. 33-36.

1.3.2.6. State of the Art Search report

The prior art search is conducted with a primary focus on novelty. First, the examiner searches among any existing documents available to the Patent Office at that specific moment[29] and decides whether the invention to which the patent application relates is new and involves an inventive step. Second, the examiner draws up the search report and cites the documents that violate the patentability requirements, linking each citation to the claims to which it refers. Where applicable, he should identify the relevant sections of the cited document[30]. The report only references the most important documents discovered. If there are multiple documents of equal relevance, the search report should only include the one with the earlier priority date.

Table 1 depicts the list of references generated during the examination of an application.

X	particularly relevant documents when taken alone (a claimed invention cannot be considered novel or cannot be considered to involve an inventive step)
Y	particularly relevant if combined with another document of the same category
A	documents defining the general state of the art
O	documents referring to non-written disclosure
P	intermediate documents (documents published between the date of filing and the priority date)
T	documents relating to theory or principle underlying the invention (documents which were published after the filing date and are not in conflict with the application, but were cited for a better understanding of the invention)
E	potentially conflicting patent documents, published on or after the filing date of the underlying invention
D	document already cited in the application
L	document cited for other reasons (e.g., a document which may throw doubt on a priority claim)

Table 1. Classification of references cited in the search report during the examination of an application[31].

Citations in Table 1 are ranked by relevance. Each reference in the search report states which claims of the application the prior art applies to. In terms of patentability, X-type references are the most important. When taken alone, an X reference indicates a lack of novelty or inventive step with one document in the prior art. Y-type citations are especially relevant when combined with another Y-document. They point to a lack of inventive step through the pairing of documents[32]. Type A references only provide technical background on the technology. They make no claim of a lack of novelty or inventive step. D-type references allude to documents that have already been cited in the application.

[29] There is an 18-day window from the patent application date to the publication of the documentation to facilitate the preparation of the search report. Also, the search report must be written in the language of the proceedings.
[30] See EPC, art. 61, § 4.
[31] See EPO Guidelines for Examination in the European Patent Office, 2003, 176ff.
[32] See Wolf, 2011.

1.3.3. Scope of Patent Protection

The scope of protection conferred by a patent or patent application is determined by the claims, since they ascribe the right of prohibition to the patent owner[33]. The scope of protection is determined retroactively by the patent as granted or modified in opposition, limitation, or nullity proceedings. Moreover, equivalents to elements indicated in the claims must be considered.

1.3.4. Patent Ownership

The right to a patent belongs to the inventor or his legal heirs. However, a patent application may be filed by any natural or legal person or by any entity legally equivalent under the applicable law to a legal person[34]. The applicant will own all rights and duties over the patent, except for moral rights which belong to the inventor. Also, no matter who applies for the patent, the inventor always has the right to be mentioned as such before the Patent Office[35].

If the invention is created by an employee during their employment, the right to a patent is governed by the law of the State in which the person is primarily employed. In Spain, the employer is obliged to pay for the patent application. By paying it, he becomes the owner of the patent. However, the employee has both the right to be named the inventor and the moral rights over the invention.

An attorney who has been hired to represent the inventor or employer does not have any rights to the invention or the patent. The patent attorney's role is limited to advising and representing the inventor or employer in the patent application process and any legal disputes that arise.

The owner of a patent has three main rights. First, he has the exclusive right to exploit the invention. Second, the patent owner has the right to prevent third parties from making, using, selling, or importing a product or process that falls within the scope of the claims of the patented invention, without permission or authorization. In case of infringement, he can request an injunction against any person who violates his patent rights, which shall be dealt with by national law[36]. He can also obtain compensation for damages suffered due to the infringement[37]. Finally, the patent owner has the right to license or transfer the patent to another person[38].

[33] The claims do not give a monopoly over the technology but define the scope of what the patent owner can prohibit.
[34] See EPC, art. 58, § 2.
[35] See EPC, art. 62, § 2.
[36] See EPC, art. 64, art. 105, § 2.
[37] See EPC, art. 67, § 2.
[38] See EPC, art. 71, § 2.

On the other hand, there are two main duties of the patent holder: to pay the annual fees and to exploit the invention.

The annual fees must be paid in advance for its entire duration within three months of the due date, which is the last day of the month of the anniversary of the filing date of the application[39]. If the payment is made after this deadline, it can still be paid with an additional charge within the following six months. However, for fees due after the publication of the patent grant, a regularization fee will also be charged. If the holder does not pay in due time and form, the patent will be invalidated, and the object of the patent will become part of the public domain.

Unless otherwise stipulated in the EP Convention, a European patent shall have the same effect and be subject to the same requirements as it would in each of the Contracting States for which it is granted[40]. In other words, the patentee has the same rights as a national patentee and is subject to the same constraints and obligations[41]. The burden of proving that the invention is being exploited in compliance with the law lies with the patent holder.

1.3.5. Patent Limitations

The exploitation of a patented invention must not be carried out in an abusive or unlawful manner, contrary to morality, public order, or public health. It is also subject to any temporary or indefinite prohibitions or limitations established or that may be established by legal provisions.

1.4. CONCLUSION

This chapter provides an in-depth examination of Industrial Property and Patent Theory. It delivers an overview of the patent process including patentability requirements across jurisdictions, the structure of a patent application, the scope of patent protection, the rights and duties of the patent's owner, and the limitations that apply to the grant of a patent. Patent Theory has been laid out according to the November 2020 amendment to the Substantive Patent Law outlined in the European Patent Convention. Moreover, patent EP 3 550 317 B1 has been used as a model to illustrate the structure of a patent document.

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[39] See EPC, rule 51, § 3.
[40] See EPC, art. 2, § 1.
[41] In Spain, the patent holder must exploit a patented invention within four years from the date of the patent application, or three years from the date of publication of the patent grant, whichever expires later. (art. 9, «BOE» no. 177, July 25th, 2015). They are required to exploit the invention either by themselves or by someone authorized by them, in Spain or in a member state of the WTO, in a manner that is sufficient to meet the demand in the Spanish market.

Understanding the process of patenting an invention, especially the examination phase and the drawing of the search report, enlightens why patent licensing negotiations are necessary. As explained above, the search report references existing documents that infringe upon the patent's novelty requirement. Especially in the case of X-type references, if the applicant wants to dispose of his invention without modifying its claims, he will need to negotiate a license with the owner of the document cited in the search report.

With this in mind, two questions arise. First, how much does one party pay for the other party's patent? And second, what rights does it entitle him to? The following chapter will provide insight into the concept of patent licenses and a literature review of the classical models used to negotiate the agreement. Thus, the different models are according to expected sales, expected profits, time, or license exclusivity.

CHAPTER 3 – LITERATURE REVIEW

The negotiation of patent-cross licenses involves agreeing on a royalty or up-front payment to offset the net balance each party must pay to the other. This amount equals the difference between the royalty payable on the higher-value portfolio and the royalty on the lower-value portfolio. Thus, to optimize a cross-license agreement, one must first have an overall view of one-way patent licensing.

Chapter 3 provides a literature review of patent licensing. When discussing a patent license, two main questions arise. First, how much must the licensee pay the licensor for his patent? And second, what rights do the patent acquisition entitle the licensee to? To answer these questions, we begin by defining the variables that affect the price of the license. Then, we review the classical models developed so far to optimize patent licensing. In addition, we evaluate the extent to which each model considers its variables. Subsequently, we review the existing conflicts within the patent licensing international context and the present regulations. This analysis leads to the proposal of patent cross-licensing and patent pools as a solution to market problems.

4.1. INTRODUCTION TO PATENT LICENSING

A patent license agreement is a legal contract that defines the conditions upon which a licensee may produce, store, sell, and/or use a licensor's patented product. There are two approaches to patent licensing: the "carrot" approach and the "stick" approach. In the former case, the patent owner, i.e., the potential licensor, must convince a potential licensee who has not infringed the patent in question to enter into a licensing agreement. The latter approach is litigation, where the potential licensee has already violated the patent and must either obtain a license or face legal action.

Patent licensing arises in several circumstances. First, it can emerge in markets where inventors are not active competitors and where the technologies might have, as side products, uses that may differ from the original application. Second, patent licensing can arise when inventors are financially constrained and unable to undertake the necessary investment to market the results of their research[42]. In this situation, licensing enables investors to reduce their financial risks by sharing the costs of developing or commercializing the patented technology. Third, monetizing a patent portfolio is a means of generating additional revenue streams. Besides, it can allow a company to gain access to new markets. Fourth, litigation processes often result in the licensing of the patented technology under dispute to avoid the costs and risks associated with the infringement of patent rights.

[42] See Hernández-Murillo, 2004.

The complexity of the negotiation of patent licenses lies in determining fair royalties that favor both licensees and licensors, as well as market competition and consumers. Intellectual property rights, in general, can operate as barriers to entry for agents that cannot afford the royalties required by the patent holder[43]. Consequently, there are antitrust regulations all around the world that dictate the basic rules that all licensing agreements must comply with to favor competition in the markets. These regulations and other guidelines will be reviewed later in the chapter. Moreover, there are several supporting materials that parties use to negotiate patent license agreements. These include patent search reports, market research reports, sample licensing agreements, technical specifications, and expert opinions. In addition, the involved parties can rely on precedent. That is, to look for existing agreements in the same or similar industries as a starting point. These agreements can guide the typical terms and conditions, including royalty rates, payment terms, exclusivity, and indemnification.

However, it's important to note that each agreement is unique, so one must tailor it to each party's needs. All patent licensing agreements go through a negotiation phase between the parties involved in it, which hampers the development of a model that standardizes the determination of fair payments. We will unravel this problem by identifying the collective variables across patent licenses. Specifically, variables on which both parties must decide and that impact the price set for the permit.

In the patent licensing negotiation, the common variables across patent licenses are called the essential conditions or “key terms” of the agreement, i.e., the most important legal and commercial aspects of the license. Although the essential terms vary somewhat depending on the type of technology being licensed (e.g., semiconductor invention, software, pharmaceutical formulations, etc.), similar issues arise in all transactions involving technologies containing IP rights. The "essential" conditions collapse into four broad clusters[44], as shown in Figure 9. The first cluster involves the subject matter of the license. This group includes the elements that define the technology and the type of patent, as discussed in the previous chapter. The second cluster approaches the rights conferred, in which the stipulation on the exclusivity of the patent is particularly relevant. The third cluster includes the financial terms that determine the payment form and terms. And fourth, the development of technology over time.

[43] This problem particularly affects technologies protected by essential patents (SEPs), i.e., patents that preserve parts of a given industry technical standard. A SEP starts out as a typical patent and becomes essential when it needs to be used to follow a particular standard for interoperability. Hence, increasing owner power. Consequently, SEP holders often demand supra-competitive royalties under the threat of denying the patent license knowing that the industry technical standard they protect is vital for the other company.

[44] See Idris, *WIPO*, 2004.

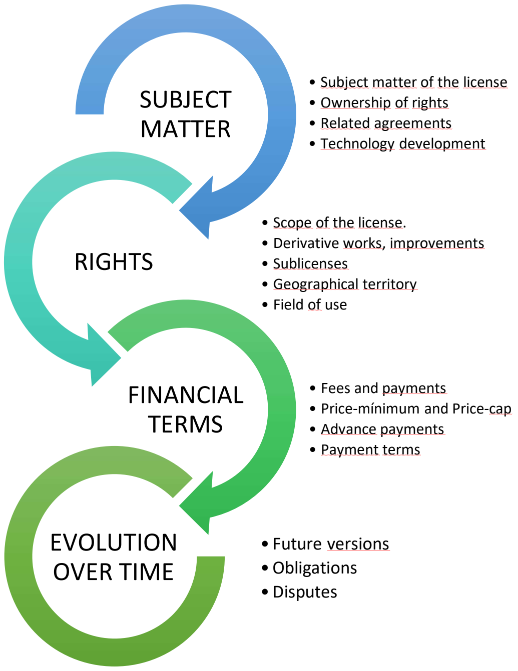

Figure 8. Essential conditions in patent licensing negotiations[45].

The “Subject matter” cluster refers to the essential terms that define the patented technology. There are several variables to consider in this cluster:

First, the type of technology to be licensed, which can be a product, a formula, a protocol, a computer program, a set of diagrams, or documentation. One of the keys to a successful negotiation involves finding out exactly what the technology is and the parts of it one needs for the organization.

Second, the delimitation of the subject matter of the license. A broad license that covers a wide range of activities may be more valuable to the licensee, but it may also be more expensive to give to the licensor. On the other hand, a restricted license that only covers specific aspects of the technology may be less valuable to the licensee but less expensive for the licensor to give.

A third variable to consider is the size of the licensor’s patent portfolio, i.e., the number of patents it includes. The larger the patent portfolio, the more expensive the license is. This variable is associated with the type of references cited in the search report. For instance, in the presence of X-type references, patent licenses will likely have to be negotiated with heavier patent portfolios.

Finally, one should consider the degree of completeness of the inventions. If the invention is not fully developed, one should assess whether the activity can be performed with incomplete technology or if the agreement allows modifications to the invention.

[45] Source: prepared by the author based on guidelines provided by the WIPO, 2023.

The “Rights” cluster refers to the variables that define the scope of the rights conferred by the license agreement. These rights can be categorized as either patent rights assignments or copyright assignments. The former group includes the right to make, use, or sell the technology, while the latter includes the right to reproduce, modify, initiate derivative works, and distribute the technology. A second variable to consider is the right to sublicense the technology to third parties in its original or modified form. Thirdly, the licensor and licensee must negotiate the geographical limitations of the license. Last, the most important variable to account for is whether one wants to negotiate an exclusive, non-exclusive, or sole patent license.

The “Financial Terms” cluster refers to the financial conditions of the license. The financials depend on how the subject matter and the scope of rights are defined because the commercial elements can impact significatively the value of the technology. The first issue to determine is the form of payment, which can be in the form of royalties, flat fees, or a combination of both. In addition, one could approach the negotiation from the licensee’s or the licensor’s point of view. The licensee's perspective involves looking at the maximum price one is willing to pay for the license regarding the costs incurred and the product sales price. For this matter, one should set this price based on market forecasts and its number of competitors. If the licensor can sell its intellectual property to several licensees, he is expected to have greater bargaining power. In contrast, if the licensee can license a reasonable substitute, the licensor's bargaining power will be reduced. The licensor's perspective involves determining the amount of money that will cover the investment in research and development of the technology and make a profit. Often, the licensee requests a provision for a cap or minimum to the royalty paid to the licensor.

The “Evolution of the technology over time” cluster considers the following variables: first, if the owner will obtain rights to future versions of the technology or product; and second, if it is necessary to include maintenance, support, and spare parts for the licensed technology in the license. In addition, the parties should reflect on their obligations besides those arising from the contract (e.g., testing, marketing, clinical trials, etc.), and it should be determined both where to resolve disputes and who to indemnify against the risk of third-party claims. Another issue to take into consideration is the time left until the patent expires. When the patent is newly issued, the licensor has a strong bargaining position; however, when the patent is about to expire, the licensor has a poor bargaining position.

Since the beginning of the 20th century, several models have been developed that attempt to optimize the price of patent licenses according to one or several of the variables included in these four groups. Following, we will provide a literature review on the main models that take them into account.

4.2. CLASSICAL MODELS FOR PATENT LICENSING.

The field of patent licensing is complex and to date there is no one-size-fits-all model or approach for determining fair royalties in any license agreement. Early work focused on emphasizing the importance of intellectual property transfer to foster innovation in the industry. Most studies focus on shedding light on the economic and strategic motives that lead companies to license their technology. However, very few of them focus on analyzing the licensor-licensee agreement, and even fewer focus on assessing the factors that influence the pricing of patent licensing. This results from the lack of available data on technology license agreements; companies have historically tried to conceal their licensing deals because they consider them lucrative strategic decisions.

In a perfect market, the price of patents would reflect their expected net present value. However, the patent market is imperfect because there is a limited number of qualified licensors and licensees, the information on technological development is asymmetric, the technology's economic performance is uncertain, and the licensing transaction involves several costs. Hence, the price of a patent falls between the licensor's reservation price (i.e., transfer costs of the licensed technology plus opportunity costs of licensing) and the expected net present value of the patent for a license[46]. There are two main determinants of the price of a patent license: the profitability of the underlying patents and the relative bargaining power of licensors and licensees.

The mathematical methodologies developed so far to maximize profits in patent licensing contracts are all supported to some extent by the Nash Bargaining Solution[47] (NBS). The NBS arises in the context of cooperative game theory as the optimal solution to a two-person profit-making bargaining problem that meets the axioms of scale invariance, symmetry, Pareto efficiency, and independence of irrelevant alternatives[48]. Specifically, the NBS provides a way to allocate the payoffs of a cooperative game among its players. It is typically irrelevant in perfect competition or monopoly settings because these market structures do not usually entail explicit negotiation or bargaining among firms. However, it can be applicable in oligopolistic markets (Cournot and Bertrand competition), vertical relationships, and bargaining over access or usage rights, as in the case of intellectual property.

[46] See Sakakibara, 2010, p. 930.

[47] The NBS is a mathematical model published in 1950 by Nobel laureate John Forbes Nash, arguably the father of modern economics, and generalized by authors such as Lloyd Shapley, Robert Aumann, Hervé Moulin, John Harsanyi, Ethud Kalai, and Ariel Rubinstein.

[48] Pareto optimality means the equilibrium lies where no party can improve their conditions without worsening at least another party. Symmetry conveys that both parties are equal in bargaining skills. Scale invariance means that an affine transformation of the opportunity cost should not alter the negotiation's outcome. And independence of irrelevant alternatives indicates that both parties are fully aware of each other's tastes and preferences.

The Nash (1953) model input consists of the operating income of the system and each party's disagreement payoffs or BATNAs[49]; the output is the payoff distribution among the parties[50]. When applied to the patent licensing field, the model inputs are the number of licenses sold and the expected revenue, the costs incurred, and the opportunity cost of each party. The output is the surplus generated by the licensing agreement, the interpretation of which determines the net royalty or fee.

Nevertheless, the NBS is unrealistic if applied to IP because it assumes symmetry. As stated before, in a patent licensing negotiation the parties rarely have equal bargaining weight, which lead to the development of the asymmetric generalization of the NBS[51]. The NSNBS model adds one input to Nash's solution: the bargaining strength of each party. The model's interpretation is that the parties first agree to give each other their corresponding disagreement payoffs and split the profit surplus according to their bargaining strengths[52]. The relative bargaining power of licensors and licensees depends on the essential terms defined in Figure 10 and varies in each patent licensing contract. Numerous studies provide methods to calculate the relative bargaining power:

First, one can determine it by the ease of alternatives to licensing, which is impacted directly by the firm size. There is an inverse relationship between the firm size and the patent licensing price[53].

Second, the exclusivity of the license also impacts the licensor-licensee relative bargaining power. Licensees with higher technological potential are more likely to be granted exclusive rights. However, they are less likely to be allowed exclusive rights when licensor and licensee products overlap significantly[54]. Other models regarding the exclusivity of the patent license examine non-exclusive, partially exclusive, compulsory, and sole licenses.

Third, another determinant of relative bargaining power is the time left until the patent expires; the shorter the time, the less bargaining power the licensor yields. The literature examines the influence of time in a licensing agreement by applying real options contracts by firms acquiring rights to commercialize new technologies[55]. Purchasing a real option enhances the bargaining power of the potential licensee in future negotiations but also increases uncertainty in the process. The Real Options model considers the current value of the patent, the probability of successful licensing, the

[49] "Best Alternative to a Negotiated Agreement", i.e., the opportunity cost of making the deal.
[50] See Nash, 1953, pp. 128-140.
[51] The model is called "Non-Symmetric Nash Bargaining Solution". See Kalai and Smorodinski, 1975.
[52] See Kryskowski, 2020.
[53] See Sakakibara, 2010.
[54] See Aulakh et al., 2013.
[55] See Ziedonis, 2007, p. 1619. An option contract "gives an investor the right, but not the obligation, to buy a valuable asset at a future date at a certain price".

potential benefits of delaying the decision to license, and the risks of uncertainty. It concludes that corporations are more willing to purchase options for inventions with uncertain commercial future. On the other hand, a new research branch aims to investigate the development of dynamic pricing models based on market value, technology value, or time to patent expiration. However, the studies have not yielded clear conclusions yet.

In conclusion, the Nash Bargaining Solution, when used correctly, can assist in forecasting the outcome of a hypothetical negotiation between a possible licensee and a patentee[56]. Since the NBS is a very general concept, its application to patent licensing must be supported by other economic methods to predict profits and the bargaining power of each party. Overall, we believe that the NBS model is partially unrealistic because it assumes a simultaneous decision-making process from both parties, it requires compliance with many assumptions, and it presumes that all players have complete information about each other preferences and decision-making process.

Another issue addressed in depth in the literature review is the debate on the optimal form of payment for patent licenses. The economic and legal implications of this decision, and the constantly evolving field of patent licensing, raise the question of whether royalties or fixed fees are preferable for these types of contracts. In this regard, the existing studies show that the preference for royalties or fixed payments mainly depends on the market structure and the degree of product differentiation.

The early theoretical literature studies the performance of fixed fees and royalty payments under a monopolistic setup[57]. The model shows that the optimal payment form depends on the level of uncertainty and the production costs of the patented cost-reducing innovations. If the production cost is high relative to the licensee's expected profit, the licensee will prefer to pay a fixed fee. On the other hand, if the production cost is low relative to the expected profit, the royalty rate will be preferred. However, the model does not always hold in real-world settings. For starters, it ignores the dynamic nature of patent licensing negotiations, including the time, duration, and flexibility of royalty payments. Second, it does not account for specific market variables such as demand elasticity, market structure, and competition levels. Thus, the model is very limited in scope.

Subsequently, from the perspective of the patentee, upfront fee mechanisms are superior to per-unit royalties for homogeneous goods under Cournot or Bertrand competition[58] in an oligopoly

[56] See Choi and Weinstein, 2001, Crampes, and Bergman.
[57] See Arrow, 1962.
[58] In Cournot competition, firms compete by choosing simultaneously the quantity of output produced, whereas in Bertrand competition firms compete by setting prices.

industry[59]. On the other hand, a producer prefers a royalty-based contract when there is product differentiation among competitors and when the producer has a large market share[60]. Overall, royalties outperform flat fees in case of risk-sharing[61], product differentiation[62], uncertainty, strategic delegation[63], and the degree of competitivity in the market[64].

In conclusion, studies reveal that the choice of fixed or royalty payments depends on multiple factors and that uncertainty about them can lead to unprofitable payment forms. Hence, recent work exposes that a hybrid contract that combines both a flat fee and a royalty component can be optimal in some situations. In this context arises the concept of "two-part tariffs", where a fixed fee is combined with a per-unit royalty to help extract more surplus for the licensor[65]. The model proves that the combination of royalties and fixed payments can align the incentives of both the licensor and licensee and thus maximize overall welfare. Motivated by these findings, the theoretical literature has further examined the use of two-part tariff contracts in monopolies and oligopolies.

Interestingly, empirical information on licensing contracts also indicates the adoption of *ad valorem* royalties rather than per-unit payments[66], although the theoretical literature pays more attention to the per-unit royalties. Scholars investigate the optimal licensing agreement between a patent holder of a cost-reducing innovation and external firms with varied uses for the technology. In contracts that include *ad valorem* royalties plus a fee, they discover that companies with a higher valuation for the innovation prefer to pay a higher rate to retain a higher share of revenues[67].

4.3. Patent Licensing Customs and Regulations.

The previous section shows the theoretical methods for modelling patent licensing agreements, as proposed in the State of the Art. In contrast, this section deals with practical approaches used in court to determine reasonable patent damages in patent infringement litigation. According to US law, upon a finding in the claimant's favor, "the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty

[59] See studies by Kamien and Tauman, 1986; Katz and Shapiro, 1986; and Kamien et al., 1992.
[60] See studies by Wang, 1998, and Kamien and Tauman, 2002.
[61] See Bouquet et al, 1998.
[62] See Muto, 1993.
[63] See Saracho, 2002.
[64] See Saracho, 2005.
[65] See Katz and Shapiro (1985).
[66] An *ad valorem* royalty is calculated as a percentage of the sales or revenue generated from the licensed product. On the other hand, a per unit royalty is a fixed amount of money calculated based on the number of units of the licensed product sold, regardless of the product's price or revenue generated.
[67] See Hernández-Murillo and Llobet, 2006.

for the use made of the invention by the infringer"[68]. In this spirit, the UK Patent Act[69] states that patent infringements must be assessed as “the capitalized value of the royalties that the infringer would have paid had he taken the license".

Generally accepted patent valuation approaches include (1) the cost approach, (2) the market approach, and (3) the income approach. The cost approach determines the worth of an intellectual property asset by calculating the cost of replacing it with an exact or equivalent good. In contrast, the market approach values the patent based on analogous transactions between unrelated parties. The income approach values patents based on the present value of the net economic benefit predicted over the asset's life. Up until some years ago, the payment of IP was regulated by a "25% rule of thumb", an income-based approach widely discussed within the licensing industry to quantify incremental income levels. The rule empirically suggests[70] a 25:75 payment ratio between the licensor and licensee, respectively, based on risk allocation. The theory is that the licensee, who bears the risk and exploits the property, should receive the most profits, although both parties should benefit from the licensed IP. However, following *Uniloc USA, Inc. v. Microsoft Corp. (2011)*, it was ruled that the 25% rule cannot be the sole method for calculating patent royalty damages.

The most widespread method for calibrating the baseline 25% rule of thumb consists of a 15-factor list known as the Georgia-Pacific factors[71]. The list delivers a series of relevant considerations in the counterfactual of a negotiation between the licensor and licensee to determine the reasonable royalties to be paid for the licensed IP. These considerations collapse into three significant issues: the importance of the patented invention to the product and market demand, the historical royalty rates for similar licenses and expert testimony regarding the patent's value.

In the absence of guideline license agreements, there are four other methods for determining reasonable royalties in patent licenses. These are (1) the comparable profit margin method, (2) the differential income method, (3) the profit split method, and (4) the R+D costs and savings methods. The Comparable Profit Margin Method calculates reasonable royalties by subtracting the infringer's standard profits from his actual internal profits at the time of the infringement. The Differential Income Method compares product profitability with and without the patent-in-suit to calculate the differential income, which is then divided by the patent owner's annual revenue to determine a reasonable royalty. Profit split methods such as the Nash Bargaining Solution may be used in the absence of

[68] See 35 US Code Section 284.
[69] EPC, Art. 64, § 2, states that any infringement of a European patent will be prosecuted under national law.
[70] See Goldscheider et al., 2002, pp. 123-124.
[71] The landmark 1970 decision in *Georgia-Pacific Corp. v. United States Plywood Corp*. established the criteria.

guideline licensing agreements. However, district courts are reluctant to admit its use in this field for two reasons. First, damages experts often fail to apply specific case facts to their calculations. Second, the model is mathematically sophisticated, which makes it hard to explain to juries how the premises of the theorem apply to the facts of the case. Lastly, the R+D costs and savings Method base reasonable royalties on R+D expenditures, cost savings, and other patent-related benefits.

On the other hand, existing regulations regarding patent licensing are referred to as antitrust laws. In general, antitrust laws prohibit unlawful business practices and mergers. The court considers whether the terms of the cross-licensing agreement violate these laws by restricting competition or creating a monopoly, among others. The laws and regulations that govern the negotiation of patent cross-licenses range by jurisdiction. Moreover, they are complex and subject to interpretation, which can vary depending on the specific circumstances of a case. Some of the best-known antitrust laws are:

- ***European Competition Law***, which includes the Treaty on the Functioning of the European Union (TFUE), especially articles 101 and 102, and the EU guidelines on the licensing of intellectual property. Also, the European Commission provides guidelines on the application of Article 101 TFUE that must be followed.
- ***US Sherman Act, Federal Trade Commission Act, and Clayton Act.*** The Sherman Act (1890) prohibits IP licenses that unreasonably restrain trade or result in monopolization (e.g., agreements that restrict output, divide markets, or fix prices). The Clayton Act supplements the Sherman Act. The FTC Act (1914) authorizes the FTC to enforce the antitrust laws.
- ***Standard-Setting Organization (SSO) Guidelines***. These organizations develop technical standards for various industries, and often require that companies that participate in the process commit to licensing any relevant patents on “Fair, reasonable, and non-discriminatory” (FRAND) terms. Some other common principles of SSOs include patent disclosure, dispute resolution via arbitration or mediation, and transparency.

When patent holders appoint a patent as essential to the standard, they engage in an obligation with the SSO to commit to licensing on FRAND[72] terms. FRAND terms intend to prevent businesses that assert control over industry technical standards from engaging in licensing abuse to benefit their monopolistic position.

[72] The individual terms in the acronym represent different aspects of the licensing agreement. "Fair" refers to the underlying licensing terms, which must be competitive and not considered illegal if imposed by a dominant firm in their relative market. “Reasonable” refers primarily to licensing fees. And “non-discriminatory” refers to both terms and fees involved in licensing agreements. This last commitment requires the licensor to treat each licensee in the same manner to ensure fairness in the competitive market among existing competitors and fair barriers to entry for newcomers.

The problem with FRAND conditions is, on the one hand, that they are very vague, which makes their practical application difficult. On the other hand, FRAND terms do not apply to all cases. SEP negotiation specialists creatively use the uniqueness of their own company, market, and product to interpret what is meant by "fair, reasonable and non-discriminatory" terms. Moreover, these conditions may vary from company to company, region to region and over time. Thus, there are opportunities to take advantage of unique circumstances and arrive at FRAND license terms. Although firms usually try to negotiate FRAND rates on their own, brand litigation is increasing.

4.4. CURRENT CONFLICTS WITHIN THE PATENT MARKET.

Currently, one of the main issues affecting markets, in terms of innovation and economic growth, is the abundance of conflicts resulting from the violation of IP rights. High-complexity technology industries face a growing patent thicket, which poses a very real danger that any single product or service launched will infringe in many patents[73]. Consequently, our patent system, while generally encouraging innovation, now risks imposing an unnecessary impediment to it by enabling multiple rights owners to tax new products, processes, and even business methods. Figure 8 shows the total case count of patent litigation taken place in the United States between the years 1980 and 2020. One can observe an increasing trend in the number of cases peaking between the years 2010 and 2014. This situation coincides with the rise of the so-called patent wars.

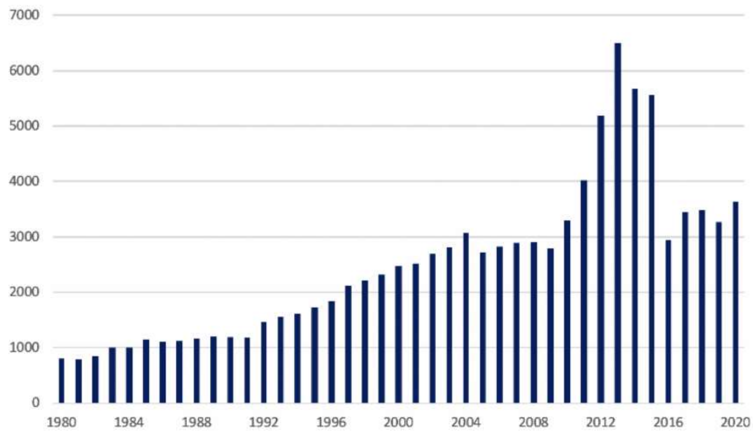

Figure 9. US Patent cases commenced: 1980 to 2020.[74]

The problem arising from patent thickets has mainly two dimensions. Shapiro (2001) calls these the complements problem and the holdup problem[75].

[73] See Von Graevenitz et al., 2007.
[74] Source: Quinn, 2021.
[75] See Shapiro, 2000.

The complements problem emerges when multiple patent holders can potentially block a given product. It can be analyzed using the same procedure Carnot developed in 1838: If a company wants to produce an item for which it needs access to two different patents, it must negotiate licenses with the respective firms. If each firm has the monopoly over their patent, the negotiation will result in in higher prices of the final product than would be if a single company controlled trade in both inventions. Thus, when multiple companies control blocking patents for a particular product, process, or business method, it harms both the consumers and producers.

Cross-licenses, patent pools, acquisitions, and cash payments in exchange for exiting the market arise as methods to solve the complements problem. These solutions involve complex negotiations over patent rights and often lead to royalty exchange agreements. However, the negotiation of royalties is not always beneficial for the parties. For instance, it is totally counterproductive if the patent was improperly granted, i.e.., if it lacked innovation or inventive step, or if the patent was too broad, covering some prior art as well as something truly new. Also, the cumulative effect of many small taxes can become quite large.

Overall, failing to solve the complements problem has several consequences. First, it magnifies the costs of static monopoly shooting prices well above marginal cost, which results in inefficiently low use of the products lowering both consumer welfare and patentee profits. Second, if a product is subject to economies of scale, these burdens may hamper its production. Third, the prospect of paying royalties reduces the incentive to design and develop new products. In other words, it stifles innovation and the commercialization of new techniques.

On the other hand, the second issue caused by patent thickets is patent holdup. The holdup problem arises in industries with a high flow of patent applications where the manufacturer has already designed its product and placed it into large scale production before the patent issues. In this case, the manufacturer is in a far weaker negotiating position because he is highly susceptible to holdup by the patentee. Holdup issues increase in the presence of royalty stacking, which occurs when a single product infringes on many patents and consequently bears multiple royalty loads. In this setting, procedures often employed by courts to determine fair royalties might perform poorly, resulting in the overcompensation of patent owners.

The key to the holdup problem is that the current patent system does not provide early-stage information about patents likely to issue, and that parties can challenge patents at the respective Patent and Trademarks Office before they have issued. This makes this problem harder to solve, since it will probably require changing the patent system itself.

In light of the above, the most feasible solution to navigate the web of overlapping patents involves unraveling the complements problem. As we have already stated, this problem emerges when multiple patent holders can potentially block a given product. In this situation, imagine that an applicant wants to file a patent through the Patent Office. The OPM will prepare the Patent Search Report[76] , which references any previous documents that infringe the patent's requisite of novelty while pointing at the specific claims[77]. If the report shows that no claims are affected by prior documents, or if the mentioned documents belong to patents registered more than 20 years ago or patents that have not paid the fees, the applicant will receive approval for the registration.

On the contrary, if any documents in force affect the core claims of the patent, the applicant will propose the other party to negotiate either a cross-license agreement, or a patent pool agreement. Once the applicant proposes the negotiation of a cross-license or patent pool, the parties involved will either accept or reject the offer. In the case of rejection, the applicant may propose the purchase of the licenses of the companies. If this offer is accepted, both parties will negotiate royalty payments. Otherwise, there will be no exchange of Industrial Property[78]. Overall, during this process the applicant will encounter coordination costs, e.g., the interaction between private and public interests, and high antitrust sensitivities that will want to know how consumers are affected by any agreement. Several studies propose conducting transactions using blockchain technology to ensure transparency[79].

4.5. Patent Cross-licensing Agreements.

A patent cross-license is a legal agreement between two firms that grant each the right to practice the other's patent. This arrangement is commonly observed in industries with a high degree of technological innovation, such as the semiconductor, telecommunications, and software industries, where new product development often necessitates integration of distinct complementary technologies from different firms. In this context, each firm possesses a technology that only holds value when combined with technologies from other participating firms. The negotiation of patent cross-licenses involves agreeing on a royalty or up-front payment to offset the net balance each party must pay to the other. This amount equals the difference between the royalty payable on the higher-value portfolio and the royalty on the lower-value portfolio.

[76] cf. Chapter 2.
[77] cf. Chapter 2.
[78] See Lorente Gómez, 2019.
[79] See Lorente Gómez, 2019.

Cross licensing arises to solve Shapiro's complements problem. The choice between negotiating a patent cross-license and a patent pool depends on the amount of technology shared. If several patents in a company intersect at the same level with the applicant's patent, then it is preferable to propose a cross-license with financial consideration for the remaining patents.

On the other hand, if these patents' documents are less relevant and belong to different companies, the applicant would need to negotiate a cross-licensing agreement with all the patents altogether. Hence, a patent pool would be preferable. Regarding the rights transfer, the main difference between a cross license and a patent pool is that the latter does not enable just the two patent holders to share their IP rights, but also other firms. Thus, coordinating such licensing can result in lower royalty rates than if the two companies' patents were priced independently. Figure 7 depicts the difference between a non-pooling situation and a pooling situation in which all blocking patents are licensed as a package.

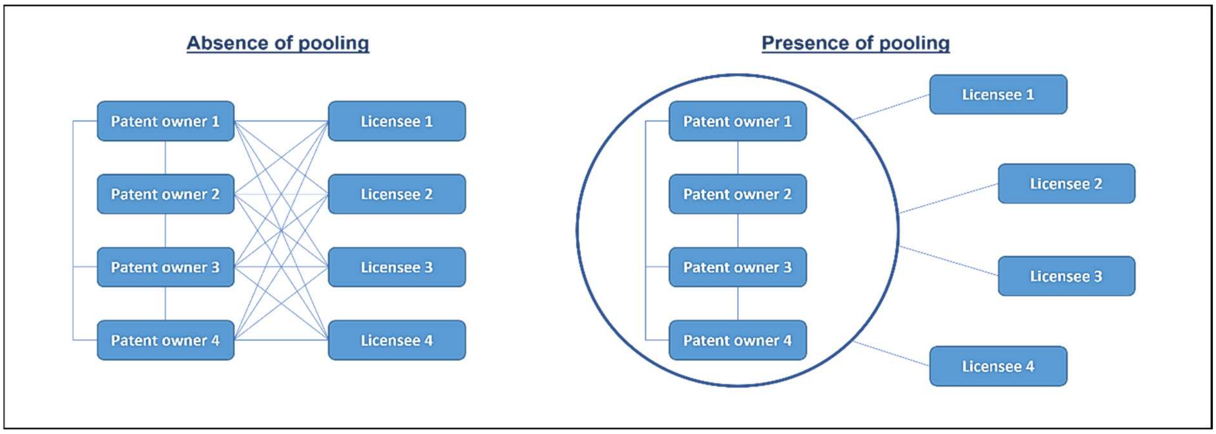

Figure 10. A situation in absence of pooling vs. the same situation with a patent pool.[80]

At present, cross licenses are the preferred means by which large companies clear blocking patent positions amongst themselves, as they enable each firm to compete freely. They are the norm in many industries, such as markets for the design and manufacture of microprocessors. Patent cross licenses have the following characteristics. First, cross licenses may or may not include fixed fees or running royalties. Companies frequently negotiate an upfront balancing payment equal to the difference between the royalty for the most valuable portfolio and the royalty for the least valuable one. Second, cross licenses may have various field-of-use geographic restrictions. Third, they may result in carve-outs. And fourth, cross licenses can be limited to patents issued (or are pending) as of the date of the license, or they can include patents that will be granted several years into the future[81].

[80] Source: prepared by the author based on data from Invntree, 2021.
[81] See Shapiro, 2000.

The main advantages of patent cross licensing are the following. First, they can help companies save money by avoiding litigation costs associated with patent infringement lawsuits and costs associated to the development of complementary technology. Second, they give access to new technology that the company may not have developed in-house, which introduces earlier the final product and realization of profits. Third, they encourage innovation. And, finally, access to patented technology through cross licensing can provide a competitive advantage over rivals.

On the other hand, traditional concerns with cross licenses among competitors include the creation of a rival provider of the final product, the usage of running royalties as a device to increase prices and effect a cartel, and the reduction of each company's incentive to innovate due to the possibility of imitating the other company's future improvements. Other potential drawbacks to parties involved in a cross license are limited access to the patented technology, the potential loss of control over the company's IP, the complex negotiation process, and an increased risk of infringement by third parties. In addition, some of the side effects that the licensing agreement could have for third-party companies include: restrictions on free competition due to the integration and collaboration of the companies; price fixing, as the two parties would have a kind of monopoly; potentially abusive dominant positions, where a new company in the sector would find it almost impossible to penetrate the market and compete against that large coalition; and the exclusion of small start-ups without many patents from the market, which could be absorbed by giants in the sector, turning the market into monopolies or oligopolies.

4.6. CONCLUSION.

This chapter aims to answer the questions: "how much should a licensee pay for the licensor's patent?" and "what rights does the license confer to the licensee?". To this effect, a comprehensive literature review has been conducted on the elements involved in a patent license negotiation, the algebraic and economic models proposed to model such agreements, and the existing practices and regulations in the field. The literature review allows for the conclusion that there are limited models that specifically analyze the agreement between a licensor and licensee. Also, the existing models are often tailored to specific scenarios, lacking standardization up to the present time. Subsequently, current issues in the intellectual property market have been described, underscoring the importance and the necessity of patent cross-licensing contracts. Finally, the chapter includes an overview of patent cross-licensing, including its advantages and disadvantages.

Following the gaps observed in the State of the Art, the objective of Chapter Four is to develop an algebraic model to optimize the net royalty in patent cross-licensing agreements.

CHAPTER 4: DEFINING THE "SIEGLINDE GAME"

Obtaining a patent cross-license involves several steps. First, the patent owner, aware of the blocking he suffers from infringing another's IP, must identify the companies with which he is in conflict. In addition, the patent owner must ascertain whether the blocking with these companies is mutual, that is, to find pairs. Second, the patent owner must assess whether he is interested in negotiating a cross-license with any pairing company. Finally, the patent owner must negotiate the net royalty to be exchanged with each counterparty.

Chapter 3 presented several algebraic models focused solely on determining the optimal royalty exchange for a product. However, on multiple occasions, conflicting patent holders do not reach that negotiation stage. This situation arises for many reasons, such as the scarcity of means to choose the best entity to negotiate with, the long duration of the process, or impending litigation.

Thus, this chapter provides a model that optimizes patent cross-licensing, taking advantage of the gaps in the literature reviewed: "The Sieglinde Game". The main objective of the model is to streamline the process of obtaining a patent cross-license, covering the three stages abovementioned. Therefore, rather than focusing on an algebraic model that exclusively determines the optimal net royalty between two patent owners, a comprehensive two-phase model is developed, which brings together computation and algebra. In the first phase, the identification of patent corrals is automatized through optical character recognition techniques and graph models. In the second and third phases, Game Theory is used to design an optimization problem to determine the utility of each party in the negotiation and optimize the net royalty. Finally, the chapter integrates the model's decision tree for illustrative purposes.

4.1. DISCUSSION OF MODEL DEVELOPMENT APPROACHES

In the pursuit of constructing an effective model capable of addressing the intricate dynamics of mutual patent disputes within an industry, this section delves into exploring potential avenues for model development. The model's core objective remains to identify the optimal pair of companies interested in negotiating cross-licensing agreements to mitigate litigation risks while determining the equitable and non-excessive royalty exchange, thereby favoring this cooperative path over litigation.

The first route that was explored for model development was the utilization of machine learning's neural networks. The allure of neural networks stems from their capacity to unravel intricate relationships in complex datasets, potentially illuminating insights that are challenging to discern through traditional methodologies. In this context, a neural network could be structured to receive inputs that encapsulate pivotal variables such as patent portfolios, technological landscapes, and potential negotiation terms. These inputs are then processed through interconnected layers, embodying the essence of the complex interactions between companies. Through iterative adjustments, the network endeavors to minimize errors and converge upon accurate output estimations, analogous to the intricate puzzle of patent licensing negotiation.

However, it was discovered that following a neural network approach currently grapples with a practical challenge. The patent data, essential for constructing and training the network, resides within PDF documents hosted on virtual servers of patent offices. Accessing, preprocessing, and structuring this data present formidable hurdles. Neural networks, being adept at learning patterns from vast data, face a substantial roadblock due to the unstructured nature of the dataset.

Given these constraints, the model's development will pivot towards an algebraic and, to a degree, traditional computational methodology. In contrast to neural networks, this approach follows a one-way trajectory from input to output. Inspired by game theory's principles, this model shall draw insights from strategic interactions, considering the delicate balance between companies' interests and their decisions to engage in cross-licensing agreements.

In essence, while the aspiration to harness the predictive prowess of neural networks remains steadfast, the present practicality directs the development towards a more traditional yet robust computational model. Drawing upon the well-established theoretical foundations of game theory and leveraging the insights derived from the neural network approach, this alternative path holds the promise of shedding light on the complexities of mutual patent disputes and steering companies toward cooperative resolutions.

4.2. Basis for the Model Approach.

This section reviews the existing techniques and models on which the model is built. The following concepts are described in depth: optical character recognition techniques, graph models, and the NSNBS model presented in Chapter 3 as the asymmetric generalization of the Nash Bargaining Solution, the cornerstone of Game Theory. The first two concepts will be central to the computational design of the model, while the latter concept constitutes the algebraic dimension of the model.

It is worth mentioning that the design of the OCR technique described in this section is out of scope of the Project; an existing one will be used. However, it is relevant to depict the technique in this chapter since it is the starting point in obtaining the database on which the model can be applied.

As discussed in Chapter 3, high-complexity technology industries face a growing patent thicket. Patent thickets hinder the probability of success of a company in bringing a new product or service into the market, for there is a real possibility that the product will infringe on another competitor's IP and be blocked. Globalization and digitalization have contributed to the boom of patent granting in the last two decades by conferring public access to intellectual property data and speeding up administrative timeframes. Thus, the speed at which offices approve patents nowadays is an obstacle to keeping track of the patents that a company's activity infringes on and vice versa. Therefore, it is common for proprietors to abandon new product lines or enter litigation rather than venture into patent cross-licensing negotiations, with the risks this entails.

Considering the above, optimizing cross-licenses first involves facilitating the collection of patent data at a national, continental, or international level, depending on where the invention will be developed or commercialized. Currently, most patent offices provide free public access to all published documents relating to patents registered in them. For each patent, the application memorandum, the prior art search report, the receipts for the payment of fees, etc., are kept.

The key issues of these data sites are, on the one hand, that there are multiple documents for each patent and, on the other hand, that these documents are in pdf format. Consequently, to obtain an overall view of the IP in the market sector of interest to the owner, it is currently necessary to review several documents for each patent and extract the relevant data manually. Hence, this study first addresses the problem of extracting and processing information from pdf files.

The information contained in portable document format (pdf) documents is difficult to handle and synthesize. Therefore, different character recognition techniques have been developed to extract non-selectable text from documents, such as neural networks, OCR techniques, and correlation between objects by identifying edges using the Fourier transform. Among them, Optical Character Recognition (OCR) has offered superior results. Its computational procedure has several stages:

First, an image must be captured by camera shooting, document scanning, etc. The method for obtaining the image is substantive because it defines how well the characters are recognized.

Second, the image is binarized by giving each of its pixels a value of either 0 or 225 for black and white colors, respectively. The pixel separation criterion depends on the binarization threshold value. If these values are less than or equal to the threshold, they will be substituted by zeros. Otherwise, the values will turn into ones. Binarization allows shadows, dots, and image gradients to be cleaned up. However, if the threshold is too high, the image may be too light and relevant information may be lost. Conversely, if the binarization threshold is too low, most of the picture will turn black.

Third, the matrix of ones and zeros resulting from the binarization is segmented or labelled through the Hoshen-Kopelman algorithm application[82]. This algorithm groups the independent clusters of ones that delimit the image characters by assigning a different number to each group. Each group of numbers represents one character. Labelling the image is the most expensive process in OCR techniques. In many cases, labelling methods provide poor quality or high memory consumption.

Fourth, the information for each character must be made independent and normalized. Hence, the coordinates of the vertices defining the minimum rectangle containing the cluster must first be found and extracted. Subsequently, the rectangular pattern is normalized to achieve a square picture.

Finally, a skeletal algorithm thins each square character. The resulting figure is formed only by the pixels necessary for character recognition. Subsequently, the thinned matrix is compared with pattern characters through a horizontal and vertical trace projection model.

In conclusion, OCR techniques can be used to extract non-selectable text from pdf documents. This text can be filtered and sorted to draw relevant information from patent documents through regular expressions to search for patterns in text strings. The following figure graphically shows the process OCR follows to extract non-selectable text from a pdf document:

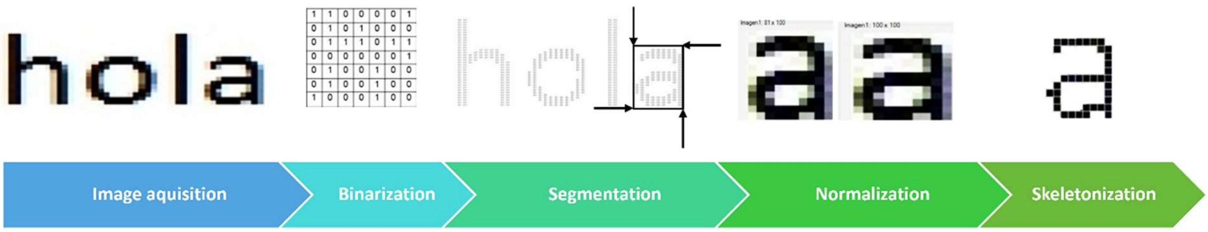

Figure 11. Process of OCR techniques[83].

A second issue to consider is how to present the filtered information so that the user can easily interpret those companies with patents that conflict with his own. It should not be forgotten that the volume of patents published annually in complex technology industries is heavy. Therefore, in addition to extracting the relevant information from each patent document, it is advisable to devise a system that shows the user the data collected clearly and orderly. This data can be constituted by the companies owning the patents with which there is a conflict, the times these companies are mentioned in prior art reports, the scope of use and filing date of their patents, etc. The presentation of the information is not unimportant since it is not helpful to possess data if you cannot interpret it. The automation of this task can be carried out by implementing a graph model.

[82] See Medina et al., 2018.
[83] Source: prepared by the author based on data from Medina et al, 2018.

Graph models are based on mathematical Graph Theory. A graph $G = (V, E)$ is a pair formed by two non-empty sets: V and E. Set V is a finite set of vertices, while E is a set of edges represented by the couple vertices it joins (u, v)[84]. Ways to classify a graph attend to its order, cycles, or direction.

A graph's order labels it as a simple graph, multigraph, or pseudograph. The graph's G order is the number of elements in the set of vertices V. Furthermore, for each vertex u in V, the number of edges leaving or arriving at v is called the degree of v, denoted $\deg v$. The graph will be said to be simple if two vertices of V connect by one edge at most, multi if two vertices connect by more than one edge, and pseudo if the same edge departs from and returns to the same vertex.

Concerning the nature of its cycles, a graph can be Eulerian, Hamiltonian, or a tree. A connected graph is Eulerian if it includes a closed cycle that connects all vertices. A connected graph is Hamiltonian if it passes through each vertex only once, except for the first and last vertex. Last, a connected graph is a tree if it has no cycles, that is, if there is a single path between two vertices that joins them without repeating vertices. The following figure shows these three graph types:

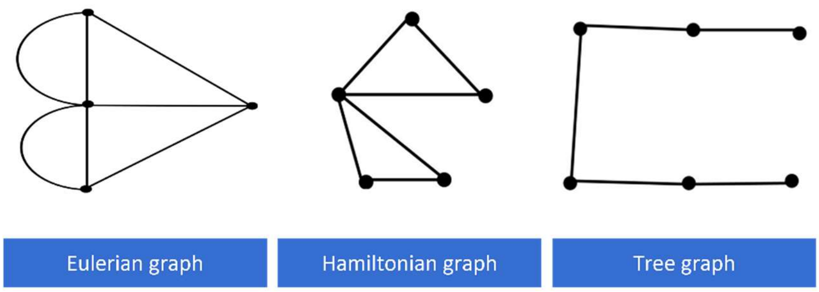

Figure 12. Classification of a graph regarding the nature of its cycles.

Last, a graph can be directed or undirected depending on the direction of its edges. A directed graph has unidirectional edges, which are bidirectional in the case of an undirected graph.

There are different ways of storing graphs on a computer. The choice between data structures depends both on the graph's characteristics and the algorithm used to manipulate it. The most straightforward and commonly used frames are lists and arrays, although a combination is often employed to store data. Lists are preferred in sparse networks because they are memory efficient. On the other hand, arrays provide fast access but can consume large amounts of memory.

Nevertheless, in both cases, it is necessary to choose an algorithm that helps to determine the location of each node in space and the optimal way to connect them according to the specifications. The most common positioning algorithms are: the Depth-first search algorithm (DFS) and breadth-first

[84] See S. Lipschutz and M. L. Lipson, 2009.

search algorithm (BFS); the Frutcherman-Reingold algorithm, which distributes the nodes in space according to the forces of attraction and repulsion between them; the Dijkstra and Bellman-Ford algorithms, which determine the shortest path in weighted degrees, and the Kruskal and Prim algorithms, which find the minimum spanning tree in undirected weighted graphs with labelled edges.

In conclusion, computational graph design facilitates the interpretation of the information enclosed in hundreds of patent documents, which facilitates decision-making.

Once the user knows about the patents with which he is in conflict, he can decide for or against negotiating a cross-license with a particular entity. If he chooses to bargain, he will enter a royalty exchange agreement. Chapter 3 reviewed multiple methods to optimize these exchanges. After weighing the contributions of each, the Non-Assymetric Nash Bargaining Solution (hereinafter, NSNBS), pursued by Kalai and Smorodisnki from Nash's proposal, is chosen as the basis for our model.

The NSNBS model is based on the Nash Bargaining Solution, developed by John F. Nash in 1950. It considers a two-person negotiating game in which two individuals can interact for mutual advantage in more than one way. No action made by one of the individuals without the approval of the other can have an impact on the other's well-being. The game provides a unique solution based on the following axioms:

- ***Individual rationality***: no party will agree to accept a payout less than the one guaranteed to it under the terms of the agreement.
- ***Pareto optimality***: no party can be improved without making at least another worse off.
- ***Symmetry***: The agreement should not differentiate between the parties should they be indistinguishable.
- ***Affine transformation invariance***: an affine transformation of the payoff and disagreement point should not affect the bargain's outcome, which ensures that the solution is robust to changes in the payments' scale or unit of measurement.
- ***Monotonicity***: every utility level demanded by player 1 enhances the maximum practical utility level that player 2 can simultaneously achieve. As a result, the utility level allocated to player 2 should also be enhanced. This axiom requires that the utility gains be proportional to the maximum profits that both players can achieve.

The Monotony axiom arises from several authors criticism to the Independence of irrelevant alternatives axiom defined in the NBS, which provided a very symmetric solution to an asymmetric game under certain contexts. The axiom of Independence of irrelevant alternatives states that all threats the parties might make are accounted for in the disagreement payoffs.

The Non-Symmetric Nash Bargaining Solution model presents the following structure:

Let d_1 and d_2 be the normalized disagreement payoffs for party 1 and party 2[85]. Let α and $1-\alpha$ represent the bargaining weight of party 1 and party 2, respectively, which quantifies their influence in the negotiation and decides how the parties split the surplus from the contract. The parties' utilities π_1 and π_2 are obtained from the constrained maximization problem:

$$(u_1 - d_1)^{\alpha}(u_2 - d_2)^{1-\alpha} \tag{1}$$

Subject to the following conditions:

$$u_1 \geq d_1 \tag{2}$$

$$u_2 \geq d_2 \tag{3}$$

$$\alpha \geq 0 \tag{4}$$

$$0 \leq d_1 + d_2 \leq 1 \tag{5}$$

The maximum payoff distribution occurs when:

$$\begin{cases} (1-\alpha)(u_1^* - d_1) = \alpha(u_2^* - d_2) \\ u_1^* + u_2^* = 1 \end{cases} \tag{6}$$

The result is obtained by solving for the optimal profit distribution:

$$\begin{cases} u_1^* = d_1 + \alpha(1 - d_1 - d_2) \\ u_2^* = d_2 + (1-\alpha)(1 - d_1 - d_2) \end{cases} \tag{7}$$

The following figure shows graphically the asymmetric solution of the Nash equilibrium:

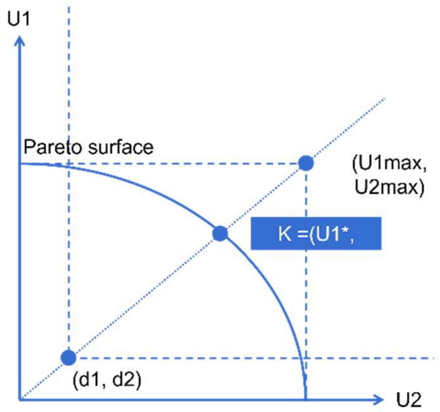

Figure 13. Graphic solution for the NSNBS model[86].

[85] The disagreement payoffs are the opportunity costs of striking the deal, that is, gains from a hypothetical negotiation which could have occurred if the parties had not reached a deal.
[86] Source: prepared by the author based on data from Kalai et al., 1975.

4.3. THE SIEGLINDE GAME.

The mathematical model developed in this section is named the "Sieglinde Game." Following the Wagnerian theme, Sieglinde is a character from the opera "Die Walküre", which embodies the pursuit of balance and reconciliation amidst conflicts[87]. Just as the model seeks equilibrium between two patent-holding companies in mutual infringement disputes and advocates for a fair solution through cross-licensing negotiations, Sieglinde symbolizes the union and reconciliation of two seemingly opposing worlds. Analogously, much like Sieglinde becomes a link for uniting contrasting forces in the opera, the model aims to find an optimal royalty agreement that fosters cooperation rather than protracted and costly litigations.

Let (N, S_j, φ_j) be a rectangular game, consisting of N players, and S_j strategies for each player i. The payoff assigned to player i according to the strategy S_j^i is determined by the payoffs function:

$$\varphi_j : \prod_{i \in N} S_j^i \to \mathbb{R}. \tag{8}$$

Let $\{C_1, C_2\} \in N$ be two companies holding a large portfolio of patent rights, p_{C_1} and p_{C_2}. The firms compete in the same high-complexity technology market sector, k, characterized by the presence of patent thickets of density ρ_k. The companies face each other repeatedly to maximize their respective profits until they reach a deadlock situation, in the face of which they can develop two main strategies, $\{S_1^i, S_2^i,\} \in S^i$. These strategies are: (1) not to cooperate either by infringing the competitors' IP at the risk of being involved in litigation or by abandoning the product line, and (2) to cooperate by negotiating a cession of use agreement, e.g., a patent cross-license.

The game takes place in the absence of perfect information, were the companies make decisions simultaneously in two stages.

FIRST STAGE: IDENTIFICATION OF PATENT CORRALS.

In the first stage of the model, a single patent-owning company C_i belonging to a market of technology k is involved. This phase focuses on determining the patent corrals of which the firm is a part, which provides an estimation of patent thickets' density in the market.

A patent corral of m companies in market k, G_k, consists of a group of patent rights owned by several firms unilaterally or bilaterally locked in a particular industry. The patent corrals affecting firm

[87] See Wikipedia, 2023.

C_i are influenced by the scope-of-use classification of C_i's patents k_i, their filing or priority date[88] t_i, and by the X-references (x_i) and Y-references (y_i) to competitors' patents in the patent search report. To avoid endogeneity in the model, the X and Y references to these patents will be combined and replaced by the total references to the owner companies C_{m-1}.

In conclusion, $G_{k_{C_i}}$ of size m is determined by all competing patent-owner companies C_{m-1} referenced in the search report of those patents owned by C_i that share the first three figures of the IPC classification code, k_i, and whose patents have not expired, attending to their priority date, t_i.

The patent corral of m companies designed for company C_i in market k can be expressed as the simple, directed graph $G_k = (C_m, E_{m-1})$ of $(m-1)$ order, where the nodes $\{C_1, \dots, C_m\} \in C_m$ are the companies integrated in the patent pool and the edges E_{m-1} represent the number of unilateral or bilateral connections between these companies. The edge labels, $\{p_{C_2}, p_3, \dots, p_{C_{m-1}}\} \in L_{m-1}$, represent the number of times the central node mentions the peripheral node to which a particular edge is attached.

In this graph, the adjacency relationships between nodes are defined by the following adjacency matrix, $A_{m\times m}$:

$$A_{m\times m} = \begin{pmatrix} 0 & 1 & 1 & & 1 \\ 1 & 0 & 0 & \cdots & 0 \\ 1 & 0 & 0 & & 0 \\ & \vdots & & \ddots & \vdots \\ 1 & 0 & 0 & \cdots & 0 \end{pmatrix} \tag{9}$$

On the other hand, the directed graph's incidence matrix, $M_{m\times(m-1)}$ is as follows:

$$M_{m\times(m-1)} = \begin{pmatrix} 1 & 1 & & 1 \\ -1 & 0 & \cdots & 0 \\ 0 & -1 & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & -1 \end{pmatrix} \tag{10}$$

The following figure shows the graphic representation of patent pool $G_k = (C_m, E_{m-1})$:

[88] The patent's filing date is essential if determining patent pools, as patents expire 20 years from that date. Therefore, it may be that the patents referenced in the search reports have already expired by the time they want to license. The filing date is particularly relevant in regions where the patent registration process follows first-to-file system. Conversely, the priority date is paramount in regions governed by a first-to-invent system.

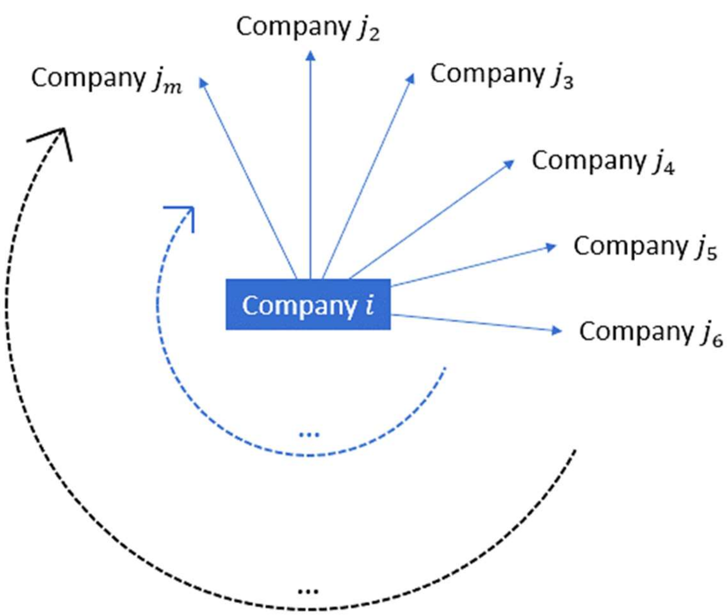

Figure 14. Graphic representation of a patent pool[89].

On the interpretation of the graph, we can draw the following general conclusions: first, the higher the number of nodes, the higher the degree of technological complexity in the market of technology k; second, the edges with the largest label value lead to the companies in most conflict with C_i; and third, the comparison between graphs made for different companies will provide us with the number of doubles and triples in the market. Hence, firm C_i will be most interested in evaluating the possibility of negotiating a cross-licensing of patents with those companies with which it has a bilateral connection, and which have the largest portfolios of affected patents. This company, C_j, is:

$$C_j = \left\{ C_j | L_{C_j} = \max(L_{m-1}), M_{i^*j^*}^{C_i} = M_{i^*j^*}^{C_i} \right\} \quad (11)$$

SECOND STAGE: DETERMINATION OF AN OPTIMAL ROYALTY.

The second stage of the model involves two companies, C_i and C_j, which intend to negotiate a patent cross-license. The objective of this stage is to obtain an optimal royalty exchange between the two companies, constrained by the red lines set by each party.

The model satisfies the axioms of individual rationality, pareto optimality, symmetry, affine transformation invariance, and monotonicity. Moreover, it is based on the following hypotheses:

[89] Source: prepared by the author on May 20, 2023.

<u>Hypothesis 1</u>: Firms i and j compete in the market under Cournot's imperfect competition model, i.e., they compete for the quantities produced of similar or substitute goods until they reach the Nash equilibrium. Each firm tries to optimize production (Q) in units according to what the competition decides to produce, to maximize revenues so that:

$$Q_i = f(Q_j) \tag{12}$$

$$Q_j = g(Q_i) \tag{13}$$

$$\left(Q_i^*, Q_j^*\right) = \left\{\left(Q_i, Q_j\right) \mid f\left(Q_j\right) = g(Q_i)\right\} \tag{14}$$

<u>Hypothesis 2</u>. Reaching a patent cross-licensing agreement means increased revenues for both companies involved $(\overline{\pi}_i, \overline{\pi}_j)$. Let the expected total revenue surplus be $\left(\overline{O}_{R_{ij}}\right)$, and let $\left(\overline{O}_{C_{ij}}\right)$ be the expected combined cost to produce and sell the products derived from the cross-license. Then, the annual profit surplus $\left(\overline{O}_{I_{ij}}\right)$ and the profit margin ratio $\left(\overline{O}_{M_{ij}}\right)$ resulting from the game are:

$$\overline{O}_{R_{ij}} = \overline{\pi}_i + \overline{\pi}_j \tag{15}$$

$$\overline{O}_{I_{ij}} = \overline{O}_{R_{ij}} - \overline{O}_{C_{ij}} \tag{16}$$

$$\overline{O}_{M_{ij}} = \frac{\overline{O}_{I_{ij}}}{\overline{O}_{R_{ij}}} \tag{17}$$

<u>Hypothesis 3</u>. If a company i adopts a cross-licensing agreement with a company j, they will agree on a royalty payment (r^*) over the expected operating revenue $\left(O_{R_{ij}}\right)$ surplus resulted. The company that obtains the most use from reaching the agreement will pay the company that earns the lowest use an amount proportionate to the utility distribution (u) in the game. In addition, the royalty amount will fall between the resistance point or minimum price $(\underline{r})$ and the breakpoint or maximum price $(\overline{r})$ agreed by the companies at the beginning of the negotiation. Therefore:

$$r\ (\%) = f\left(u_i, u_j\right) = f(O_R) \tag{18}$$

$$\underline{r} < r < \overline{r} \tag{19}$$

<u>Hypothesis 4</u>. For a royalty to be optimal, both parties must obtain a larger benefit from cooperating than they can gain on their own without cooperating. That is, each company's profit resulting from the game $(\overline{\pi}_i)$ must be greater than its opportunity cost (d_i):

$$\overline{\pi}_i \geq d_i \tag{20}$$

$$\overline{\pi}_j \geq d_j \tag{21}$$

The variables which determine optimal royalty sharing resulting from a negotiation are each of the companies' opportunity costs (d_i, d_j) and bargaining power (α).

The opportunity cost of each party, d_i is the benefit sacrificed by choosing one option over another available alternative. In this game, the alternatives to a cross-licensing negotiation for IP infringement are to abandon the product line $\left(d_{i_1}\right)$ or face litigation $\left(d_{i_2}\right)$.

The annual opportunity cost from abandoning the product line is the company's average operating income before launching the product that infringes the competitor's IP $\left(\overline{O}_{I_i}\right)$. Therefore:

$$d_{i_1} = \overline{O}_{I_i} \tag{22}$$

On the other hand, the annual opportunity cost of company i from taking legal action depends on the average annual legal costs incurred $\left(\overline{L}_i\right)$, and the expected net compensation that firm i might receive due to the other firms' infringement $\left(\overline{W}_i\right)$. The annual compensation covers the profits obtained by company j because of the infringement $\left(\overline{D}_j\right)$, the loss of useful life of the company i's patents throughout the trial $\left(\overline{E}_i\right)$, and the legal costs incurred by company i $\left(\overline{L}_i\right)$; each divided by its respective number of years. Hence, the opportunity cost of taking legal action is defined as follows:

$$d_{i_2} = \overline{D}_j + \overline{E}_i \tag{23}$$

Let β_i be the probability of firm i abandoning the product line and $(1 - \beta_i)$ the probability of the firm pursuing litigation. Consequently, the normalized opportunity cost (d_i^+) is thus denoted by:

$$d_i^+ = \frac{\beta_i \overline{O}_{I_i} + (1-\beta_i)(\overline{D}_j + \overline{E}_i)}{\overline{O}_{I_{ij}}} \tag{24}$$

The sum of the normalized opportunity cost for each company cannot exceed one. In that case, a deal could not be made because there would not be enough profit to give each party their opportunity cost. Therefore:

$$0 \leq d_i^+ + d_j^+ \leq 1 \tag{25}$$

On the other hand, the bargaining power, α, depends on both the ease of alternatives to licensing and the useful life of the patents in its portfolio. The ease of alternatives to licensing depends directly on the size of the company's portfolio that is subject to the negotiation $\left(p_{C_i}\right)$. The useful life of the patents in the portfolio depends on the average filing date of the patents $\left(\overline{t}_{C_i}\right)$. Therefore, the bargaining power of firm i (α) is defined as follows:

$$\alpha = \frac{p_{C_i}\bar{t}_{C_i}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}} \tag{26}$$

From this equation, we obtain the bargaining power of firm j $(1-\alpha)$:

$$1-\alpha = \frac{p_{C_j}\bar{t}_{C_j}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}} \tag{27}$$

Applying the asymmetric Nash equilibrium solution from Equation (7), the surplus partition generated by technology-sharing benefits in this game is determined by the following equations:

$$u_i^* = \frac{p_{C_j}\bar{t}_{C_j}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}}\left(\frac{\beta_i\overline{O}_{I_i}+(1-\beta_i)(\overline{D}_j+\overline{E}_i)}{\overline{O}_{I_{ij}}}\right)+\frac{p_{C_i}\bar{t}_{C_i}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}}\left(1-\frac{\beta_j\overline{O}_{I_j}+(1-\beta_j)(\overline{D}_i+\overline{E}_j)}{\overline{O}_{I_{ij}}}\right) \tag{28}$$

$$u_j^* = \frac{p_{C_i}\bar{t}_{C_i}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}}\left(\frac{\beta_j\overline{O}_{I_j}+(1-\beta_j)(\overline{D}_i+\overline{E}_j)}{\overline{O}_{I_{ij}}}\right)+\frac{p_{C_j}\bar{t}_{C_j}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}}\left(1-\frac{\beta_i\overline{O}_{I_i}+(1-\beta_i)(\overline{D}_j+\overline{E}_i)}{\overline{O}_{I_{ij}}}\right) \tag{29}$$

In these equations, u_i^* and u_j^* represent the utilities or payoffs that companies i and j obtain by reaching a cross-licensing agreement, relative to the total profit expected from patent-sharing. In other words, the utility distribution refers to the level of satisfaction that each player receives when the game reaches the Nash equilibrium in an asymmetric game. The utility resulting from solving this model has no units, it must be interpreted fractionally.

Four important conclusions can be drawn from equations (28) and (29). First, the greater the value of company i's portfolio compared to company j's, in terms of number of patents and their useful life, the lower the utility that company i obtains from the agreement. Second, the minimum that each firm is willing to accept as a payoff from the agreement is its opportunity cost, i.e., the benefit that the firm would obtain if it chose an alternative other than negotiating. Third, the higher the IP infringement of company j, the higher the opportunity cost of company i, and vice versa. Fourth, the profit remaining from both opportunity costs is split according to each company's bargaining weight.

After determining the utility distribution among the parties involved in the cross-license agreement, we can calculate the optimal net royalty to be exchanged between them. Let $r_{j\to i}$ be the unilateral royalty to be paid by company j for access to the patent portfolio from company i. Applying ***Hypothesis 2*** and ***Hypothesis 3***, we obtain:

$$r_{j\to i} = u_i^*\overline{O}_{M_{ij}} \tag{30}$$

$$r_{i\to j} = u_j^*\overline{O}_{M_{ij}} \tag{31}$$

Consequently, the revenue payoff between the parties is distributed as follows:

$$\overline{\pi}_i^* = u_i^* \overline{O}_{I_{ij}} = r_{j\to i} \overline{O}_{R_{ij}} \tag{32}$$

$$\overline{\pi}_j^* = u_j^* \overline{O}_{I_{ij}} = r_{i\to j} \overline{O}_{R_{ij}} \tag{33}$$

Equations (28) and (29) show the flow of royalties between companies i and j, which is graphically represented as shown in Figure 15:

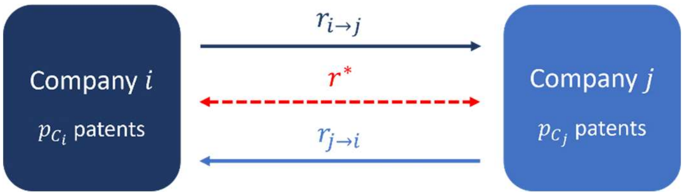

Figure 15. Royalties flow chart[90].

Let vector $\vec{r}^*$ represent the net royalty exchange from the company that obtains the most utility from the cross-license agreement to the company that obtains the least utility. Then, from Equation (30) and the figure above, the percentual net royalty amount calculated over the total revenue generated by technology-sharing is determined by:

$$r^*(\%) = |r_{j\to i} - r_{i\to j}| \times 100 \tag{34}$$

Consequently, the net royalty amount (R_{ij}) is calculated as follows:

$$R_{ij} = r^*(\%) \times \overline{O}_{R_{ij}} \tag{35}$$

4.4. The Model's Decision Tree.

Figure 16. Decision tree of the Sieglinde Game.Figure 16 depicts the decision tree for the proposed patent game. In the first stage, firm i processes and synthesizes vast volumes of information to locate firm j, with whom it is in a more severe impasse due to mutual intellectual property infringements. Then, in the second stage, an optimal royalty exchange is determined based on the Nash equilibrium of Game Theory. For the royalty to be optimal, both parties must obtain a larger benefit from cooperating than they can gain on their own without cooperating.

[90] Source: prepared by the author on May 21, 2023.

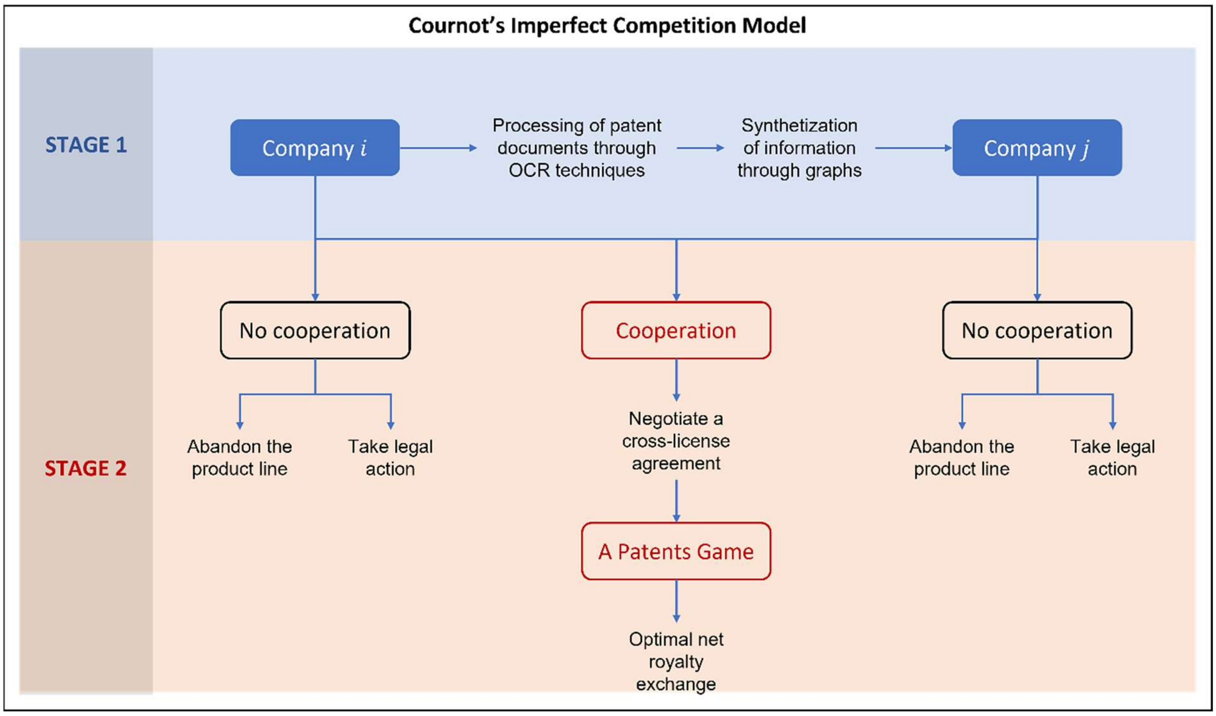

Figure 16. Decision tree of the Sieglinde Game[91].

4.5. CONCLUSION.

Chapter 4 described the state-of-the-art techniques and models that serve as the basis for proposing the Patent Game. These are the OCR techniques, the graph model, and the non-symmetric Nash equilibrium solution from Game Theory.

"The Sieglinde Game" seeks to streamline and optimize the process of obtaining a patent cross-license to boost profits and avoid IP infringement lock-in situations in technologically complex markets. The model aims to provide a net royalty that offers each party to the negotiation a larger benefit than it would obtain if it decided not to cooperate, either by abandoning the product line or taking legal action. In addition, the game assumes a Cournot model of imperfect competition, in which firms compete for the quantity produced until reaching equilibrium. Also, the model's output is a royalty calculated on the gross revenues produced due to the technology-sharing agreement.

The aim of the following chapter will be to apply the proposed model to the 5G market sector, where large companies such as Huawei and Ericsson face huge blocking situations due to the infringement of each other's patents.

[91] Source: prepared by the author on May 21, 2023.

CHAPTER 5: APPLICATION OF "THE SIEGLINDE GAME"

Chapter 5 validates the model developed in by applying it to a real scenario that falls within the current context of digitalization, 5G.

The chapter describes the conflict derived from Intellectual Property blocking in the 5G market, including the challenges faced, the measures taken to curb them and viable alternatives to these measures. The solutions inspection includes a review of the basic concepts of 5G geopolitics and the trade war between China and the United States, approaching them from the perspective of Industrial Property rights. Subsequently, the case study is introduced and solved by applying the "Sieglinde Game" developed. During the model application, each step is justified. Finally, the game results are analyzed to discover any shortcomings in the execution.

5.1. GEOPOLITICS OF 5G TECHNOLOGY.

In the 20th century, a state's power was often reflected in the strength of its industries (steel, coal, automobiles, etc.), which determined its status as a global player. However, in the digital era of the 21st century, world hegemony increasingly depends on the ability of states to control information through the creation and use of new technologies. In this context, the patent race for 5G dominance has become the center of a struggle for global hegemony.

5G is the fifth generation of wireless communications technologies and standards and forms the cornerstone of the future development of the Internet of Things (IoT). This technology offers faster connections, lower latency, and enhanced energy efficiency and network capacity to meet growing data demands and facilitate new services, such as autonomous cars, smart cities, telemedicine, drones, and artificial intelligence.

The struggle for 5G dominance is backed by strategic and economic drivers. In first place, the government that dominates 5G controls the network-contained data, which offers an advantage in intelligence and counterintelligence work to protect the country's national and international interests and potentially attack its geopolitical enemies. Second, control over the 5G network data allows a country to determine what needs are in the marketplace, thus predicting which products will sell best and shaping new industries. Third, 5G has the potential to become a globally critical infrastructure, so its implementation will be essential for countries that do not want to be left behind in the competitive market. Consequently, such countries will be at the mercy of the technology monopolistic government.

By mid-2022, the number of countries with deployed 5G networks was already around 70, led by North America, Europe, China, North Korea, and Australia, while 15 countries were beginning to implement such networks. Figure 17 shows the 5G deployment status by nation worldwide. Countries marked in dark blue are those where 5G networks are already installed; many correspond to countries where 5G technology has been developed. In light blue are marked the countries in the 5G deployment phase. Finally, states in green had signed agreements with companies developing the technology by June 2022, but implementation had not yet begun in those countries.

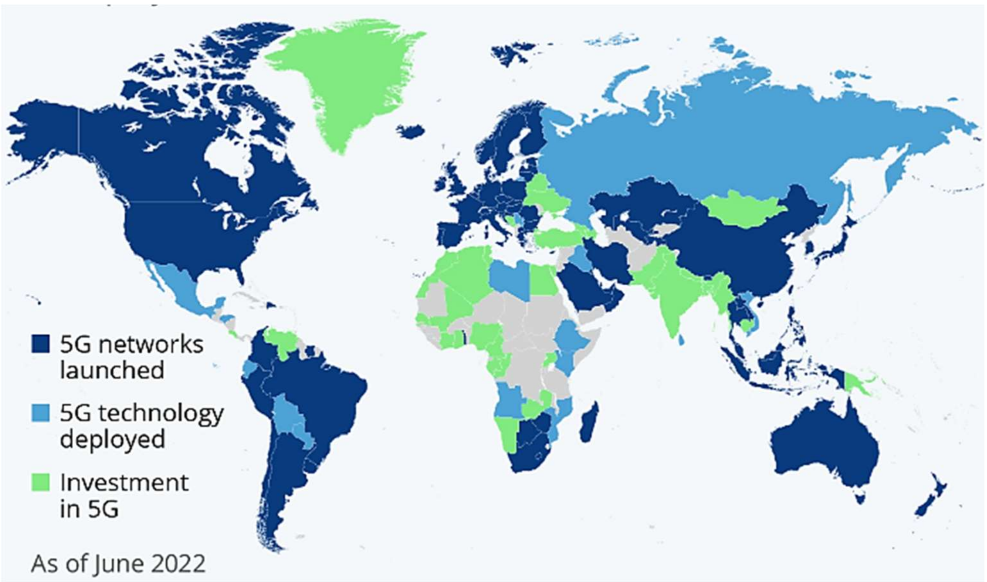

Figure 17. Status of 5G network deployment worldwide, as of June 2022[92].

The conflict over 5G technology dominance originated in the context of the trade war between the United States and China, which began in 2015 at the end of the Obama presidency and intensified under the Trump and Biden administrations[93]. This conflict revolves around the technological race of both world powers to reach the global hegemony recently held by the United States. On the one hand, the Chinese government has focused its foreign policy in recent years on achieving strategic autonomy through the "Made in China 2025" plan presented in 2015, by which it intends to stop being the world's factory and lead the production of technology-intensive goods. Following this strategy, China seeks to boost its economy and strengthen its international geopolitical presence. On the other hand, the United States, which has seen its position as the world's leading power threatened, has continuously tried to block the transfer of Chinese technology to prevent China from catching up technologically, as this would have severe economic and military implications for the US.

[92] Source: Statista, 2022.
[93] See Feas, E., 2023.

The first company to invest in the development of 5G was Huawei, a Chinese technology giant with extensive financial support from the Pekin government that provides competitive equipment at reduced prices, which has led him to hold the world's leading technology manufacturer position. Huawei's great success is based on the low prices at which the company sells its 5G products and its vertical integration structure, that lets the company offer the complete system to operators. One of the biggest challenges of 5G technology is that installing the equipment requires an extremely expensive extension of fiber optics, and many states have trouble bearing those costs. Huawei saw this challenge as an opportunity to entrench its monopoly in the international 5G market and offered many countries to build them 5G networks at unbeatable prices. The United Arab Emirates, Russia and several countries in Europe and Latin America accepted the offer and began the testing phase.

However, Huawei's growth raised concerns in other countries, especially the United States, about the Chinese company's security and influence in the global telecommunications infrastructure. Citing Huawei's close relationship with the Chinese government and intelligence service, as well as a history of industrial espionage, the US imposed restrictive measures on Huawei to limit its participation in 5G deployment and promote its own technology company: Qualcomm. These measures boil down to export controls and the granting of subsidies to motivate innovation at the national level[94]. In particular, the most notorious restriction involved licensing the manufacture of semiconductors abroad using American equipment, which Huawei needs to fabricate its products. This situation led to the semiconductor crisis in 2020 and 2021, as many companies, fearing potential restrictions, began to stockpile semiconductors on a massive scale, further contributing to their shortage and rising prices.

US restrictive measures to maximize technological distance from China have unbalanced the playing field dangerously for global players such as Europe. Europe has a global semiconductor manufacturing share of less than 10%[95], so it has faced challenges in the fight for 5G dominance, with delays in deployment and dependence on foreign suppliers. Although European companies such as Nokia and Ericsson have a growing presence, their share in the market has been eclipsed by Huawei. However, in the last year major European powers have banned Chinese-made equipment on the same grounds as the United States: that such hardware poses a threat to national security due to Huawei and ZTE's close ties to Chinese state forces.

In conclusion, the struggle for 5G dominance has resulted in a full-scale patent race among the world's leading powers. As of June 2022, there are 46,322 patent families associated with 5G, among

[94] See Feás, E., 2023.
[95] See Feás, E., 2023.

which 29,037 families include at least one granted patent[96]. The distribution of patents in the 5G market shows that Huawei's potential monopoly over 5G has evolved into an oligopoly led by Huawei, Qualcomm, Nokia, Ericsson, Samsung and LG. Figure 18 shows the market share of the top six 5G technology development companies based on patent families declared with at least one patent granted in IP5 countries[97].

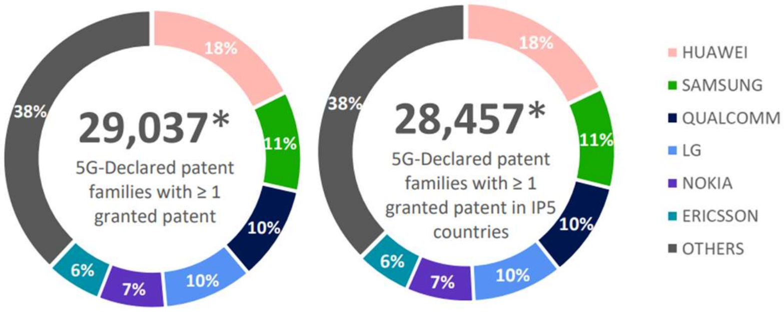

Figure 18. Share of top six companies of 5G declared patent families[98].

In addition, to show the magnitude of patents applied for in the development of 5G, the breakdown of patents belonging to the top six companies is shown in Figure 19. These amounts demonstrate that Wireless communication, which includes 5G, is an industry sector of high technological complexity.

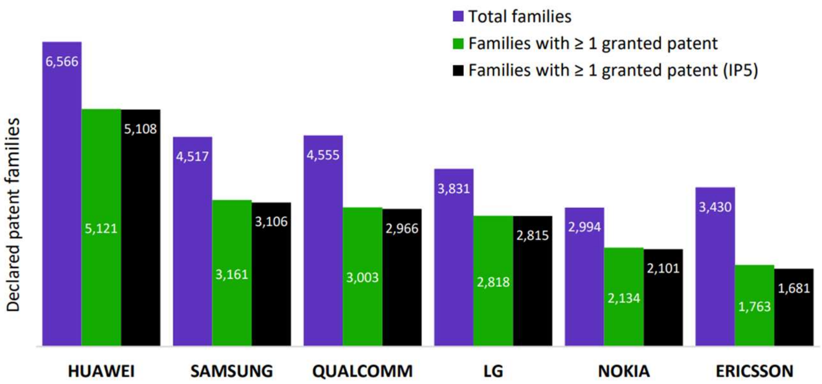

Figure 19. Breakdown of 5G declared patent families owned by top six companies, as of June 2022[99].

As shown in Figure 19, the number of technical contributions to 5G is immense. This situation presents a significant problem in the industry, as it makes it much easier for a company that wants to launch a product, for example, a cell phone with 5G connectivity, to infringe one or more competing

[96] See Clarivate Patent Services, 2022.
[97] The IP5 jurisdictions include the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), the State Intellectual Property Office of the People's Republic of China (CNIPA), the Japan Patent Office (JPO), and the Korean Intellectual Property Office (KIPO).
[98] Source: Clarivate Patent Services, 2022.
[99] Source: Clarivate Patent Services, 2022.

patents. Consequently, to ensure interoperability, fair competition and widespread adoption of the technology, justice bodies agreed that 5G patents should become standard-essential patents.

A standard-essential patent (SEP) is a patent that claims an invention that must be used to enable a technology standard to function, such as 5G, Bluetooth, USB ports, etc. Manufacturers that use a standard to produce their products must pay a license fee to the owners of the SEPs. Currently, the biggest problem with SEPs is that their holders often demand supra-competitive royalties under the threat of denying the patent license knowing that the industry technical standard they protect is vital for the other company[100]. However, the existing regulation, i.e., the FRAND conditions, is not specific enough to prevent this issue.

Therefore, companies that sell products integrating some standards have had to acquire patents from competitors to mitigate their essential patent risks, such as Google, which acquired Motorola's patents, or Apple, which joined with other companies to buy Nortel's portfolio. However, as seen in Figure 19, the tech giants Huawei, Nokia, etc., have managed to make the most cash due to their large portfolios of 5G SEPs.

Considering the above, the number of 5G patent infringement lawsuits is increasing, e.g., Ericsson and Apple in 2022, Nokia and Apple in 2023, Oppo and Nokia in 2022, Huawei and Verizon in 2021, etc. Regarding these lawsuits, the retailing companies argue that, without their products, 5G standards would have no commercial outlet. Conversely, the 5G patent owner firms object that it is thanks to their technological advances that the goods sold acquire the added value for the consumer. Given the speed at which the 5G market is growing, the lengthy duration of patent infringement lawsuits means significant costs and potential penalties for infringers. Therefore, many companies are in the process of negotiating individual or cross-licenses with owners of 5G SEPs.

However, negotiating royalties on patent licenses is proving to be a complicated task, as Huawei, financially backed by the Beijing government, offers deals at a much lower price than the rest of its competitors, which some describe as dumping. At the legal level, the European Commission recognizes that "licensing of essential patents is often a complicated and costly exercise for both patent holders and technology implementers" and that "a much clearer and predictable framework is needed that incentivizes good faith negotiations rather than resorting to litigation"[101]. Therefore, it is necessary to design a model that optimizes the negotiation of patent licenses so that the royalty agreed between the parties is fair and does not significantly harm competitors.

[100] See Sidak, 2015.
[101] See Sandri, 2022.

5.2. THE HUAWEI CASE.

Huawei Technologies Co., Ltd. Is a Chinese multinational technology corporation founded in 1987 by Ren Zhengfei and headquartered in Shenzhen, province of Guangdong. It creates, designs, manufactures, and sells telecommunications equipment, consumer electronics, smart gadgets, and rooftop solar goods. The company, which began by producing phone switches, has expanded its operations and now sells services in over 170 nations and regions. First, Huawei surpassed Ericsson as the world's largest telecommunications equipment maker in 2012. Second, it overtook Apple as the world's second-largest smartphone manufacturer in 2018. And third, Huawei topped Samsung and Apple in terms of global phone shipments for the first time in 2020.

Despite its international success, Huawei has encountered challenges in some countries due to disproportionate state support, linkages to the PLA and the Ministry of State Security (MSS), and fears that Huawei's infrastructure technology may enable Chinese government surveillance. With the development of 5G wireless networks, the US and its allies have urged not to do business with Huawei or other Chinese telecommunications companies such as ZTE.

Huawei is aware that its R&D investment plays a key role in the development of its 5th-generation wireless communication products, which translates into a better position than its competitors in the 5G market sector. Therefore, it has increased its Research and Development (R&D) expenditures to surpass those of its competitors, as shown in Figure 20.

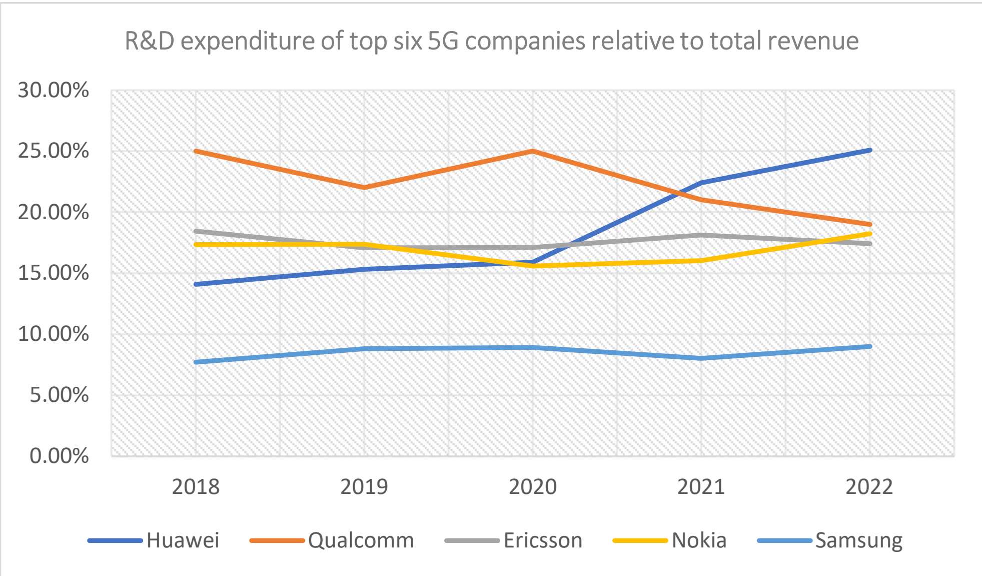

Figure 20. R&D expenditure of top six 5G companies relative to their total revenue, from 2018 to 2022[102].

[102] Source: prepared by the author based on data from Statista, 2022, and Macrotrends, 2022.

However, in this case, it is not enough to invest in R&D to increase the company's profits since the 5G market is a sector of high technological complexity, as seen in the previous section, where the presence of patent thickets has led to multiple deadlock situations. In this context, Huawei must evaluate the possibility of negotiating patent cross-licenses with one of its competitors versus pursuing litigation. In this regard, the "Sieglinde Game" will be applied on the Huawei Case below.

5.3. APPLICATION OF "THE SIEGLINDE GAME" TO THE HUAWEI CASE.

5.3.1. Phase 1 – Determination of Huawei's 5G patent corral.

In order to analyze potential blocking situations in the 5G industry from Huawei's point of view, patents on 5G technology were accessed from the EPO patent search engine, filtering by the applicant ("Huawei"), classification code ("H04W[103]"), and for the time frame comprising the 15 years between January 1, 2007, and December 31, 2022[104]. From this dataset consisting of 12,791 patents, a sample covering the last 50 patent applications of 2017 was taken to determine the 5G developing companies with which Huawei shares blocking situations and with which it participates in a patent corral.

As previously mentioned, the documents registered in the virtual patent offices are accessible in pdf format, which hinders the extraction of the information enclosed in them. Therefore, for each patent in the sample, the cover page of the patent document and the prior art search report were downloaded. Following, the text was extracted from these documents through the implementation of OCR techniques using a free Internet tool. Furthermore, the text extracted from each patent was stored in an individual .txt file.

Subsequently, a Python code was developed to process the contents of the text files, extract the relevant information, sort it in a table-like format, and store it in a single text file. The program works as follows: first, it opens a dialogue window for the user to select a folder of text files stored on his hard disk; then, it goes through the text files one by one and extracts from them the information referring to the publication date, filing date, applicant, international patent classification code, as well as the companies mentioned in the X and Y references of the prior art search report; third, for each text file it reads, it stores the extracted information in a list and adds it as a new row in the text file named "results. txt". Consequently, the program output consists of a table of six rows and 100

[103] International Patent Classification (IPC) code H04W gathers patents included in section H, which refers to inventions related to electricity; group H04, which refers to electric communication techniques; and subgroup H04W, which groups together those inventions that concern wireless communication networks.

[104] While the typical lifespan of a patent spans 20 years, the search filter has been applied within a 15-year timeframe. This temporal scope has been chosen due to the observation that registrations of 5G-related patents commenced as early as 2007.

columns, where each row represents a patent and each column a feature of the patent. The output table of the word processing program is located in ***Annex*** I and the Python code is in ***Annex II*** under the name "*Word Processing Code*".

The table extracted from the patent documents was long and hard to interpret. Therefore, a graph model was programmed in Python to illustrate Huawei's patent corral, which can be found in ***Annex II*** under the name "*Graph Code*". The operation of the initial graph program is as follows: first, the text file "results.txt" obtained from the processing of the patent sample documents is read; second, the companies mentioned in the X and Y references are extracted and the number of times each one is mentioned is counted; third, the company contained in the "Applicant" category of the table is added to the graph as a central node and the other companies mentioned in the references as surrounding nodes, following ***Equation (9)*** and ***Equation (10)***; and fourth, the graph is stored in an image file.

Figure 21 shows the patent corral, G_{H04W}, in which the initial company "Huawei" acts as the central node and connects with the surrounding nodes. These nodes are the C_{m-1} companies mentioned in the X-and-Y-references of the sample's prior art Search Reports.

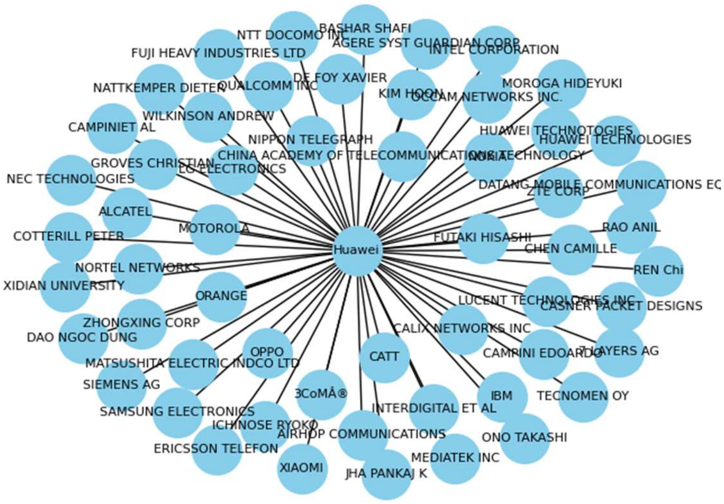

Figure 21. Huawei's X and Y references to other 5G patents.

As can be seen in Figure 21, since the 5G industry is of high technological complexity, the number of companies referenced in Huawei patents is very high, leading to a crowded graph that is hard to interpret. Therefore, the code was refined: once the program detected the number of times each company was referenced in Huawei's patents, the top 20% were filtered out; then, those 20% companies were shown in the nodes, and the number of times each company had been mentioned was indicated in the respective edges[105].

[105] To simplify, reference to 5G standard 3GPP was not taken into consideration for this game.

Let the vector v be defined by the subspace of the top 20% $(m-1)$ firms (i,j) that compete for patenting some technology k within the same market than firm i in the presence of patent thickets. The top firms are determined by evaluating the size of their patent portfolios, p_{c_j}. Then, to solve for Huawei's filtered patent corral, the general graph, $G_{k_{m^*}} = \left(C_{m^*}, E_{(m^*-1)}\right)$, must be specified with the following indexes, variables, and objective function.

Table 2 shows these graph's specifications:

Indexes
$\boldsymbol{i}$ = Huawei. $\boldsymbol{j}$ = each company in vector $\boldsymbol{v}$ competing with Huawei in market $\boldsymbol{k}$. $\boldsymbol{k}$ = H04W (wireless communication networks).
Variables
$\boldsymbol{m}$ = total number of firms competing in the patent corral. $\boldsymbol{p_{c_j}}$ = **size of patent portfolio of firm $\boldsymbol{j}$**, represented by the number of X-and-Y references to firm $\boldsymbol{j}$ in the prior art search reports of Huawei's patents.
Objective function
$\boldsymbol{G_{H04W_{m^*}} = \{G_{H04W_m} \in G_{H04W} \mid m^* \in m, rank(p_{c_{m^*}}) > 80\% \lvert p_{c_m} \rvert\}}$

Table 2. Patent corral specifications.[106]

The filtered patent corral, $G_{H04W_{m^*}}$, is shown in Figure 22.

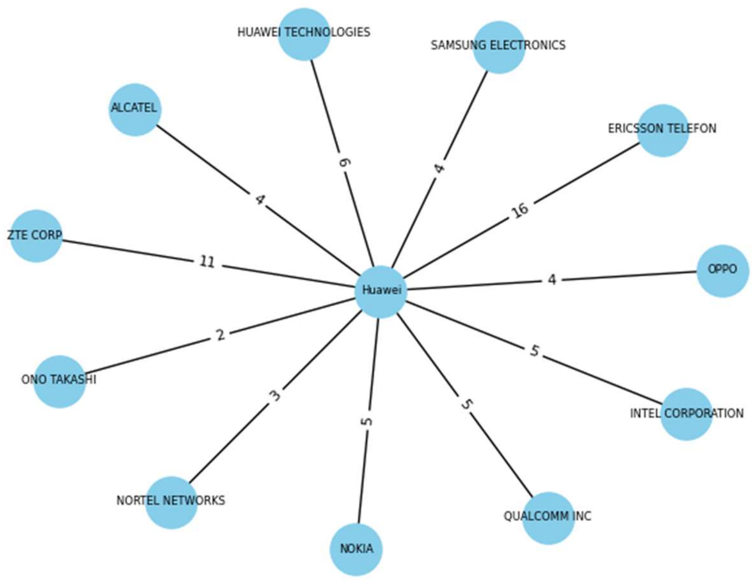

Figure 22. Top 20% references from Huawei to other 5G patent-owning companies.

[106] Source: prepared by the author on June 25, 2023.

Since the sample consists of 500 patents out of the 12,791 5G patents registered by Huawei at the EPO, it is considered that the firms referenced in the prior art search reports included in the sample and shown in Figure 22 must be extrapolated to the total population by applying a correction factor of $\frac{12{,}791}{50} \approx 256$. In addition, references to Huawei in these search reports must be omitted. Hence, the companies referenced in Huawei's patent search reports, as well as the number of times each company is mentioned, are shown in Table 3. Total reference to Huawei's competing firms..

Company	References to the company found in the sample	References to the company extrapolated to 270,007 total patents
Ericsson	16	4,096
ZTE	11	2,816
Nokia	5	1,280
Qualcomm	5	1,280
Intel	5	1,280
Oppo	4	1,024
Samsung	4	1,024
Alcatel	4	1,024
Nortel	3	768
Ono Takashi	2	512

Table 3. Total reference to Huawei's competing firms[107].

In conclusion, from the application of Equation (11), we obtain that Huawei is most interested in negotiating a license agreement with Ericsson.

If we apply the same process to a sample of 50 Ericsson patents registered at the EPO, we obtain the following graph, illustrated in Figure 23:

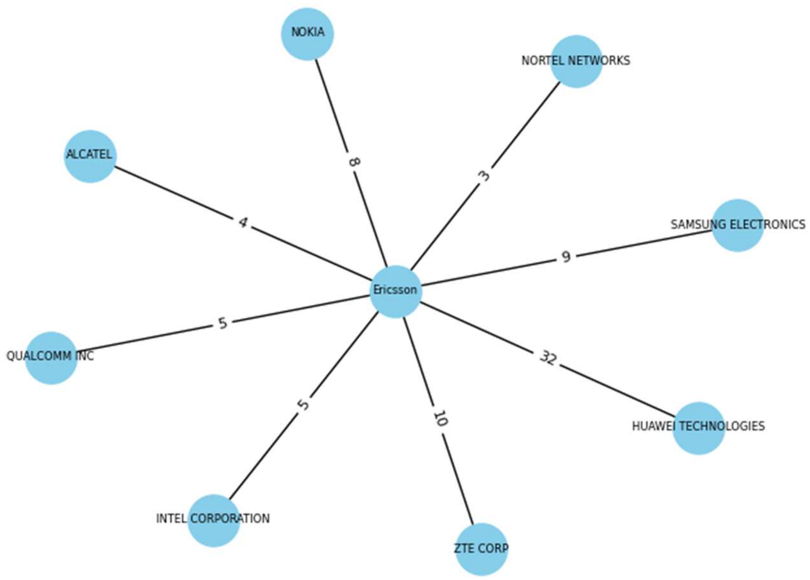

Figure 23. Top 20% reference from Ericsson to other 5G patent-owning companies.

[107] Source: prepared by the author on June 25, 2023.

According to the information provided by the EPO, Ericsson has registered 6,601 patents related to 5G in their office. Applying the corrective factor $\frac{6,601}{50} \approx 132$, we obtain than the extrapolated number of references from Ericsson to Huawei, in 5G matters, is $32 * 132 = 4,224$. Thus, Huawei and Ericsson are most interested in negotiating a cross-license agreement.

5.3.2. Phase 2 – Determination of an optimal royalty.

The second stage of the model involves two companies, C_i and C_j, which intend to negotiate a patent cross-license. The objective of this stage is to obtain an optimal royalty exchange between the two companies, constrained by the red lines set by each party. To formulate the optimization problem, the indexes, parameters, variables, and objective function of the game must be first specified, as it is shown in Table 4:

Indexes
$\boldsymbol{i}$ = Huawei. $\boldsymbol{j}$ = Ericsson. $\boldsymbol{k}$ = H04W (wireless communication networks).
Parameters
$\boldsymbol{p}_{\boldsymbol{C}_{i(j)}}$ = size of Huawei's (Ericsson's) 5G portfolio that is being negotiated. $\bar{\boldsymbol{t}}_{\boldsymbol{C}_{i(j)}}$ = useful life of Huawei's (Ericsson's) patents. $\boldsymbol{\beta}_{i(j)}$ = probability of Huawei (Ericsson) abandoning the product line that caused the infringement. $\overline{\boldsymbol{D}}_{i(j)}$ = annual profits obtained by Huawei (Ericsson) from infringing the other party's patents. $\overline{\boldsymbol{E}}_{i(j)}$ = annual compensation obtained by Huawei (Ericsson) due to loss of useful life of Huawei's (Ericsson's) patents. $\overline{\boldsymbol{O}}_{\boldsymbol{R}_{ij}}$ = total annual revenue obtained from the game. $\overline{\boldsymbol{O}}_{\boldsymbol{I}_{ij}}$ = total annual operating income obtained from the game.
Variables
$\boldsymbol{d}^+_{i(j)}$ = opportunity cost of Huawei (Ericsson). $\boldsymbol{\alpha}$ = bargaining strength of Huawei. $\boldsymbol{u}^*_{i(j)}$ = utility obtained by Huawei (Ericsson) from the game. $\overline{\boldsymbol{\pi}}^*_{i(j)}$ = annual revenue payoff distributed to Huawei (Ericsson) because of the game. $\boldsymbol{r}^*(\%)$ = net percentual royalty derived from the game. $\boldsymbol{R}_{ij}$ = net royalty amount based on total revenue.
Objective function
$\boldsymbol{max}_{u_i^*,u_j^*}(\boldsymbol{u_i} - \boldsymbol{d}_i^+)^{\alpha}(\boldsymbol{u_j} - \boldsymbol{d}_j^+)^{1-\alpha}$

Table 4. Optimization problem specifications[108].

To solve the game, we must first calculate the utilities that Huawei and Ericsson obtain from the game. To do this, it is necessary to determine the opportunity cost and the bargaining power of both Huawei and Ericsson.

[108] Source: prepared by the author on June 30, 2023.

Considering Equation (26) and Equation (27), the bargaining strengths of each party is determined by the size of each company's portfolio that is subject to the negotiation (p_C), and the average useful life of the patents in the portfolio $(\bar{t}_C)$.

The size of each portfolio is extracted directly from applying the correction factor to the references to the company in the graphs obtained from the previous phase. To calculate the lifetime of such portfolios, it would be optimal to search for each referenced patent in the search reports and calculate its lifetime according to its expiration date. However, in this study, the average lifespan will be approximated as follows: in the case of Huawei, references to Ericsson follow an increasing trend over the period analyzed; in the case of Ericsson, references to Huawei follow a decreasing trend. In the EPO's virtual patent library, it is estimated that 5G patents started to be registered in about 2004. Therefore, the average useful life of each portfolio is estimated as follows:

$$\bar{t}_{C_{HUAWEI}} = 1\left(\frac{2}{3}\right) + 20\left(\frac{1}{3}\right) = 7.33\ years \tag{36}$$

$$\bar{t}_{C_{ERICSSON}} = 1\left(\frac{1}{3}\right) + 20\left(\frac{2}{3}\right) = 13.67\ years \tag{37}$$

The parameters for calculating the bargaining strengths are provided in Table 5:

Company	Size of portfolio $(\boldsymbol{p_c})$	Average useful life of the portfolio $(\bar{\boldsymbol{t}}_{\boldsymbol{c}})$
Huawei	4,224	7.33
Ericsson	4,096	13.67

Table 5. Size of the companies' portfolio size and average useful life[109].

Thus, the bargaining power of each party is calculated as follows:

$$\alpha_{HUAWEI} = \frac{p_{C_i}\bar{t}_{C_i}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}} = \frac{4{,}224(7.33)}{4{,}224(7.33)+4{,}096(13.67)} = 0.3561 = 35.61\%$$

$$(1-\alpha)_{ERICSSON} = \frac{p_{C_j}\bar{t}_{C_j}}{p_{C_i}\bar{t}_{C_i}+p_{C_j}\bar{t}_{C_j}} = 0.6439 = 64.39\%$$

Considering Equation (24), the opportunity cost of each party is determined by the probability of taking each of the alternatives to licensing $\left(\beta_{i(j)}\right)$, the annual profits obtained by each party from infringing the other party's patents $\left(\overline{D}_{i(j)}\right)$, the potential annual compensation obtained by each party due to loss of useful life of the other's patents $\left(\overline{E}_{i(j)}\right)$, and the total annual operating income obtained from the game $\left(\overline{O}_{I_{ij}}\right)$.

The likelihood that a company will decide to abandon the product line that has caused the infringement of another's intellectual property can vary widely depending on several factors, such as

[109] Source: prepared by the author on June 1, 2023.

the severity of the infringement, the strength of the infringed patent, the resources and legal strategies of the parties involved, and commercial and financial considerations. Since there is no current information available on these factors, the following will be assumed:

$$\beta_i = \beta_j = 0.5$$

As for the profits earned by each party due to infringement of the opponent's intellectual property, these will be assumed to correspond to an amount of the revenues earned from the 5G activity in the previous year (2022) proportional to the infringed patents of the competitor. Therefore:

$$\overline{D}_i = 2022\, Total\ OI \left(\frac{pc_j}{n°\ total\ patents\ i + pc_j}\right) \quad (38)$$

On the other hand, the annual compensation that each party expects to receive for the loss of useful life of its patents will be estimated as the proportion of the revenue earned from the exploitation of the company's 5G patents in 2022 that corresponds to the portfolio infringed by the competition. This compensation is reflected in the following equation:

$$\overline{E}_i = 2022\, Total\ OI \left(\frac{pc_i}{n°\ total\ patents\ i}\right) \quad (39)$$

Finally, it will be assumed that the total benefit generated by the game is approximately 150% of the combined profit obtained by Huawei and Ericsson in the year 2022. The same procedure will be applied to calculate the total revenue.

$$O_{I(5G)_{i_{2022}}} = Total\ O_{I_{i_{2022}}} \left(\frac{n°\ 5G\ patents\ i}{n°\ total\ patents\ i}\right) \quad (40)$$

$$\overline{O}_{I_{ij}} = 150\% \left(O_{I(5G)_{HUAWEI_{2022}}} + O_{I(5G)_{ERICSSON_{2022}}}\right) \quad (41)$$

$$\overline{O}_{R_{ij}} = 150\% \left(O_{R(5G)_{HUAWEI_{2022}}} + O_{R(5G)_{ERICSSON_{2022}}}\right) \quad (42)$$

The parameters for calculating the normalized opportunity costs are provided in Table 6:

Company	$\boldsymbol{\beta}$	**Total Operating Income 2022 (M$)**	**Total patents**[110]	**Total 5G patents**	$\overline{D}$ **to be paid (M$)**	$\overline{E}$ **(M$)**	$O_{I(5G)_{2022}}$ **(M$)**
Huawei	0.5	5,114	121,620	12,791	166.62	177.61	537.84
Ericsson	0.5	2,678	49,897	6,601	209,01	219.83	354.28

Table 6. Parameters for calculating the normalized opportunity cost of Huawei and Ericsson[111].

[110] According to the number of patents registered in the EPO.
[111] Source: prepared by the author based on data from Statista and Macrotrends, on June 20, 2022.

The parameters that define the benefit surplus from the game are provided in Table 7:

Company	Total Revenue 2022 (M$)	Total Operating Income 2022 (M$)	5G Revenue 2022	5G Operating Income 2022	$\overline{O}_{I_{ij}}$ (M$)	$\overline{O}_{R_{ij}}$ (M$)
Huawei	92,379	5,114	9,6716	537.84	1,338	19,914
Ericsson	26,910	2,678	3,560	354.28		

Table 7. Parameters that define the benefit and revenue obtained from the game[112].

Therefore, from Equation (26), the opportunity cost of each party is calculated as follows:

$$d^{+}_{HUAWEI} = \frac{0.5(537.84)+0.5(209.01+177.61)}{1{,}338} = 0.3454$$

$$d^{+}_{ERICSSON} = \frac{0.5(354.28)+0.5(166.62+219.83)}{1{,}338} = 0.2768$$

The sum of each party's opportunity cost is in the range [0,1], so Equation (25) is verified.

After calculating Huawei's and Ericsson's opportunity cost and bargaining power, the utility distribution obtained by Huawei and Ericsson from negotiating a patent cross-license is determined by Equations (28) and (29):

$$u_i^* = 0.6439(0.3454) \ + 0.3561(1 - 0.2768) = 0.48$$

$$u_j^* = 0.3561(0.2768) + 0.6439(1 - 0.3454) = 0.52$$

The utility distribution among the parties involved in the cross-license agreement is key to calculating the optimal net royalty to be exchanged between them. Applying Equation (30) and Equation (31), we obtain:

$$r_{ERICSSON \to HUAWEI} = 0.48\left(\frac{1{,}338}{19{,}914}\right) = 0.03225$$

$$r_{HUAWEI \to ERICSSON} = 0.52\left(\frac{1{,}338}{19{,}914}\right) = 0.03494$$

Consequently, the revenue payoff between the parties is distributed as stated in Equation (32) and Equation (33):

$$\overline{\pi}^*_{HUAWEI} = 0.03225(19{,}914) = 642.24$$

$$\overline{\pi}^*_{ERICSSON} = 0.03494(19{,}914) = 695.76$$

Then, from Equation (34), the percentual net royalty amount calculated over the total revenue generated by technology-sharing that Ericsson must pay Huawei is determined by:

[112] Source: prepared by the author based on data from Statista and Macrotrends, on June 20, 2022.

$$r^*(\%) = |0.03494 - 0.03225| \times 100 = 0.269\ \%\ over\ total\ revenue$$

Consequently, the net royalty amount (R_{ij}) that Ericsson must pay Huawei is:

$$\boxed{R_{ij} = r^*(\%) \times \overline{O}_{R_{ij}} = 0.269\% \,(19{,}914) = \$\ \mathbf{53.56}\ \boldsymbol{M}}$$

5.4. Analysis of Results.

Table 8 shows an overview of the calculated variables for Huawei and Ericsson. In addition, Figure 24 shows the royalty flow chart resulting from the negotiation game of a patent cross-license between both parties.

Company	$d^+_{i(j)}$	α	$u^*_{i(j)}$	$\overline{\pi}^*_{i(j)}$ **(M$)**	$r^*(\%)$	R_{ij} **(M$)**
Huawei	0.3454	0.3561	0.48	642.24	0.269	53.56
Ericsson	0.2768	0.6439	0.52	695.76		

Table 8. Overview of the variables calculated in the game[113].

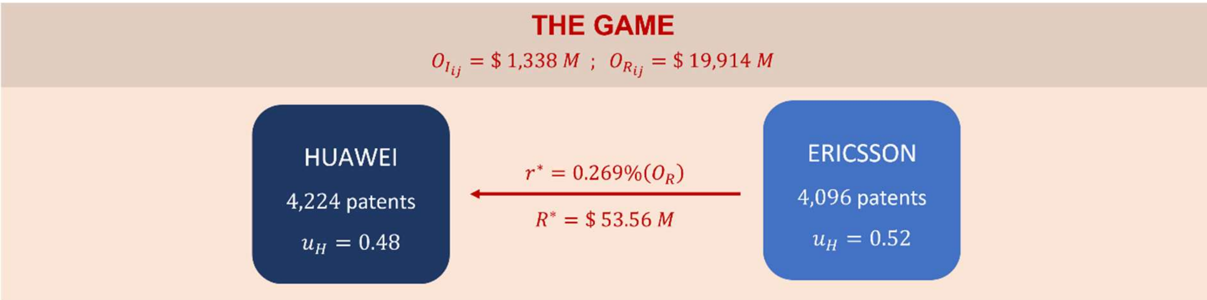

Figure 24. The Game's royalties flow chart[114].

Table 8 shows that Huawei's opportunity cost (0.3454) is higher than Ericsson's (0.2768). If the utility distribution only depended on the opportunity cost, Huawei should obtain a higher utility. This statement is based on the fact that the value Huawei gains from choosing an alternative other than negotiating a patent cross-license with Ericsson is higher than the value Ericsson would obtain in the same situation. However, Ericsson's bargaining power (64.39%) is much higher than Huawei's (35.61%), based on the size of the portfolio offered by both companies and the lifetime of each. Therefore, since each company's utility relates the opportunity cost of each party to its bargaining power, Ericsson's utility is higher than that obtained by Huawei.

Another fact to note, as expected, is that each party receives benefits above its opportunity cost. This fact is a logical consequence of the model since, if either company received a lower value

[113] Source: prepared by the author on July 8th, 2023.
[114] Source: prepared by the author on July 8th, 2023.

than their opportunity cost, it would choose the alternative rather than negotiate a patent cross-license with the other party.

On the other hand, as is seen in both Table 8 and Figure 24, the game utility for Ericsson is four percentage points higher than the game utility for Huawei. This fact means that, given the data analyzed, Ericsson earns a higher profit than Huawei if the two companies share their intellectual property. Therefore, what is logical and reflected in the results, is that Ericsson is the company that will have to make up financially for the difference in profit that both parties make from the business.

Finally, if we look at the percentage of net royalty, we can see that it is tiny. One might wonder whether the result obtained makes sense since, as discussed in Chapter 3, the method historically most used to determine royalties for IP infringement is the "25% rule". If we look at the calculations, the percentage royalty in the model has been determined as a percentage of the total expected revenue from the game. In contrast, the "25% rule" calculates the net royalty as a function of expected profits. Since, in this case, expected profits are much lower than revenues due to high investment and production costs, the percentage royalty obtained falls in the expected order of magnitude.

5.5. LIMITATIONS TO THE STUDY.

This section reviews the limitations encountered when applying the model to the Huawei case.

Firstly, the sample of patents chosen is short due to the laborious process of obtaining and processing the patent documents through OCR techniques. The data obtained are more than sufficient to evaluate the model's performance. However, the results obtained are hardly transposable to the universe of patents in the 5G technology competition.

Second, the patent corral in the first phase of the game has been determined by considering only the companies mentioned in the prior art search reports rather than the referenced patents themselves. This limitation is of minor importance because, although counting patent-holding companies can cause the same company to be mentioned several times because of a single patent, the reality is that if the reports mention a patent several times, the patent has a higher value within the portfolio. Therefore, theoretically, the company's portfolio value under negotiation remains equal.

Third, the estimation of the input parameters to the model has been carried out in a very simplified manner, given the lack of publicly available information and the complexity of the estimation. For example, the profit expected from the 5G patent set was calculated from the net profit found in the balance sheets of both companies. Since both Huawei and Ericsson carry out economic activities in independent fields of use, this approximation has a lot of variability since the distribution of costs in the different activities in which each company is engaged is very uneven, and in the application of the model it has been considered uniform. Therefore, the expected revenues and profits from the game are not realistic.

Fourth, the model captures interactions between pairs of firms competing in the same market. However, in markets of high technological complexity, interactions commonly occur between more than two companies, forming broad patent thickets that require the negotiation of patent pools. In the case of 5G technology, since it is considered a necessary standard for any company that wants to commercialize a product containing it, it may be more practical to extend the model to analyze games between more than two players.

5.6. CONCLUSION.

In Chapter 5, the model based on Graph Theory and Game Theory developed in Chapter 4 has been applied to the 5G technology market.

First, the context in which companies compete for 5G dominance has been described, considering both economic and geopolitical motives. Subsequently, the role of Huawei, a Chinese multinational company, has been analyzed in the 5G market. In just seven years, Huawei has evolved from nearly holding a monopoly over 5G to being one of the six companies that conform the oligopoly. This situation has arisen due to the patent race undertaken by the world powers to prevent China from gaining control of the information contained in 5G networks and, thus, global hegemony.

The patent race undertaken by these countries has generated a market of high technological complexity characterized by the presence of patent thickets. The high density of these patent thickets has caused major blockages for companies, preventing them from continuing to innovate and develop their products. Consequently, the model defined in Chapter 4 has been applied to the Huawei Case to help identify the patent thickets to which it belongs and to determine the company with which it is most interested in negotiating a patent cross-license: Ericsson. The model has allowed us to determine the optimal royalty exchange between these companies.

Finally, the results obtained have been analyzed, and the limitations found in the model and its application have been discussed.

The following chapter will provide the economic report of the study, which examines the costs associated with the different patent game strategies for Huawei and Ericsson.

CHAPTER 6: ECONOMIC REPORT

This chapter introduces the economic report, which examines the costs associated with the different patent game strategies for Huawei and Ericsson. Specifically, it explores the ramifications of discontinuing the product line, pursuing legal action for patent infringement, or mutually cooperating through cross-licensing negotiations. By juxtaposing the incurred costs for each company based on their chosen strategy, this chapter seeks to substantiate the efficacy of cross-licensing agreements as cost-saving mechanisms.

6.1. COST SAVINGS

As previously outlined, when confronted with a scenario of mutual patent infringement from a competitor, a company can adopt three strategies: if it chooses not to cooperate with the patent holder, it can either discontinue the product line or initiate legal proceedings. Conversely, if the company seeks to collaborate with said holder, it can engage in cross-licensing negotiations. Each strategy incurs distinct costs for the company. Therefore, it becomes pertinent to assess the economic savings accrued by each party through the pursuit of a cross-licensing agreement, as this contributes to the assessment of the viability and appeal of the model.

When applying each strategy to the case, should Huawei or Ericsson opt to abandon the product line, they will not incur additional costs nor generate future benefits from that activity. Conversely, if they choose not to cooperate and instead litigate against the opposing party for patent infringement, they will accrue legal expenses and indemnification costs if the lawsuit is lost. Finally, if they negotiate a cross-licensing agreement, only one of the parties will incur expenses tied to the net royalty (Ericsson paying Huawei $53.56 million). Furthermore, in the cooperative strategy, both parties will encounter consultancy expenses and others resulting from the negotiation process. Nonetheless, these expenditures will be disregarded in this exercise for simplification purposes.

In this study, economic savings is defined as the expenditure each company incurs through negotiating a cross-licensing agreement in comparison to the costs they would incur by choosing not to cooperate and instead initiating legal proceedings. Table 9 illustrates the economic savings for Huawei and Ericsson based on whether they happen to win or lose the IP infringement lawsuit.

Cost savings	Huawei wins the trial	Ericsson wins the trial
Huawei	$\overline{L}_i$	$\overline{L}_i + \overline{W}_j = \overline{L}_i + (\overline{D}_i + \overline{E}_j + \overline{L}_j)$
Ericsson	$\overline{L}_j + \overline{W}_i - R_{ij} = \overline{L}_j + (\overline{D}_j + \overline{E}_i + \overline{L}_i) - R_{ij}$	$\overline{L}_j - R_{ij}$

Table 9. Equations for Cost savings for Huawei and Ericsson.

In the absence of perfect information and under the assumption of a litigation scenario between Huawei and Ericsson, the likelihood of winning such a lawsuit is estimated through the bargaining power of each party, as defined in equations (26) and (27). The estimation of savings for each company is as follows:

$$Cost\ Savings_{HUAWEI} = \alpha(\overline{L}_i) + (1-\alpha)\left(\overline{L}_i + \left(\overline{D}_i + \overline{E}_j + \overline{L}_j\right)\right) \quad (43)$$

$$Cost\ Savings_{ERICSSON} = \alpha\left(\overline{L}_j + \left(\overline{D}_j + \overline{E}_i + \overline{L}_i\right) - R_{ij}\right) + (1-\alpha)\left(\overline{L}_j - R_{ij}\right) \quad (44)$$

The legal costs for patent infringement in Europe can vary significantly based on case complexity, duration, jurisdiction, and other factors. Therefore, in this study, legal expenses are calculated based on the highest European average costs for both the first instance and appeal stages for each infringed patent[115]. In this manner:

$$European\ Legal\ Cost = Max.County\ Court\ Cost + Max.Appeals\ Cost \quad (45)$$

$$European\ Legal\ Cost = 1{,}500{,}000 + 1{,}500{,}000 = \$3\ M$$

Equation (43) captures the maximum legal cost per infringement of a single patent. The expression for estimating costs arising from litigation involving multiple patent infringements is:

$$L_i = European\ Legal\ Cost \cdot m_i \quad (46)$$

Given that Ericsson's cited patent portfolio in Huawei's patents consists of 4,096 patents, and Huawei's patent portfolio by Ericsson amounts to 4,224, the legal cost for each company is as follows:

$$L_i = L_{HUAWEI} = \$3\ M \cdot 4{,}096 = \$12.288\ M$$

$$L_i = L_{ERICSSON} = \$3\ M \cdot 4{,}224 = \$12.672\ M$$

Based on the economic data presented in Table 9, the savings matrix for both Huawei and Ericsson takes the following form:

Cost savings	**Huawei wins the trial**	**Ericsson wins the trial**
Huawei	$\$12.288\ M$	$\$411.58\ M$
Ericsson	$\$357.85\ M$	$-\ \$40.89\ M$

Table 10. Cost savings for Huawei and Ericsson.

As evident from Table 10 and as anticipated, each company realizes substantial savings when negotiating a cross-licensing agreement in the event the opposing company wins the lawsuit. However, it is observed that when the company itself anticipates winning the lawsuit, negotiating a cross-

[115] See Castaño, 2022, p. 137.

licensing agreement results in savings for Huawei but not for Ericsson, as it would be Ericsson paying the sum of royalties to Huawei.

Since the game unfolds in the absence of perfect information, we establish the probability of each company winning or losing the lawsuit through their respective bargaining power. Thus, the estimated savings for Huawei and Ericsson are as follows:

$$Cost\ Savings_{HUAWEI} = 35.61\%(\$12.288\ M) + 64.39\%(\ \$411.58\ M) = \$269.39\ M$$

$$Cost\ Savings_{ERICSSON} = 35.61\%(\$357.85\ M) + 64.39\%(-\ \$40.89\ M) = \$101.10\ M$$

The implication stemming from these findings is that, according to the hypotheses posited and the anticipated savings for each company, both Huawei and Ericsson stand to benefit from negotiating a cross-licensing agreement instead of initiating legal proceedings. If one also considers the revenue each company would accrue from utilizing the other's patents following the agreement, the expected benefit for both companies is projected to be even greater.

6.2. Conclusions

This chapter undertakes an economic analysis of costs stemming from the application of the "Sieglinde Game" to the 5G sector, building upon the economic data estimated in preceding chapters.

From the examination of the savings derived from entering into a cross-licensing agreement versus pursuing a legal course, it is inferred that, overall, the expenses for each party associated with cross-licensing negotiations are lower than the costs linked to potential Intellectual Property infringement litigations. Consequently, the efficacy of the cross-licensing agreement as a cost savings mechanism is established. As anticipated, economic savings are more substantial for each company in scenarios where the opposing party prevails in the hypothetical trial. Furthermore, it is essential to emphasize that the anticipated economic savings are contingent on the probability of winning the hypothetical lawsuit for each party, as reflected in this study by the bargaining power.

CHAPTER 7: CONCLUSIONS

Chapter 7 is the closing chapter of the thesis, in which objectives initially set are evaluated and from which a series of conclusions are drawn. In addition, it includes the lines of future research that can provide additional value to the project carried out so far.

7.1. KEY INSIGHTS AND GENERAL CONCLUSIONS.

The foundation of this thesis rests upon a pressing contemporary issue. In the landscape of sophisticated markets, intricate patent thickets materialize as corporations vie for technological supremacy. Prolonged patent wars beget a labyrinthine patent nexus, exacerbating deadlock scenarios that cast shadows over equitable competition, innovation, and societal progress. In the face of patent infractions, corporate entities deal with the following trilemma: to halt infringing product lines, initiate legal entanglements for dominion over contested patents, or navigate the intricate paths of negotiations, seeking refuge in the haven of cross-licensing agreements.

The initial hypothesis of the thesis asserts that cross-licensing negotiations represent the strategy most beneficial to both corporations and the market due to the resultant cost savings and innovation catalyst. Moreover, throughout the study, a review of existing patent licensing literature reveals notable gaps within the current state of knowledge, which underscores the compelling rationale behind the model's development.

Accordingly, this thesis seeks to develop a model that optimizes cross-licensing exchanges and aims to render these licenses a viable resolution to deadlock scenarios. The study concludes that the design of such a model is intricate, primarily owing to the opacity surrounding patent licensing agreement details. Therefore, in our view, the model should not merely optimize royalty exchanges but also simplify the assessment process of the utility of negotiating cross-licensing agreements, for in the lack of streamlining, corporations may shy away from negotiation in favor of litigation.

It is imperative to note that the model functions exclusively within contexts of imperfect competition, underpinning principles of individual rationality, pareto optimality, symmetry, affine transformation invariance, and monotonicity.

The paramount conclusion of this study is that the proposed "Sieglinde Game" offers a net royalty solution that mutually benefits both negotiating parties, preempting costly litigation. Evidence demonstrates that, as predicted by the model, corporations achieve substantial savings through cross-licensing negotiations, contrary to litigation. Furthermore, while the model is applied in the context of a 5G market deadlock, its inherent adaptability renders it applicable to diverse contexts characterized by bilateral intellectual property infringement deadlocks.

It is vital to stipulate that due to the challenge of accessing economic and strategic data from practical case corporations (Huawei and Ericsson), the outcomes derived in this study are estimations. Therefore, decisions should not be solely predicated on the numerical findings of this thesis.

Subsequently, the potential avenues for future research aimed at refining the model are delineated.

7.2. Evaluating the Achievement of Thesis Objectives.

The thesis has fulfilled its main goal, i.e., to define an algebraic model based on cooperative Game Theory and Graph Theory that optimizes value trade-offs in cross-licensing agreements. To this end, "The Sieglinde Game" is a model that determines the optimal net royalty to be exchanged by the parties involved in patent cross-licensing, based on the study of the opportunity costs of each party, their bargaining power, and the expected net benefit of the game. These elements have been integrated into an optimization problem that allows to calculate the asymmetric Nash Bargaining Equilibrium. In addition, the model contributes to boost innovation, improve business-to-business relations, and optimize transaction costs, which was one of the objectives of the thesis.

The thesis has fulfilled its objective of testing the model by contrasting it with data obtained from the European Patent Office (EPO) database and analyze the results to extract conclusions on the viability of the model. In this aspect, the model has been applied to the Huawei Case, in which the exchange of patents in the 5G market, characterized by being an industry of high technological complexity, is analyzed. High-complexity technology industries face a growing patent thicket, which poses a very real danger that any single product or service launched will infringe in many patents. Consequently, the blocking positions in which Huawei finds itself are analyzed in order to determine the patent corrals which Huawei is a part of and subsequently negotiate an optimal net royalty with the most suitable competing company. Based on the data analyzed, the company with which Huawei was most interested in negotiating a patent cross-license was Sweden's Ericsson. Also, the model establishes a net payment of US$53.56 million from Ericsson to Huawei.

The thesis fulfils its objectives of updating the reader on current issues regarding intellectual property and patents and informing about the existing regulations in the market. Prior to the development of the model, a literature review of the relevant Intellectual Property concepts is provided, focusing on patents. Additionally, the literature concerning patent licensing is revised. In the thesis, the variables that affect the price of the license are defined, and the classical models developed so far to optimize patent licensing are reviewed. Subsequently, the existing conflicts within the patent licensing international context and the present regulations are described and evaluated.

On the other hand, the proposed model is based on Cooperative Game Theory, specifically on the adaptation of the Asymmetric Nash Equilibrium to patent infringement conflicts. Consequently, it can be affirmed that the development of the thesis has fulfilled the objective of learning complex mathematical methods and applying them to a real-life economic problem.

Furthermore, the model's implementation has been carried out via Python Code. Thus, the aim of deepening programming skills and designing code that can be applied in real-life situations has been thoroughly met.

In short, the thesis has served to reflect on the management of intellectual property between companies in the industrial value chain, understanding it as a key element that determines the interaction between the companies, and that causes a direct impact on the market either by accelerating innovation or slowing it down by not knowing how to avoid blocking situations.

7.3. FUTURE RESEARCH LINES.

Listed below are several developments and proposals that go beyond the scope of the present project and can be taken as future avenues of research to provide additional value.

In my view, the most compelling avenue for future research lies in translating the model developed in this thesis into a machine-learning neural network. This proposition holds substantial promise as neural networks, once trained, possess autonomous learning capabilities and can discern patterns within databases to formulate non-linear prediction models that yield more realistic outcomes. As expounded within this thesis, the principal hurdle in actualizing such a neural network resides in the structural composition of the input database. To furnish a dependable model, the network would necessitate access to a comprehensive dataset encompassing patents stored in a format distinct from PDFs, alongside data encompassing variables influencing cross-licensing negotiation outcomes between the involved parties.

Furthermore, with the aim of advancing and refining the model developed in this thesis, the following lines of research are proposed:

First, considering the limitations encountered when applying the model, it is proposed to design a computational model that integrates advanced OCR techniques: Hence, it would only be necessary to download the .pdf files from the virtual database before implementing the model. This arrangement would reduce the database creation time, thus allowing to work with larger samples and allowing for more accurate and reliable results. Ideally, the designed code would directly import the searched files from the web page. However, this is currently impossible without the owner's permission.

Secondly, it is proposed to extend the model to study the interaction between more than two companies to optimize intellectual property exchanges in a patent pool format. This arrangement would yield interesting conclusions about the actual functioning of the market since the strategies implemented by one company do not depend only on the decisions of another but of all the companies in the market.

Thirdly, it would be convenient to design a model for estimating the parameters that serve as input to the model proposed in this thesis. This fix would provide more accurate results of the opportunity cost of each company in the negotiation and the total expected benefit of the game. In addition, it would be interesting to include in the estimation predictive values on the profitability of the technology in the years following the agreement instead of estimating the parameters using only profits obtained in past years.

Fourth, it is suggested to improve the graph code to provide a directed graph whose edges are bidirectional in the case of a mutual blocking situation due to intellectual property infringement between two companies. This new graph would save time in the search for patent corrals.

Finally, a profitability analysis could be carried out to obtain the boundary condition on the period for which the patent cross-licensing should be extended as a function of the costs and revenues incurred by the company and their evolution period after period.

Annex I – Sample of Huawei 5G Patents

Date of publishing	Date of filing	Applicant	CDC	X References	Y References
06.08.2008	17.01.2007	Huawei	H04Q	ZHONGXING CORP;	
31.12.2008	15.02.2007	Huawei	H04L	ZTE CORP;ORANGE ;ERICSSON TELEFON ;	
29.04.2009	30.07.2007	Huawei	H04L	NOKIA;	
27.05.2009	20.09.2007	Huawei	H04M		CAMPINIET AL ;HUAWEI TECHNOLOGIES ;CAMPINI EDOARDO ;
07.08.2008	03.01.2008	Huawei	H04L	7 LAYERS AG ;ZTE CORP ;CALIX NETWORKS INC ;JHA PANKAJ K;	
10.06.2009	25.09.2007	Huawei	H04B	NORTEL NETWORKS ;MOTOROLA ;	
09.09.2009	26.12.2007	Huawei	H04L	HUAWEI TECHNOLOGIES ;	
31.07.2008	15.01.2008	Huawei	H04B	ONO TAKASHI ;NIPPON TELEGRAPH ;KIM HOON ;	ONO TAKASHI ;
15.07.2009	29.01.2008	Huawei	H04Q	ERICSSON TELEFON	
07.10.2009	05.02.2008	Huawei	H04Q	NORTEL NETWORKS ;SAMSUNG ELECTRONICS ;QUALCOMM INC ;NORTEL NETWORKS ;	
01.02.2017	07.05.2003	Huawei	H04L		
07.10.2009	29.02.2008	Huawei	H04L		LUCENT TECHNOLOGIES INC ;ERICSSON TELEFON ;
13.05.2020	04.05.2018	Huawei	H04W	HUAWEI TECHNOLOGIES ;XIDIAN UNIVERSITY ;AIRHOP COMMUNICATIONS ;	
19.02.2020	12.06.2018	Huawei	H04W	WILKINSON ANDREW ;ZTE CORP ;	WILKINSON ANDREW ;
08.04.2020	27.06.2018	Huawei	H04W	ERICSSON TELEFON ;ALCATEL ;	
22.04.2020	14.06.2018	Huawei	H04W	HUAWEI TECHNOTOGIES ;FUJI HEAVY INDUSTRIES LTD ;ICHINOSE RYOKO ;	
18.03.2020	06.06.2018	Huawei	H04L	HUAWEI TECHNOLOGIES ;FUTAKI HISASHI ;DE FOY XAVIER ;	
26.02.2020	14.03.2018	Huawei	H04W	ERICSSON TELEFON ;MOROGA HIDEYUKI ;	
19.02.2020	28.04.2018	Huawei	H04W	INTEL CORPORATION ;NOKIA ;	DATANG MOBILE COMMUNICATIONS EQUIPMENT CO;INTEL CORPORATION;
19.02.2020	28.04.2018	Huawei	H04W	MEDIATEK INC ;INTEL CORPORATION ;	
15.01.2020	28.03.2018	Huawei	H04K	COTTERILL PETER C ;CHEN CAMILLE ;	
05.07.2017	28.09.2005	Huawei	H04M	NEC TECHNOLOGIES ;AGERE SYST GUARDIAN CORP; INTEL CORPORATION ;	
26.04.2023	29.06.2021	Huawei	H04W	ZTE CORP ;OPPO ;	
08.02.2023	02.04.2021	Huawei	H04W	OPPO ;	
28.10.2020	29.09.2019	Huawei	H04W	NTT DOCOMO INC ;ZTE CORP ;	DAO NGOC DUNG ;HUAWEI TECHNOLOGIES ;
10.03.2021	27.06.2019	Huawei	H04W	REN Chi ;SAMSUNG ELECTRONICS ;	ZTE CORP ;
05.05.2021	21.05.2019	Huawei	H04W		OPPO ;
17.03.2021	10.05.2019	Huawei	H04W	ZTE CORP ;INTERDIGITAL ET AL ;	
02.12.2020	12.02.2019	Huawei	H04W	CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY ;ZTE CORP ;	
30.09.2020	23.11.2018	Huawei	H04W	QUALCOMM INC ;ERICSSON TELEFON; INTEL CORPORATION ;	INTERDIGITAL ET AL ;
05.04.2017	08.12.2005	Huawei	H04M	TECNOMEN OY ;	IBM ; IBM ;
15.08.2007	27.12.2005	Huawei	H04L	OCCAM NETWORKS INC.; 3CoM® ;	
05.04.2017	29.04.2006	Huawei	H04L		GROVES CHRISTIAN ;
16.01.2008	26.05.2006	Huawei	H04L	NTT DOCOMO INC ;CASNER PACKET DESIGNS ;MATSUSHITA ELECTRIC INDCO LTD ;	
17.10.2007	05.07.2006	Huawei	H04L	HUAWEI TECHNOLOGIES ;SIEMENS AG ;	
30.07.2008	02.10.2006	Huawei	H04Q	QUALCOMM INC ;ERICSSON TELEFON ;	MATSUSHITA ELECTRIC INDCO LTD ;
27.06.2007	20.12.2006	Huawei	H04B	NATTKEMPER DIETER ;ALCATEL ;NIPPON TELEGRAPH ;	
02.11.2017	28.04.2017	Huawei	H04W	QUALCOMM INC ;	
08.09.2017	28.02.2017	Huawei	H04W	ERICSSON TELEFON ;ALCATEL	
17.10.2018	21.11.2016	Huawei	H04W		ERICSSON TELEFON ;
27.04.2017	24.10.2016	Huawei	H04W	QUALCOMM INC ;	
06.04.2017	19.09.2016	Huawei	H04W	ZTE CORP ;BASHAR SHAFI ;	
14.04.2021	21.06.2019	Huawei	H04W	SAMSUNG ELECTRONICS ;OPPO ;	
10.03.2021	21.06.2019	Huawei	H04W		LG ELECTRONICS : ERICSSON TELEFON;
14.04.2021	20.06.2019	Huawei	H04W	ERICSSON TELEFON ;RAO ANIL ; XIAOMI ;SAMSUNG ELECTRONICS ;	
28.04.2021	22.05.2019	Huawei	H04W	NOKIA ;NOKIA ;	
02.12.2020	08.03.2019	Huawei	H04W	ERICSSON ;ZTE CORP	NOKIA ;
24.03.2021	15.05.2019	Huawei	H04W	LG ELECTRONICS ;CATT ; ZTE	ERICSSON TELEFON ;
27.01.2021	07.05.2019	Huawei	H04W	ERICSSON TELEFON ;	ALCATEL ;ERICSSON TELEFON ;
03.03.2021	13.05.2019	Huawei	H04W		ERICSSON TELEFON ;

ANNEX II – PYTHON CODE

WORD-PROCESSING CODE

```
import re
import os
from tkinter import Tk
from tkinter.filedialog import askdirectory
Tk().withdraw()
carpeta_entrada = askdirectory(title="Selecciona una carpeta de archivos de texto")
archivos_texto = [f for f in os.listdir(carpeta_entrada) if f.endswith(".txt")]
resultados = []
for archivo in archivos_texto:
    archivo_actual = os.path.join(carpeta_entrada, archivo)
    info_archivo = []
    with open(archivo_actual, 'r', encoding='latin-1') as file:
        contenido = file.read()
    fecha_publicacion_regex = re.search(r"Date of publication:\s*(\d{2}\.\d{2}\.\d{4})", contenido)
    if fecha_publicacion_regex:
        fecha_publicacion = fecha_publicacion_regex.group(1)
    else:
        fecha_publicacion = "None"
    fecha_filing_regex = re.search(r"Date of filing:\s*(\d{2}\.\d{2}\.\d{4})", contenido)
    if fecha_filing_regex:
        fecha_filing = fecha_filing_regex.group(1)
    else:
        fecha_filing = "None"
    if "Applicant:" in contenido:
        index = contenido.index("Applicant:")
        propietario = contenido[index + len("Applicant:"):].split()[0]
    else:
        propietario = "None"
```

```
if "Int CL:" in contenido:
   index2 = contenido.index("Int CL:")
   clasificacion = contenido[index2 + len("Int CL:"):].split()[0]
else:
   clasificacion = "None"
matches_x = re.finditer(r'(?<=\n)X\b', contenido)
referencias_x = []
if matches_x:
   patron_x = re.compile(r'(?<=\n)[Xx]\b(?:.|\n)*?\(([^()]+?)\[')
   patron_x2 = re.compile(r'(?<=\nX\b)(.*?)(?=:)')
   for match_x in matches_x:
      coincidencia_x = match_x.start()
      referencia_x1 = patron_x.search(contenido, coincidencia_x)
      referencia_x2 = patron_x2.search(contenido, coincidencia_x)
      if referencia_x1:
         referencia_texto_x1 = referencia_x1.group(1)
         referencia_sin_saltos_de_linea_x1 = referencia_texto_x1.replace("\n", "")
         referencias_x.append(referencia_sin_saltos_de_linea_x1)
      if referencia_x2:
         referencia_texto_x2 = referencia_x2.group(1)
         referencia_sin_saltos_de_linea_x2 = referencia_texto_x2.replace("\n", "")
         referencias_x.append(referencia_sin_saltos_de_linea_x2)
else:
   referencias_x.append("None")
matches_y = re.finditer(r'(?<=\n)Y\b', contenido)
referencias_y = []
if matches_y:
   patron_y = re.compile(r'(?<=\n)[Yy]\b(?:.|\n)*?\(([^()]+?)\[')
   patron_y2 = re.compile(r'(?<=\n[Yy]\b)(.*?)(?=:)')
   for match_y in matches_y:
      coincidencia_y = match_y.start()
      referencia_y1 = patron_y.search(contenido, coincidencia_y)
```

```
            referencia_y2 = patron_y2.search(contenido, coincidencia_y)
            if referencia_y1:
                referencia_texto_y1 = referencia_y1.group(1)
                referencia_sin_saltos_de_linea_y1 = referencia_texto_y1.replace("\n", "")
                referencias_y.append(referencia_sin_saltos_de_linea_y1)
            if referencia_y2:
                referencia_texto_y2 = referencia_y2.group(1)
                referencia_sin_saltos_de_linea_y2 = referencia_texto_y2.replace("\n", "")
                referencias_y.append(referencia_sin_saltos_de_linea_y2)
    else:
        referencias_y.append("None")
    # Agregar la información del archivo actual a la lista de resultados
    info_archivo.append(fecha_publicacion)
    info_archivo.append(fecha_filing)
    info_archivo.append(propietario)
    info_archivo.append(clasificacion)
    info_archivo.append(referencias_x)
    info_archivo.append(referencias_y)
    resultados.append(info_archivo)
archivo_salida = "C:/Users/[redacted]/resultados.txt"
with open(archivo_salida, "w") as file:
    file.write("Date of publishing     Date of filing     Applicant     CDC     X References     Y References\n")
    file.write("-----------------------------------------------------------------------------------------------------------------------------------------------------------\n")
    for resultado in resultados:
        fecha_publicacion = resultado[0]
        fecha_filing = resultado[1]
        propietario = resultado[2]
        clasificacion = resultado[3]
        referencias_x = ";".join(resultado[4])
        referencias_y = ";".join(resultado[5])
        fecha_publicacion = fecha_publicacion.ljust(23)
```

```
        fecha_filing = fecha_filing.ljust(19)
        propietario = propietario.ljust(15)
        clasificacion = clasificacion.ljust(10)
        referencias_x = referencias_x.ljust(75)
        referencias_y = referencias_y.ljust(50)
        file.write(f"{fecha_publicacion} {fecha_filing} {propietario} {clasificacion} {referencias_x}
{referencias_y}\n")
```

GRAPH CODE

```
import matplotlib.pyplot as plt
import networkx as nx
from collections import Counter
G = nx.Graph()
archivo_entrada = "C:/Users[redacted]/resultados.txt"
with open(archivo_entrada, 'r') as file:
    next(file)
    next(file)
    todas_referencias_xy = []
    for linea in file:
        valores = linea.split()
        fecha_publicacion = valores[0]
        fecha_filing = valores[1]
        propietario = valores[2]
        clasificacion = valores[3]
        if len(valores) > 5:
            referencias_xy = [empresa.strip().replace(";", "") for empresa in ' '.join(valores[4:]).split(';') if
empresa.strip()]
        else:
            referencias_xy = []
        G.add_node(propietario)
        for empresa in referencias_xy:
```

```
            G.add_node(empresa)

        for empresa in referencias_xy:
            G.add_edge(propietario, empresa)
        todas_referencias_xy.extend(referencias_xy)
    contador_empresas = Counter(todas_referencias_xy)
porcentaje_empresas = 0.20
total_empresas = len(contador_empresas)
num_empresas_filtradas = int(total_empresas * porcentaje_empresas)
empresas_filtradas = dict(contador_empresas.most_common(num_empresas_filtradas))
G_filtrado = nx.Graph()
for nodo in G.nodes:
    if nodo in empresas_filtradas:
        G_filtrado.add_node(nodo)
for u, v in G.edges:
    if u in empresas_filtradas and v in empresas_filtradas:
        contador = G.edges[u, v]['contador']
        G_filtrado.add_edge(u, v, contador=contador)
pos = nx.spring_layout(G)
edge_labels = nx.get_edge_attributes(G, 'contador')
nx.draw(G, pos, with_labels=True, node_color='skyblue', node_size=1000, font_size=8)
nx.draw_networkx_edge_labels(G, pos, edge_labels=edge_labels, font_size=8)
plt.savefig("C:/Users/[redacted]G09.png")
plt.clf()
G_filtrado.add_node(propietario)
for nodo in G_filtrado.nodes:
    if nodo != propietario:
        contador = empresas_filtradas[nodo]
        G_filtrado.add_edge(propietario, nodo, contador=contador)
pos_filtrado = nx.spring_layout(G_filtrado)
```

```
edge_labels_filtrado = nx.get_edge_attributes(G_filtrado, 'contador')

nx.draw(G_filtrado, pos_filtrado, with_labels=True, node_color='skyblue', node_size=800, font_size=6)

nx.draw_networkx_edge_labels(G_filtrado, pos_filtrado, edge_labels=edge_labels_filtrado, font_size=8)

plt.savefig("C:/Users/[redacted]/GF9.png")

for empresa, count in contador_empresas.items():
   print(f"{empresa}: {count}")
```

CHAPTER 8: BIBLIOGRAPHY

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