Universitat Autònoma de Barcelona

THREE ESSAYS ON INDUSTRIAL ORGANIZATION: COMPETITION, PRICE SETTING, REGULATION

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To my husband and my parents

Contents

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Chapter 1

Introduction

Over the past three decades, widespread online search and online advertising have emphasised that the search engine has a crucial role in the economy. Nowadays it is quite common that users conduct an online query for information that they are seeking, or shoppers begin the shopping process online rather than at a physical store. Online search and online advertising depend crucially on search engines. Search engines provide users with access to available web content and give businesses the opportunity of online advertising and target marketing. In this regard, the usefulness and degree of accuracy of search results are important factors that lead users and businesses to attract to that search engine. Since all search engines have the same access to all available public web content, what sets them apart is their search algorithm. Different search engines have different search algorithms that determine the quality of search results offered by that search engine. The quality of search results is an important factor in competition between search engines that affects the structure of the market. In the early stage of the market, there were several competing search engines, but the entrance of Google significantly altered the structure of the market. Based on Statcounter, in 2019, Google with an advance search algorithm had a market share above 92% at the global level, 93% in Europe, and 89% in North America. The high degree of concentration raises the question of whether there is a tendency toward monopolisation in the market. In this respect, the study of dynamic competition between search engines is one of the objectives of this doctoral dissertation to specify the evolution of market structure over time.

The second aim of this dissertation is to study the effects of two important policies implemented by the European Payment Council (EPC) and European Commission (EC) namely the Single Euro Payment Area (SEPA) project and the interchange fee reduction on competition between banks and price levels, respectively. The goal of those regulations was to establish a single integrated financial market in Europe. After World War II, some European countries took steps to form a union. One such action was to create an integrated competitive financial market in Europe with the aim of eliminating barriers to make cross-border payments across Europe. In this light, the EPC have launched the SEPA project that supported by the EC and the European Central Bank (ECB). The aim of this project was to impose the same conditions, rights, and obligations for all non-cash euro retail payments in Europe. Before the introduction of SEPA, each European country was served by its own domestic payment system that was created under national rules and standards and therefore was incompatible among countries. Consequently, customers faced some difficulties to make cross-border payments such as higher transaction prices and need to have different bank accounts in the European countries that they made a trade. The EPC, the EC, and the ECB have triggered to solve those problems by implementation of the SEPA project. This project harmonised the national payment systems and implemented uniform pricing for domestic and cross-border retail payments. Under the SEPA system, all cross-border payments were treated like domestic ones. As SEPA resulted in fundamental changes in the retail payment market and all banks were obliged to comply with SEPA, it is important to analyse the impact of this project on competition between banks in the retail payment market.

In addition, the EC with the aim of developing an integrated financial market intervened in the card payment market to overcome the diversity of an interbank fee that banks pay to each other whenever a card payment is carried out and reduce its level. This fee is known as the interchange fee and is an important part of the cost of accepting cards by merchants that it ultimately affects retail prices. The diversity of the interchange fees across Europe was problematic since it prevented further integration and made barriers to create an internal market. In line with the SEPA project, the EC proposed the European Parliament and the Council to put a cap on the interchange fee in order to overcome the diversity problem and facilitate cross-border payments in Europe. In 2015, the European Parliament and the Council imposed a cap on the interchange fee for all domestic and cross-border payments with debit and credit cards among the European Economic Area (EEA). Based on this regulation the maximum permissible interchange fee for a transaction carried out with credit cards was 0.3% of the transaction amount and 0.2% for debit ones. Besides, the level of the interchange fee has drawn attention of some public authorities such as Spanish competition authority. They argued that the interchange fee was set arbitrarily high that went against anticompetitive principles. Their main concern was that the high interchange fee restricted competition between merchants' banks resulting in higher cost of accepting cards and higher retail prices. Therefore, they implemented a regulatory change in the card payment market to reduce the level of this fee. The interchange fee reduction in 2005 and 2014 are two important interventions by the Spanish competition authority. The objective of those regulations was to reduce the cost of accepting cards through the lower interchange fee and ultimately obtain a reduction in retail prices. The capping interchange fee in 2014 was the same as the EC's regulations in 2015; in an operation carried out with credit cards, the maximum permissible interchange fee was 0.3% of the transaction amount and 0.2% for debit ones. As the card payment market is characterised as a two-sided market, the reduction of the interchange fee has an effect on merchants and cardholders: how much to the merchants reflect the reduction and how much cards are being used. Therefore, the last objective of this dissertation is to empirically examine the impact of the interchange fee reduction on retail prices in Spain by considering two sides of the market.

This doctoral thesis has three core chapters. Chapter 2 studies factors that affect the structure of the search engine market in a dynamic model. Chapter 3 analyses the effects of SEPA on competition between banks and welfare in a static model. Chapter 4 empirically studies the effects of a reduction in the interchange fee on retail prices in Spain. In the following, there is a summary of the three chapters.

Chapter 2. R&D Investment and Competition: A Dynamic Model in The Search Engine Market

In this chapter, I analyse competition between two search engines (as for example Google and Bing) in a dynamic model. In this regard, I explore and solve a dynamic duopoly investment game for two competing search engines where they simultaneously invest in R&D to improve the quality of search results over time. Following Argenton and Prufer (2012), I consider quality as the degree of accuracy and usefulness of search results, uniqueness of results, page load speed, and real-time relevance. By applying the open-loop differential game, I examine whether and under what circumstances asymmetry between search engines tends to increase or decrease over time and whether increasing dominance with monopolisation is possible. The results show that under certain conditions, the asymmetry between search engines vanishes over time and the optimal path of quality and R&D investment converge to the steady-state equilibrium. At the steady-state equilibrium, search engines have the same quality and invest symmetrically in R&D. I further find that under a specific condition, the asymmetry between search engines increases over time and the market structure turns from duopoly to monopoly. Then, I explore the monopoly model as a benchmark.

The issue of increasing or decreasing asymmetry between search engines has not been addressed in the theoretical literature. This will be central to my analysis, and it distinguishes my approach from much of the existing literature. In my knowledge, this chapter is the first attempt that analyses the impact of R&D investment on competition between search engines in a dynamic model and determines whether the distance between firms tends to widen or narrow over time.

Chapter 3. Single Euro Payment Area and Banking Industry: Discriminatory Pricing vs. Non-Discriminatory Pricing

The Single Euro Payment Area (SEPA) project eliminates the incompatibility of domestic payment systems across European countries. It also enforces uniform pricing between national and international transactions. How does this policy affect competition among European banks in the retail payment market? To address this question, I explore and solve a model of non-linear price competition between two asymmetric banks in terms of capital by considering price discrimination in pre-SEPA and uniform pricing in post-SEPA under the presence of economies of scale. Analysis stands on two phases: the pre-SEPA phase where payment systems are diversified across countries and banks are allowed to discriminate between the price of domestic and cross-border payments, and the post-SEPA phase where banks complied with the SEPA system and applied the uniform pricing for making domestic and cross-border payments. I study the effects of SEPA on competition between banks and welfare by comparing the two phases. The main contribution of this chapter would be to study influences of SEPA project by focusing on price setting in pre- and post-SEPA. The results show that the transaction pattern has a vital role in the effects of SEPA on competition between banks. Competition is less intense in post-SEPA when the transaction pattern is domestically oriented. Moreover, comparison of pre- and post-SEPA suggests that SEPA intensifies competition when economies of scale are large enough. I further show that consumer surplus improves in post-SEPA as a result of uniform pricing but the effect of SEPA on welfare depends on the compliance cost with SEPA.

Chapter 4. Card Payment Market and Retail Prices: An Empirical Analysis of The Effects of The Interchange Fee on Price Levels in Spain

This chapter empirically examines how changes in the interchange fee affect retail prices. The interchange fee is a payment from the merchant's bank (called the acquirer) to the cardholder's bank (called the issuer) per card transaction. This is a fundamental fee that affects the card payment usage by a cardholder and the card acceptance by a merchant. In this chapter, I focus on two sides of the card payment market and study the short- and long-run relationships between the interchange fee and retail prices considering a panel of 10 different merchant sectors in Spain from the first quarter of 2008 to the fourth quarter of 2019. On the merchant side, I study the extent to which interchange fee changes affect the cost of accepting cards. Then, I analyse the effect of the change in this cost on retail prices. On the cardholder side, I study the extent to which interchange fee changes affect card payment usage, and then, I analyse the relationship between card payment usage and retail prices. Finally, the total effect is obtained by aggregating the effects of two-sides on retail prices. The results show that in the long-run, retail prices decrease as a result of declining interchange fee as had been expected by antitrust authorities. Evaluating the effects of the interchange fee reduction on retail prices is an important policy question that previous works have not been examined from two-sided market theory. The main contribution of this chapter is to fill this gap.

Chapter 2

R&D Investment and Competition: A Dynamic Model in The Search Engine Market

2.1. Introduction.

With the rapid growth of online search and online advertising, search engines have become a common staple of life in the 21st century. Search engines are critical gateways for users and businesses. On the one hand, search engines allow users to find what they are looking for on the Internet, and on the other hand, search engines give businesses the opportunity of offering their products or special deals at the precise instant that the user shows a special interest in particular products or services.

The rise of online search and online advertising coincides with a strong market concentration. Google controlled 92.71% of the global market share and Microsoft search engine (Bing) stayed as the most powerful rival of Google with 2.3% of the market worldwide in 2019[1]. The high degree of concentration raises the question of whether increasing dominance with monopolisation is possible. Relatedly, the European Commission (EC) received several complaints issued by smaller search engines against the potential anti-competitive behaviour of Google in Europe. For instance, Microsoft complained that based on European Union (EU) competition law, some practices by Google were anti-competitive. Such practices entailed close access of rival to its query database leading to steer users to use one particular search engine (violation of Article 101 Treaty on the Functioning of the European Union (TFEU) and of Article 102 TFEU), restrictions on the access of rivals to key content provided by other firm's websites, such as videos posted on YouTube (violation of Article 102 TFEU), and so on. Microsoft argued that Google's behaviour surpassed competition in order to retain its dominant position. In this respect, the EC launched several investigations regarding the practices used by Google. The EC claimed that Google has abused its market dominance and breached EU antitrust rules. Therefore, Google was fined a total of more than 8 billion Euros on three different occasions. In July 2020, the EU claimed that anti-competitive actions against Google have been fruitless. So the new EU strategy was to throw new rule book at Google in which the EU's Digital Services Act (DSA) enforced big tech firms (Google) to provide access to data for smaller firms under sensible and non-discriminatory conditions (Chee, 2020).

The high market concentration and above anti-competitive actions motivate this chapter. I analyse competition between two search engines (as for example Google and Bing) and identify the key factors that affect the evolution of market structure in a model of dynamic competition between them. Then, I analyse whether (and under what circumstances) asymmetry between search engines tends to

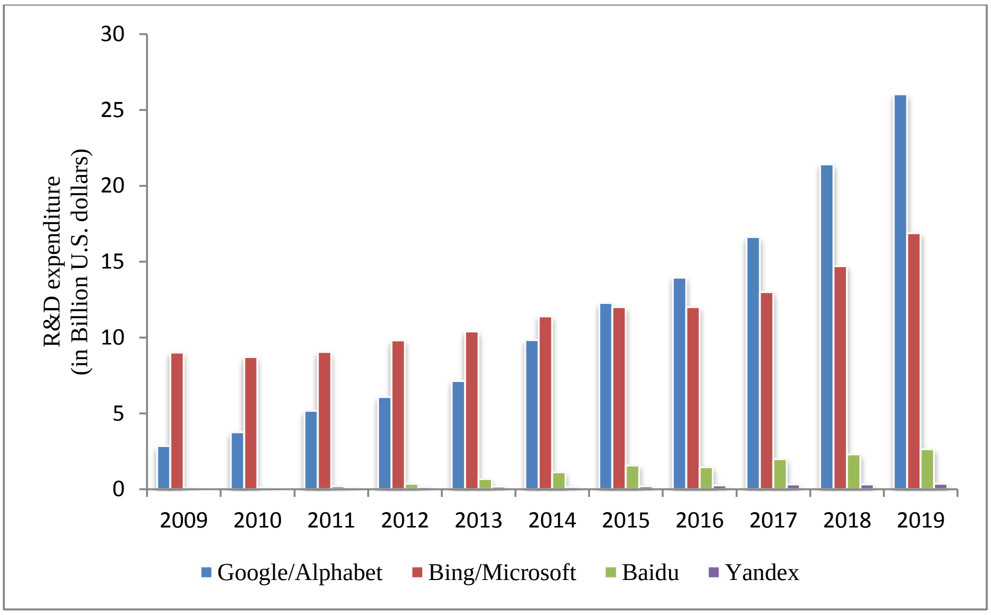
[1] https://gs.statcounter.com/search-engine-market-share.

increase or decrease over time and whether there is a tendency toward monopolisation in the market.

To address the above concerns, I explore and solve a dynamic duopoly investment game where two search engines simultaneously invest in R&D to improve the quality of their search results. Pollock (2011) underlines that the online search market is R&D intensive since search engines must constantly invest in R&D to maintain and improve the quality of their search results to offer a higher benefit to users. The quality can be defined by different criteria such as the degree of accuracy and usefulness of search results, uniqueness of results, page load speed, and real-time relevance (Argenton and Prufer, 2012). In this chapter, the search quality is a measure of all the mentioned attributes. I assume that there are two asymmetric search engines in terms of quality, the high quality search engine versus the low quality one. Users conduct a query for information that they are looking for on the Internet. In my model, market share is a function of quality, so the search engine with higher quality has a larger market share. Thus, improving the search quality is essential to provide more accurate information needed by users and therefore to gain market share.

The main source of profit for search engines is through the fees charged to businesses from users' clicks on advertising links. For instance, in 2019, 70.9% of Google's revenues came from advertising links. Increasing the advertising profit requires attracting more businesses, and this requires having a large-based user who will visit the business's site. Stucke and Ezrachi (2016) argue that quality plays an important role in competition between search engines since they offer free of charge search services to users. Therefore, in order to provide high quality search results and attract more users' queries, search engines have an incentive to invest in R&D. Figure 2.1 shows R&D investment by some search engines between 2009 and 2019. The amounts of R&D investment by Google and Bing are considerable. Until 2014, Bing invested in R&D more than other search engines and roughly the same level as Google in 2015. In the next year, Google increased its R&D investment relative to Bing. Although Google has a dominant position, it still invests more in R&D than its rivals in recent years.

Figure 2.1. R&D investment by search engines.



Source: Macrotrends.net

The model is constructed based on the following *evidence*. *First*, search engines do not charge their users to conduct a query. *Second*, the quality of the search result improves as a search engine handles more users' queries. This is so because each time that a user types a keyword, the suggested links and clicking behaviour of users are sorted by the search engine, gathers this information along with more information obtained from other users with similar search keywords[2]. The search engine learns that for a particular keyword, users have mostly clicked on some links than other ones resulting to provide more relevant results. Argenton and Prufer (2012) consider this feature as an indirect network externality. *Third*, search engines will attract businesses more easily as they get more users' queries. In turn, businesses will favor the search engine with greater market share. *Fourth*, having more users' queries facilitates innovation. More queries enable a search engine to test new features rapidly and deliver more relevant results.

I study competition in R&D investments by search engines over time in an open-loop differential game. In particular, I focus on the steady-state equilibria and the factors affecting the evolution of market structure over time. I find the open-loop Nash equilibrium of the game wherein the distance between search engines vanishes over time and the low quality search engine can be able to compete more effectively to attract users in the market. In general, I show that the optimal path of R&D investment and quality reach steady-state equilibrium over time. At the steady-state, search engines have the same quality and invest symmetrically in R&D. Also, I find a condition under which the high quality search engine is able to forge further ahead in a process of increasing dominance and the market structure turns from duopoly to monopoly. This result is consistent with the result of Argenton and Prufer (2012) who find that there is a strong tendency toward monopolisation. I also explore and solve a monopoly model as a benchmark. I characterise the R&D and quality path that is optimal for the monopolist. The comparison of duopoly and monopoly results reveals that monopolist invests less in R&D than search engines in the competitive environment.

Despite the important role of R&D investment and quality in the search engine market, few studies explore this issue. Lianos and Motchenkova (2013) consider the search engine market as a two-sided market where a search engine is a platform that connects two distinct groups: users and businesses. They study a monopoly search engine that invests in R&D in order to improve search quality. They find that the monopolist invests less in R&D than the social optimum resulting in higher advertising prices and lower search quality. The approach I take in this chapter is different from Lianos and Motchenkova (2013) in the sense that I explore and solve a dynamic duopoly investment game to analyse whether the distance between firms tends to widen or narrow over time. This approach is quite important in the dynamic game and distinguishes my analysis from much of the existing literature.

Several works study the structure of the search engine market, but they do not take into account R&D investment in their analysis. In earlier work, Telang et al. (2004) develop a vertical differentiation model to study the quality competition between an incumbent and an entrant in the search engine market. They consider a two period game: in the first period, users have only one choice since there is only one incumbent in the market; in the second period, one competitor enters the market with the newest technology. The results show that the incumbent with lower quality can survive in the market since search engines run different algorithms for the same query and offer different search results. Pollock (2011) studies market structure and welfare in the search engine

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[2] In fact, search engines use historical data from previous search queries. An obvious reason is the feature of spell-check. The search engine uses this feature to offer alternative suggestions for such queries with spelling mistakes (DIW econ, 2009).

[3] The description of two-sided market is explained in more detail in Chapter 4.

market. He argues that firms in this market face a high fixed cost and low marginal cost. Under this cost structure, his model predicts that the structure of the market turns from oligopoly to monopoly. He also compares the quality offered by monopolist with one that is socially optimal. He argues that if monopolist provides higher quality than the socially optimal level, then the intervention is not necessary. In contrast, if quality offered by monopoly digresses from the optimal provision, then some forms of regulation are required. Argenton and Prufer (2012) study the quality-based competition between three search engines under a discrete choice model. They consider some specifications of the market such as incomplete information of consumers about the quality of search engine, some degree of horizontal product differentiation, and network externalities. The results show that the current market structure is not stable and there is a strong tendency toward monopolisation. Zhao and Tsc (2011) develop a two-sided market model to study market structure and competition between search engines. They argue that a search engine with super search technologies can generate higher market power and, as a result, the structure of the market may reduce to monopoly.

One strand of literature focuses on choosing quality level by search engines. White (2013) argues that providing the high quality results of users' queries have benefits and costs for the search engine. It is due to the combination of two types of results that are displayed; Organic or unpaid results and advertised or paid results. On the one hand, advertiser's results should compete with the organic results in the same market. High quality organic results induce that users pay less attention to the advertisements. Thus, a search engine may have less incentive to display high quality organic results. On the other hand, high quality organic results bring higher market share and profits. He concludes that the search engine's profit relies extremely on the type of unpaid results and he suggests that a search engine can get greater profit by displaying more relevant informational links instead of an additional business link. Stucke and Ezrachi (2016) consider three factors affecting degradation quality. First, the ability of a search engine to offer lower quality search results in a way that it will be able to maximise profit from online advertising such as rank advertising results higher than organic results or mix organic results with less relevant advertising results. Second, when users cannot accurately identify quality, then competition pressure has less effect on improving quality and search engines can degrade search quality. Third, the low switching cost to a competing service is a factor that does not allow search engines to provide more irrelevant advertising results. They argue that if the quality degradation is a result of attaining or maintaining a monopoly, intervention by competition authority is necessary.

The other strand of literature focuses on the knowledge-sharing service property where users are free to ask and answer questions that shared knowledge amongst users of the search engine. Kim and Tse (2012) study competition between an inferior search engine with knowledge-sharing services (Naver) and a superior search engine without knowledge-sharing services (Google) in a differential game model. They study the competitive effect of accumulated knowledge by focusing on the open-loop strategy. The results show that the inferior search engine can survive in the market with the advantage of knowledge sharing services even if it has a small amount of online content. The reason is that the inferior search engine's database still draws the attention of searchers who keen to ask questions online. In a later work, Kim and Tse (2014) study competition between an inferior and a superior search engines under knowledge-sharing services in a static model. They find that if the amount of online information is limited, both search engines should adopt closed knowledge-sharing to maximise their profit. In contrast, when the amount of online information is high, the best strategy for the inferior search engine is to choose closed knowledge-sharing, while for the superior one is to go for open knowledge-sharing services.

The structure of this chapter is as follows. Section 2.2 describes the search engine industry. Section 2.3 presents the model (the duopoly investment game with two asymmetric search engines) and the results. Section 2.4 lays out and solve the monopoly model. Section 2.5 compares R&D investment in the duopoly and monopoly models. Section 2.6 provides some concluding remarks. Appendices gather the proofs.

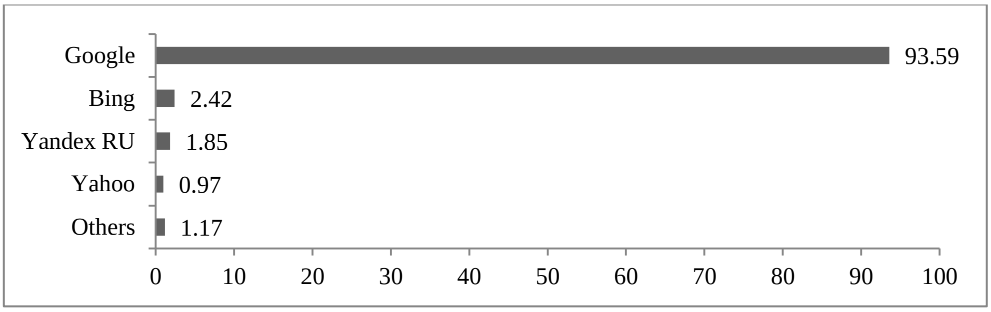
2.2. Description of Search Engine Market.

In the early stage of the market, there were five major search engines: Yahoo!, Lycos, Excite, Infoseek, and Altavista with the leader position of Yahoo!. Each search engine was able to cover a small part of the total web space, and different search engines indexed different web pages (Zhao and Tsc, 2011). So, if users could not find the information they were looking for in a search engine, they switched to other ones easily due to the low switching cost (Bradlow and Schmittlein (2000), Lawrence and Giles (1998, 2000)). In the middle of 1998, the structure of the market changed and some search engines exited the market. This process began with the entry of Google in 1998. To understand how Google succeeded in the market, I first explain some basic principles that are inherent to search engines.

Search engines rely on software and hardware to regularly explore the web, gather contents, keep them up to date and sort them in a web repository after some filtering. These tasks are performed by the web crawling system. The indexing system creates data structures of the web repository and ranks its content in order to provide more relevant results of a search query. When a query is submitted, the query processing system evaluates the search query by processing the index of web content and matches the search query as accurate as possible to data indexed in the repository. The web coverage, method, and the principle of content ranking are proprietary information that leads different search engines to offer different search results (DIW econ, 2009). Google invented an advanced algorithm called PageRank, which worked based on the Science Citation Index (SCI)[4] and ranked web pages in a range from 0 to 10 to specify the importance of them in the web space (Hammonds, 2003). PageRank algorithm delivered reasonably more accurate results, leading to Google became popular in 2000. At that time, the Inktomi Corporation provided search engine services to Yahoo! and Microsoft search engine. In competition with Google, the Inktomi failed to provide high quality search results. So, Yahoo! switched to Google, instead Microsoft search engine used AltaVista until 2004. After that, Yahoo! and Microsoft launched their own search technologies. In 2009, the Microsoft search engine was improved and re-launched as Bing. Yahoo! made an agreement with Bing to use Bing's search technology. Due to Google's advanced search algorithm, in 2002, Google surpassed Yahoo! and has maintained its leading position since then. This illustrates how the search algorithm differentiates search engines in terms of quality. Figures 2.2 and 2.3 show market shares of search engines in Europe and North America in 2019, respectively. The figures illustrate that Google has captured the highest market share and Bing is standing as its most powerful rival.

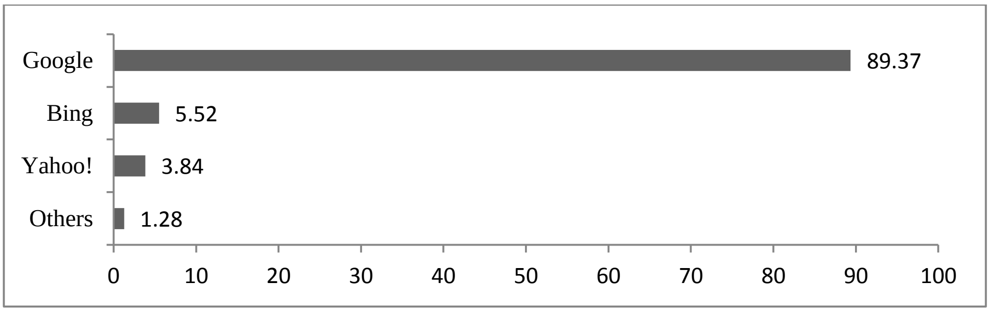
[4] This index is used to determine the importance of different scientific publications according to the number of publications and bibliographic sources obtained in other scientific works.

Figure 2.2. Search engine market shares in Europe in 2019 (%).



Source: Statcounter and own calculation[5].

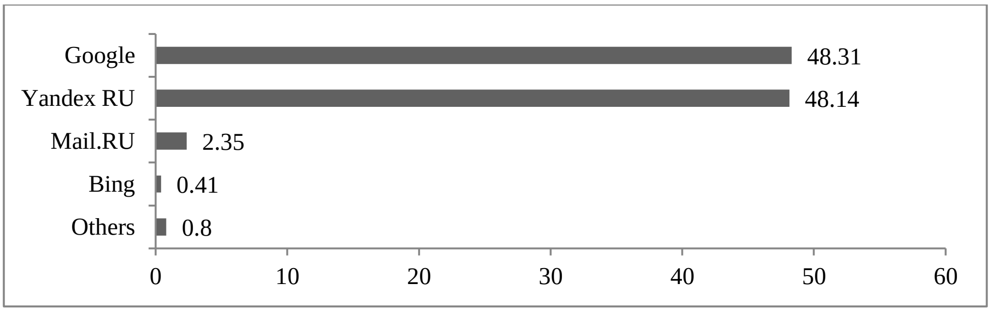
Figure 2.3. Search engine market shares in North America in 2019 (%).



Source: Statcounter and own calculation.

Besides, in Russia, the main rival of Google is Yandex. Yandex launched in 1997 and Google entered Russia in 2004. Yandex's advantage came from specialisation on the Russian language and culture and offered much as Google features to its users such as free email, maps, music, videos, photo storage, apps, etc. (Eferin et al., 2019). Figure 2.4 shows market share of search engines in Russia.

Figure 2.4. Search engine market shares in Russia in 2019 (%).



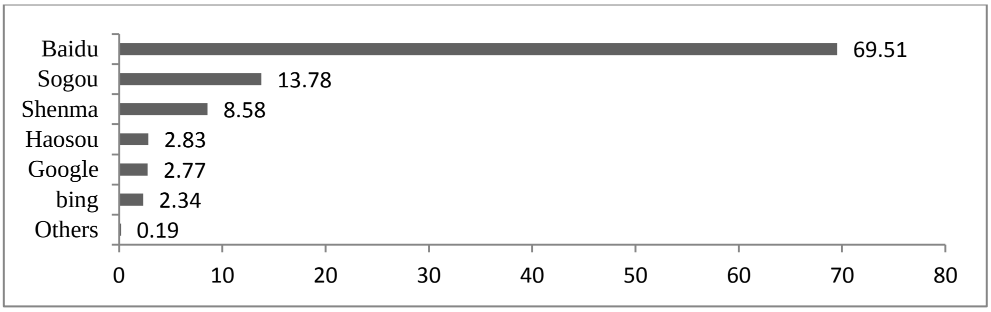
Source: Statcounter and own calculation.

Although Google maintains its stronghold in Europe and North America, there are some countries where Google does not have a leading position such as China and South Korea. In China, Baidu was

[5] https:// gs.statcounter.com/search-engine-market-share/all/north-america/#yearly-2019-2020-bar.

launched in 2000 and Google entered the Chinese online search market in 2006. Baidu surpassed Google and stayed as the main search engine in China. Baidu had around 69% market share, while Google accounted for about 3% in 2019. Baidu's success was due to the fact that it had an advantage in the Chinese language and culture, fully compliant with the local laws and censorship imposed on operations. These facts enabled Baidu to design better search technology for the needs of local users (Bielinski, 2018). Moreover, Baidu offered some services such as links to pirated songs, TV shows, and movies from Chinese web sites that Google did not offer initially. Figure 2.5 shows market share of search engines in China in 2019.

Figure 2.5. Search engine market shares in China in 2019 (%).



Source: Statcounter and own calculation.

Naver is a local search engine in South Korea that was found in 1999 and had the lead position since 2003. Its success was related to its knowledge sharing services launched in 2002. Naver kept closed this data from access to other search engines such as Google. Since the content in the Korean language was relatively small, compared to the content in English or Chinese, the knowledge sharing services became the most important advantage of the search engine in South Korea (Zhao and Tsc, 2011). It limited the usefulness of Google, and its advanced search algorithm was not sufficient to achieve a dominant position. In 2015, Naver had 77% market share in South Korea while Google had less than 3% (Return on Now, 2015).

2.3. Dynamic Differential Duopoly Game.

Consider two search engines with different qualities indexed by $i \in\{1, 2\}$, each providing search online services, and suppose that search engines simultaneously invest in R&D in order to improve the quality of their search results.

Utility of Consumers. Users are uniformly distributed on the segment [0, 1], whereas search engine 1 is located at 0 and search engine 2 is located at 1. Each user makes a query in one of the two search engines. I assume that users derive neither positive nor negative effects on utility from advertising results. The cost of conducting a query is zero, while the user's utility from querying in search engine i is:

$$\vartheta(y_i^t)= \emptyset y_i^t - \tau|x - x_i|$$

where $\emptyset > 0$ and y_i^t is the quality of search engine i. Parameter $\tau > 0$ is the product differentiation. The term $\tau|x - x_i|$ captures the user disutility (search costs) where x_i is the location of search engine i ($x_1 = 0$ and $x_2 = 1$) and x is the location of a user.

*Market Share***.** The market share of search engines 1 and 2 are:

$$\alpha_1^t = \frac{1}{2} + \emptyset\sigma\,(y_1^t - y_2^t)$$

$$\alpha_2^t = \frac{1}{2} + \emptyset\sigma\,(y_2^t - y_1^t)$$

where $\sigma = \frac{1}{2\tau} > 0$ is the degree of substitutability between the two search engines. Let $y^t = y_1^t - y_2^t$ measures the quality 'gap' between the two search engines; search engine 1 has higher quality than search engine 2 if $y > 0$ (search engine 2 has higher quality if $y < 0$). This definition is standard in literature and shows how a firm is ahead or behind of its rival in respect of quality in the market. Then, market share of each search engine can be rewritten as a function of y^t as follows.

$$\alpha_1^t = \frac{1}{2} + \widetilde{\emptyset}y^t$$

$$\alpha_2^t = \frac{1}{2} - \widetilde{\emptyset}y^t$$

with $\widetilde{\emptyset} = \emptyset\sigma > 0$.

Investment Cost. Search engine i continuously invests the amount of u_i^t at period t in R&D so as to increase the quality of its search algorithm. I assume that the investment cost of each search engine (Γ_i^t) is a strictly convex function of its R&D investment. Furthermore, the marginal cost of investing in R&D for search engine 1 decreases with an increase in the quality gap, and for search engine 2 increases with an increase in the quality gap (*Fourth* fact). Investment cost of each search engine is defined as follows:

$$\Gamma_1^t = (\bar{c} - cy^t)u_1^t + b\frac{(u_1^t)^2}{2}$$

$$\Gamma_2^t = (\bar{c} + cy^t)u_2^t + b\frac{(u_2^t)^2}{2}$$

where $\bar{c}$, c, b are positive constant over time.

Quality Growth. I assume that the dynamic associated with the quality gap is a function of the present quality gap and R&D investment conducted by search engines 1 and 2, and is defined by the following equation:

$$\dot{y} = \theta y^t + k(u_1^t - u_2^t) \qquad (2.1)$$

with $k > 0$ and the initial condition $y^0 = y(0)$[6]. Parameter θ captures the effect of the existing quality gap on its growth. Based on the *Second* fact that the model builds on, parameter $\theta \neq 0$ but it can be positive or negative. Therefore, if $\theta > 0$ ($\theta < 0$), it implies that the growth rate over time increases (decreases) with the present quality gap.

Profit. The primary objective of this chapter is not the business side; therefore, I omit how businesses compete for online advertising and assume that there exists a unique equilibrium to such

[6] In the differential game approach, the variable u_i^t is known as a control variable and y^t is known as a state variable.

competition for advertising game. I assume that the profit of each search engine in online advertising is quadratic and given by:

$$\pi_1^t = f\alpha_1^t + \frac{\rho}{2}(\alpha_1^t)^2$$

$$\pi_2^t = f\alpha_2^t + \frac{\rho}{2}(\alpha_2^t)^2$$

with $f > 0$. The profit is a strictly concave function of the market share: $\frac{\partial^2 \pi_i}{\partial \alpha_i^2} = \rho < 0$. By substituting the market share of each search engine into the profit function, I get:

$$\pi_1^t = \bar{\rho}(y^t)^2 + my^t + n$$

$$\pi_2^t = \bar{\rho}(y^t)^2 - my^t + n$$

where $\bar{\rho} = \frac{\rho}{2}\widetilde{\emptyset}^2$, $m = (f + \frac{\rho}{2})\widetilde{\emptyset}$, and $n = \frac{4f+\rho}{8}$. The profit functions are quadratic in the state.

Pay-off. The pay-off for search engine i is thus

$$\Pi_i^t = \pi_i^t - \Gamma_i^t \tag{2.2}$$

The pay-off of each search engine depends on the quality gap and the amount of R&D invested. Since the production of quality is costly, market share and thus advertising revenues must be high enough to yield a positive pay-off. In order to find optimal solutions to the differential game (2.1) – (2.2), I consider the case where both search engines make decisions on the amount of R&D investment at the initial date (t=0) and commit to a given time path of investment. It means that search engines cannot change their decisions after they have been made. Therefore, I consider open-loop strategies[7]. Applying these strategies make the model tractable and easy to understand. The open-loop Nash equilibrium of the game is a combination of pairs of strategies of both search engines which ensure that none of the search engines can unilaterally alter its strategy as long as the other search engine plays its Nash strategy (Reinganum (1982), Fershtman and Kamien (1987), among others). Proof of Lemma 2.1 in appendix A describes in more detail this strategy.

Timing. First. Given y^0 and u_i^0 where $i \in \{1, 2\}$, each search engine chooses the path of R&D investment in order to improve their search algorithm over time. At each period t, search engines incur investment cost Γ_i^t. Then, users choose their preferred search engine to query, and finally search engines make some profits from online advertising.

2.3.1. Open-Loop Equilibria.

Each search engine maximises its pay-off subject to the dynamic of quality gap constraint for given initial R&D levels and initial state condition.

[7] An alternative method to solve the dynamic game is the equilibrium closed-loop strategies. In this case, search engines can change their decisions as the game evolves: search engines do not commit themselves to a particular path at the initial stage and can respond to the state of the system.

$$\max_{u_i^t} \Pi_i^t = \max_{u_i^t} \int_0^\infty e^{-rt} \Pi_i^t \, dt$$

s.t

$$\dot{y} = \theta y^t + k(u_i^t - u_j^t)$$

$$y^0 = y(0), u_i^0 = u_i(0), u_j^0 = u_j(0) \text{ where } i, j \in \{1,2\} \text{ and } i \neq j.$$

The parameter $r \in [0,1)$ is the discount rate. Each search engine maximises its pay-off with respect to its own R&D investment. The solution is presented in Proposition 2.1.

Proposition 2.1: The Quality-R&D system

i) for search engine 1 is:

$$\begin{cases} \dot{y} = \theta y^t + k(u_1^t - u_2^t) \\ \dot{u_1} = \left(-A + \frac{c}{b}\theta\right) y + \left(B + \frac{c}{b}k\right) u_1^t - \frac{c}{b} k u_2^t + D \end{cases} \tag{2.3}$$

ii) for search engine 2 is:

$$\begin{cases} \dot{y} = \theta y^t + k(u_1^t - u_2^t) \\ \dot{u_2} = \left(A - \frac{c}{b}\theta\right) y + \left(B + \frac{c}{b}k\right) u_2^t - \frac{c}{b} k u_1^t + D \end{cases} \tag{2.4}$$

where $\mathrm{A} = \left(\frac{(\mathrm{r}-\theta)\mathrm{c}+2\mathrm{k}\bar{\rho}}{\mathrm{b}}\right)$, $\mathrm{B} = \left(\mathrm{r} - \theta - \frac{\mathrm{ck}}{\mathrm{b}}\right)$, $\mathrm{D} = \frac{(\mathrm{r}-\theta)\bar{\mathrm{c}}-\mathrm{km}}{\mathrm{b}}$.

Proof: See Appendix A.

The term $-A + \frac{c}{b}\theta$ has an important role in the analysis. It captures the growth rate of R&D investment in terms of the present quality gap. If the sign of this term is positive and $y > 0$, then the growth rate of R&D investment of search engine 1 increases with the present quality gap while the growth of R&D investment of search engine 2 decreases with y. In contrast, when the term $-A + \frac{c}{b}\theta$ is negative and search engine 1 has higher quality ($y > 0$), then the growth of R&D investment of search engine 1 decreases with y while the growth of R&D investment of search engine 2 increases with y. The same intuitions are obtained when search engine 2 has higher quality than search engine 1. In the following, I explain the role of this term on the steady-state equilibrium.

In order to find the optimal path, first I determine the steady-state equilibrium for the dynamic systems (2.3) and (2.4) and then based on the characteristics of the steady-state, I examine whether there is an optimal path that converges to this point.

Lemma 2.1: The steady-state open-loop equilibrium $(\mathrm{y^s}, \mathrm{u_i^s})$ is symmetric and characterises as

$$(y^s, u_1^s) = (y^s, u_2^s) = \left(0, \frac{-D}{B}\right) \tag{2.5}$$

where $\mathrm{B} = \left(\mathrm{r} - \theta - \frac{\mathrm{ck}}{\mathrm{b}}\right)$ and $\mathrm{D} = \frac{(\mathrm{r}-\theta)\bar{\mathrm{c}}-\mathrm{km}}{\mathrm{b}}$.

Proof: See Appendix A

At the steady-state, search engines have the same level of quality since $y^s = 0$ and they symmetrically invest in R&D to maximise their pay-offs. In other words, at the steady-state, there is no difference between search engines and they have the same pay-off as follows:

$$\Pi_1 = \Pi_2 = n + \frac{D}{B}(\bar{c} + \frac{bD}{2B})$$

with $n = \frac{4f+\rho}{8}$, $\mathrm{B} = \left(\mathrm{r} - \theta - \frac{\mathrm{ck}}{\mathrm{b}}\right)$, $\mathrm{D} = \frac{(\mathrm{r}-\theta)\bar{\mathrm{c}}-\mathrm{km}}{\mathrm{b}}$, $m = (f + \frac{\rho}{2})\widetilde{\emptyset}$, $\rho < 0, f > 0$.

The steady-state is positive if the following conditions hold:

i) $D < 0$ and $\mathrm{B} > 0$

or

ii) $D > 0$ and $\mathrm{B} < 0$

Given the conditions in which the steady-state is positive, I conduct the analysis of stability to figure out whether there are paths of quality and R&D investment that converge to the steady-state over time, i.e. the distance between firms tends to narrow over time. Lemma 2.2 shows the steady-state properties.

Lemma 2.2: The symmetric steady-state qualifies as a saddle point when $(-A + \frac{c}{b}\,\theta) > \frac{(r-\theta)\theta}{k}$. If this condition does not hold, then the steady-state is an unstable node.

Proof: See Appendix A.

The existence of the saddle steady-state indicates that in the neighbourhood around this point, there is at least one path of quality and R&D investment converging to this equilibrium over time while other ones diverge. In this regard, first I solve systems (2.3) and (2.4) and then determine the optimal paths that give the best possible R&D investment and quality for the dynamic systems.

Proposition 2.2: The solution to the Quality-R&D system,

i) for search engine 1 is

$$\begin{cases} Y^t = C_1 e^{\varsigma_1 t} + C_2 e^{\varsigma_2 t} \\ U_1^t = C_1 \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_1} . e^{\varsigma_1 t} + C_2 \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} e^{\varsigma_2 t} - \frac{D}{B} \end{cases} \tag{2.6}$$

ii) for search engine 2 is

$$\begin{cases} Y^t = C_1 e^{\varsigma_1 t} + C_2 e^{\varsigma_2 t} \\ U_2^t = C_1 \frac{-A + \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_1} . e^{\varsigma_1 t} + C_2 \frac{-A + \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} e^{\varsigma_2 t} - \frac{D}{B} \end{cases} \tag{2.7}$$

where $\mathrm{A} = \left(\frac{(\mathrm{r}-\theta)\mathrm{c}+2\mathrm{k}\bar{\rho}}{\mathrm{b}}\right)$, $\mathrm{B} = \left(\mathrm{r} - \theta - \frac{\mathrm{ck}}{\mathrm{b}}\right)$, $\mathrm{D} = \frac{(\mathrm{r}-\theta)\bar{\mathrm{c}}-\mathrm{km}}{\mathrm{b}}$, $\varsigma_1 > 0 > \varsigma_2$ are eigenvalues and C_1 and C_2 are constant.

Proof: See Appendix A.

Proposition 2.3: The optimal path

i) for search engine 1 is:

$$\begin{cases} Y^t = C_2 e^{\varsigma_2 t} \\ U_1^t = C_2 \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} e^{\varsigma_2 t} - \frac{D}{B} \end{cases} \quad (2.8)$$

ii) for search engine 2 is:

$$\begin{cases} Y^t = C_2 e^{\varsigma_2 t} \\ U_2^t = C_2 \frac{-A + \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} e^{\varsigma_2 t} - \frac{D}{B} \end{cases} \quad (2.9)$$

where constant C_2 is determined from initial conditions.

Proof: See Appendix A.

2.3.1.1. Illustration.

This subsection illustrates the numerical simulations of systems (2.6) and (2.7). First, I consider the case where there is a saddle steady-state and find conditions under which the asymmetry between search engines will narrow over time. Then, I consider the case where the steady-state is an unstable node and show that asymmetry between search engines increases over time and, as a result, the high quality search engine obtains a monopoly position in the market.

i) The steady-state is characterised as a saddle point.

In order to analyse the behaviour of search engines under the existence of saddle steady-state, I design 4 different scenarios as follows.

Scenario 1. $y(0) = 0$, $u_1(0) = u_2(0)$.

Figures 2.6-a and 2.6-b show optimal paths of quality gap and R&D investment when the two search engines start from the symmetric situation. It is observed that there is no quality gap and the two search engines invest equally in R&D, and the R&D investment converges to u^s over time[8].

Figure 2.6-a. Quality gap growth.

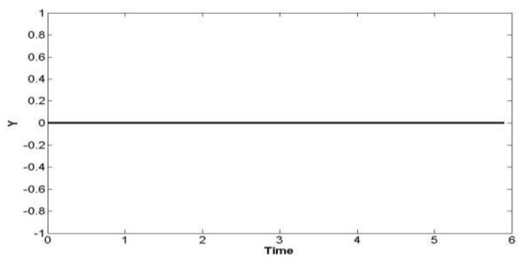
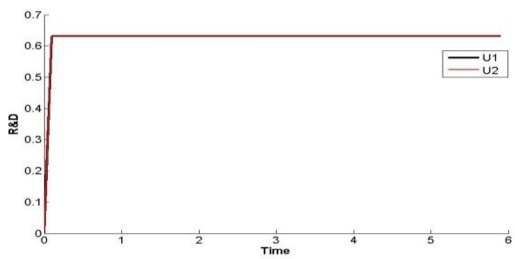


Figure 2.6-b. R&D investment growth.



Scenario 2. $\theta < 0$, $\left(-A + \frac{c}{b}\theta\right) < 0$, $y(0) > 0$, and $u_1(0) = u_2(0)$.

[8] Parameter values are $\bar{c} = 2, k = 1.5, \theta = -0.19, \tau = 1.5, \rho = -0.8, b = 0.6, c = 0.5, \emptyset = 1, r = 0.2, f = 1$, and initial conditions are $y(0) = 0, u_1(0) = u_2(0) = 0$.

Figures 2.7-a and 2.7-b show the quality gap growth and R&D investment growth of search engines 1 and 2, respectively[9]. Under this scenario, both search engines are on their optimal Quality-R&D path when search engine 1 invests more than search engine 2 in R&D and its level decreases while the R&D level of search engine 2 increases towards a unique steady-state over time. Under this condition, the asymmetry between search engines vanishes over time and the system converges to the symmetric steady-state equilibrium. This is because the growth rate of quality gap and R&D investment of search engine 1 decrease with the quality gap, search engine 1 by investing more in R&D can balance the lower rate of growth of its R&D investment. By decreasing the quality gap, the R&D investment for search engine 1 becomes expensive while for search engine 2 becomes cheap. Therefore, R&D investment of search engine 1 decreases while R&D investment of search engine 2 increases over time.

Scenario 3. $\theta < 0$, $\left(-A + \frac{c}{b}\,\theta\right) > 0$, $y(0) > 0$, and $u_1(0) = u_2(0)$.

Under this scenario, both search engines are on their optimal Quality-R&D path when search engine 2 invests more than search engine 1 in R&D and decreases its R&D investment over time towards steady-state (Figures 2.8-a,b)[10]. Here also the asymmetry between the two search engines narrows over time, the low quality search engine gains market share and the two search engines may be active in the steady-state. The reason is that at the beginning of the game, the quality gap is large and the growth of R&D investment of search engine 2 has a decreasing rate with the quality gap. Therefore, search engine 2 by investing more in R&D decreases the quality gap over time, and search engine 1 invests at a decreasing rate since R&D investment is more expensive for it.

Scenario 4. $\theta > 0$, $(-A + \frac{c}{b}\,\theta) > 0$, $y(0) > 0$, and $u_1(0) = u_2(0)$.

In this scenario, in order to both search engines to be on their optimal Quality-R&D path and reach equilibrium, search engine 2 must invest significantly in R&D at the beginning of the game and then decreases its investment over time towards steady-state. In this scenario, similar to the previous ones, the asymmetry between the two search engines narrows over time (Figures 2.9-a,b)[11].

Figure 2.7-a. Quality gap growth.

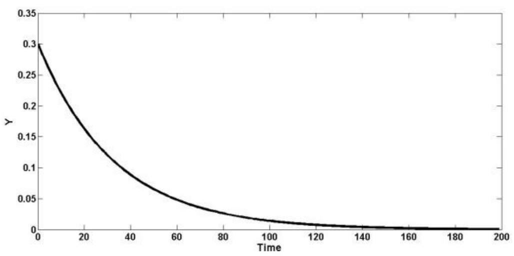
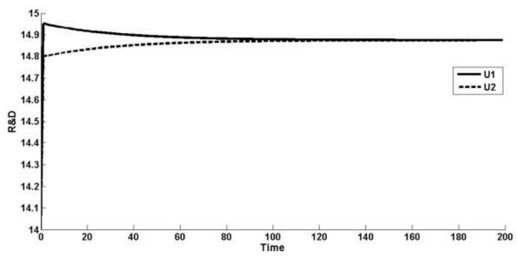


Figure 2.7-b. R&D investment growth.



[9] Parameter values are $\bar{c} = 2, k = 1, \theta = -0.3, \tau = 1.5, \rho = -0.8, b = 1, c = 1, \emptyset = 1.5, r = 0.6, f = 1$, and initial conditions are $y(0) = 0.3, u_1(0) = u_2(0) = 14$.

[10] Parameter values are $\bar{c} = 2, k = 1.5, \theta = -0.2, \tau = 1, \rho = -0.9, b = 1, c = 0.5, \emptyset = 1, r = 0.2, f = 1$, and initial conditions are $y(0) = 0.3, u_1(0) = u_2(0) = 1$.

[11] Parameter values are $\bar{c} = 2, k = 1, \theta = 0.3, \tau = 1.5, \rho = -0.8, b = 1, c = 1, \emptyset = 1.5, r = 0.6, f = 1$, and initial conditions are $y(0) = 0.3, u_1(0) = u_2(0) = 0.2$.

Figure 2.8-a. Quality gap growth.

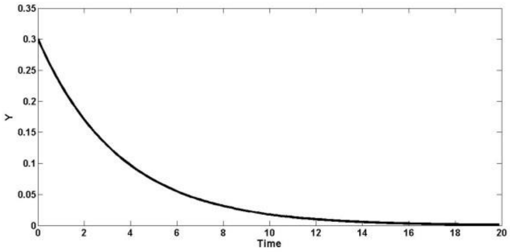


Figure 2.8-b. R&D investment growth.

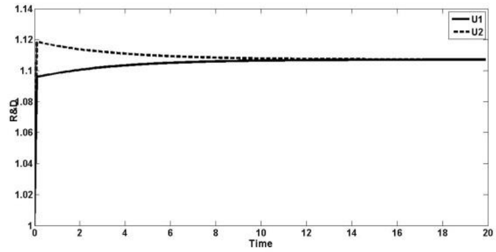


Figure 2.9-a. Quality gap growth.

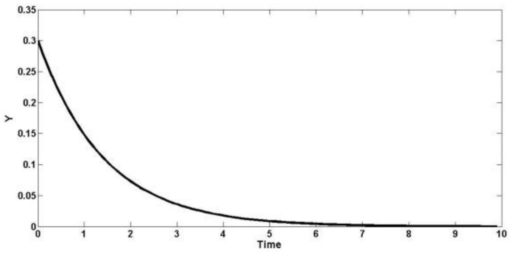
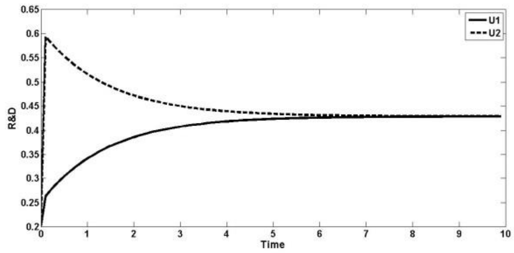


Figure 2.9-b. R&D investment growth.



In the previous four scenarios, I found situations in which asymmetry between search engines vanished over time. In the following, I show that when $\theta > 0$ and $\left(-A + \frac{c}{b}\,\theta\right) < 0$, there is no stable path that approaches the steady-state equilibrium.

ii) The steady-state is characterised as an unstable node.

Proposition 2.4: If $\theta > 0$ and $\left(-A + \frac{c}{b}\,\theta\right) < 0$, then the condition of Lemma 2.2 does not hold and the steady-state is characterised as an unstable node.

Proof: See Appendix A.

Conditions of Proposition 2.4 holds when r is sufficiently large as it satisfies $r > 2(\theta - \frac{k\bar{\rho}}{c})$. The high discount rate indicates that the present value of future pay-off shrinks. Therefore, search engines have less incentive to invest in R&D since the production of quality through R&D investment becomes expensive for them. Search engine 1 can balance the high discount rate by $\theta > 0$ and $\left(-A + \frac{c}{b}\,\theta\right) < 0$. At the beginning of the game, the quality gap is small, and so, the growth rate of R&D investment of search engine 1 is high. Thus, search engine 1 benefits from the increasing growth rate of quality gap and the high R&D growth rate, and search engine 2 cannot compete effectively with search engine 1 since the investment in R&D is more expensive. Therefore, asymmetry between the two search engines grows over time whereas the low quality search engine decreases its respective R&D investment and market share over time. Consequently, the structure of the market tends to the monopoly. Figures 2.10-a, 2.10-b, 2.10-c illustrate this scenario[12].

[12] Parameter values are $\bar{c} = 0.5, k = 1, \theta = 0.2, \tau = 1, \rho = -0.7, b = 1, c = 0.5, \emptyset = 1, r = 0.8, f = 1.2$, and initial conditions are $y(0) = 0.5, u_1(0) = 0.2, u_2(0) = 0$.

Figure 2.10-a. Quality gap growth.

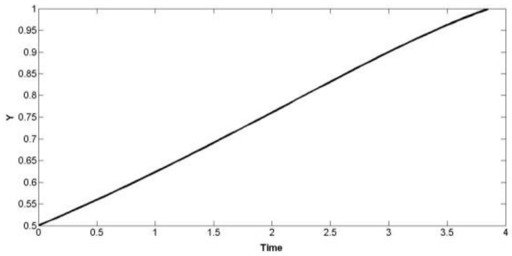


Figure 2.10-b. R&D investment growth.

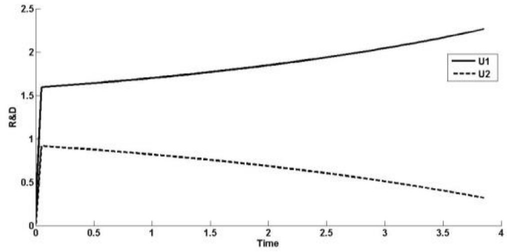
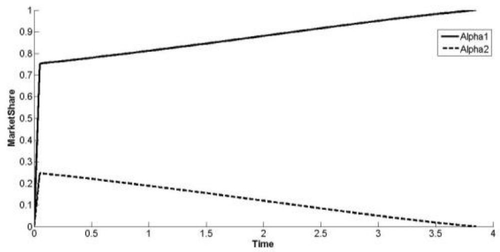


Figure 2.10-c. Market share over time.



2.3.2. Comparative Statics.

The purpose of this subsection is to examine how steady-state R&D investment responds to changes in some parameter values. The following proposition summarises the main results.

Proposition 2.5: At the steady-state equilibrium,

i) if marginal profit with respect to quality, $\frac{\partial \pi}{\partial y} = (f + \frac{\rho}{2})$, is greater (smaller) than $\frac{c\bar{c}}{b\tilde{\emptyset}}$, then

$$\frac{\partial u^s}{\partial \theta} > 0 \; (\frac{\partial u^s}{\partial \theta} < 0 \,), \frac{\partial u^s}{\partial r} < 0 \; (\frac{\partial u^s}{\partial r} > 0).$$

ii) u^s increases with k ($\frac{\partial u^s}{\partial k} > 0$) under three different conditions: 1) $\theta > 0,\ r > \theta$, and $\left(f + \frac{\rho}{2}\right) > \frac{c\bar{c}}{b\tilde{\emptyset}}$, or 2) $\theta > 0, r < \theta$, and $\left(f + \frac{\rho}{2}\right) < \frac{c\bar{c}}{b\tilde{\emptyset}}$, or 3) $\theta < 0$, and $\left(f + \frac{\rho}{2}\right) > \frac{c\bar{c}}{b\tilde{\emptyset}}$.

iii) u^s decreases with b ($\frac{\partial u^s}{\partial b} < 0$) under two different conditions: 1) $\theta > 0,\ \theta < r$, and $\left(f + \frac{\rho}{2}\right) > \frac{(\theta - r)\bar{c}}{k\tilde{\emptyset}}$, or 2) $\theta < 0$ and $\left(f + \frac{\rho}{2}\right) > \frac{(\theta - r)\bar{c}}{k\tilde{\emptyset}}$.

Proof: See Appendix A.

The part (i) of the above Proposition shows the specific condition under which u^s increases with θ and decreases with r. Proposition 4 showed when r is large, the steady-state is an unstable node. By keeping constant the other conditions, based on the negative sign of $\frac{\partial u^s}{\partial r}$, it is concluded that u^s is small when steady-state is an unstable node. Parameter k measures the effect of the R&D investment on the growth of quality gap. As part (ii) of the above Proposition shows, the relationship between u^s and k depends on different conditions. If one of them holds, then an increase in k leads to an increase in u^s. Parameter b captures the convexity of the R&D investment cost. If any of the conditions in part (iii) holds, then as b increases the investment cost increases. So it facilitates to find an interior solution to the maximisation problem and therefore u^s decreases.

2.4. Dynamic Optimisation for Monopoly.

In this section, I describe the basic assumptions of a monopoly model and study under which conditions the path of R&D investment and quality converge to the steady-state equilibrium over time. Even if a monopolist does not face competition, it still has an incentive to invest in R&D in order to obtain a higher number of queries from which it brings more online advertising profits.

Utility of Consumers. In the monopoly case, the utility of a user from using the search engine is given by:

$$\vartheta(y_M^t) = \emptyset\, y_M^t - \tau.x$$

with $\emptyset, \tau > 0$. The subscript M stands for monopoly and y_M^t is the stock of quality of monopoly. The term $\tau.x$ measures the user disutility from not being able to consume his preferred services.

Market Share. Market share of the monopoly is given by:

$$\alpha_M^t(y_M^t) = \widetilde{\emptyset} y_M^t\ , \qquad \alpha_M^t \leq 1$$

with $\widetilde{\emptyset} = \frac{\emptyset}{\tau}$, and is an increasing function of quality.

Investment Cost. The monopolist invests an amount of u_M^t at period t in R&D to improve its search algorithm. The investment cost is as follows:

$$\Gamma_M^t = (\bar{c} - c y_M^t) u_M^t + b\frac{(u^t)^2}{2}$$

where $\bar{c}, c, b > 0$. The marginal cost of investing in R&D is strictly convex in terms of $u^t$and decreases with the level of quality achieved by the search algorithm.

Quality Growth. The dynamic associated with the quality is a function of the stock of quality and the R&D investment. Therefore,

$$\dot{y}_M = \theta y_M^t + k u_M^t \tag{2.10}$$

with $k > 0$. Parameter θ measures the impact of the stock of quality on its growth over time and could be positive or negative.

Profit. The profit is given by:

$$\pi_M^t = f.\alpha_M^t + \frac{\rho}{2}(\alpha_M^t)^2$$

with $f > 0$, $\frac{\partial \pi_M^t}{\partial \alpha_M^t} > 0$ and $\frac{\partial^2 \pi_M^t}{\partial {\alpha_M^t}^2} < 0$ ($\rho < 0$), i.e. the profit is a concave function of the market share. By inserting the market share into the profit function, I get:

$$\pi_M^t = \mathrm{m}(y_M^t)^2 + \bar{\rho}\, y_M^t$$

where m$=\frac{\rho}{2}(\widetilde{\emptyset})^2 < 0$ and $\bar{\rho} = f\,\widetilde{\emptyset}$. Like in the duopoly case, the profit is a quadratic function in the state.

Pay-off. The pay-off is defined as follows:

$$\Pi_M^t = \pi_M^t - \Gamma_M^t \tag{2.11}$$

The problem of the monopolist is to find optimal control that maximises the discounted pay-off function, subject to the quality growth and initial conditions in an infinite time horizon:

$$\max_{u_M^t} \Pi_M^t = \max_{u_M^t} \int_0^\infty e^{-rt}\, \Pi_M^t dt$$

s.t.

$$\dot{y}_M = \theta y_M^t + k u_M^t$$

$$y_M^0 = y_M(0) \text{ and } u_M^0 = u_M(0)$$

where $r \in [0,1)$ is the firm's discount parameter.

2.4.1. Optimal Solution.

Dynamic optimisation of the monopolist yields simultaneous solutions for $\dot{y}_M$ and $\dot{u}_M$. The following Proposition states the dynamic Quality-R&D system.

Proposition 2.6: The Quality-R&D system for monopolist is:

$$\begin{cases} \dot{y}_M = \theta y_M^t + k u_M^t \\ \dot{u}_M = \left(-A + \frac{c}{b}\theta\right) y_M^t + (\mathrm{B} + \frac{c}{b}\mathrm{k}) u_M^t + D \end{cases} \tag{2.12}$$

where $A = \frac{(\mathrm{r}-\theta)\mathrm{c}+2\mathrm{mk}}{\mathrm{b}}$, $\mathrm{B} = (\mathrm{r} - \theta - \frac{\mathrm{ck}}{\mathrm{b}})$, $D = \frac{(\mathrm{r}-\theta)\bar{\mathrm{c}}-\bar{\rho}\mathrm{k}}{\mathrm{b}}$.

Proof: See Appendix B.

Similar to the duopoly case, the term $-A + \frac{c}{b}\,\theta$ captures the growth rate of R&D investment in terms of the present stock of quality. If the sign of this term is positive (negative), then the growth rate of R&D investment by monopolist increases (decreases) with the present stock of quality. Proposition 2.6 shows that there are different paths of quality and R&D investment. In order to find the optimal path, I continue the analysis by exploring the stability condition. First by imposing the stationary condition in system (2.12), I obtain the steady-state equilibrium:

$$(y_M^s, u_M^s) = \left(\frac{kD}{Ak+B\theta}, \frac{-\theta D}{Ak+B\theta}\right) \tag{2.13}$$

At the steady-state, the monopolist invests just enough to maintain its quality at the desired level that maximises its pay-off:

$$\Pi_M^s = \left(mk^2 - c\theta k - \frac{b}{2}\theta^2\right)\left(\frac{D}{Ak+B\theta}\right)^2 + (\bar{c}\theta - k\bar{\rho})\left(\frac{D}{Ak+B\theta}\right)$$

For $\theta > 0$, u_M^s is positive when $D > 0$ ($D < 0$) and $Ak + B\theta < 0$ ($Ak + B\theta > 0$) which results in a negative amount for y_M^s. Alternatively, y_M^s is positive when $D > 0$ ($D < 0$) and $Ak + B\theta > 0$ ($Ak + B\theta < 0$), but under these conditions, u_M^s is always negative. In contrast, when $\theta < 0$, the steady-state can be positive. The negative θ implies that quality growth decreases with the present stock of quality. So from now on, I consider $\theta < 0$, and the steady-state is positive according to the following conditions:

i) $D < 0$ and $Ak + B\theta < 0$
or
ii) $D > 0$ and $Ak + B\theta > 0$

The term $Ak + B\theta < 0$ can be rewritten with respect to the growth rate of R&D investment: $-A + \frac{c}{b}\,\theta > \frac{(r-\theta)\theta}{k}$. The following Lemma shows that in case (i), the steady-state equilibrium is characterised as a saddle point, while in case (ii) it is not a stable node.

Lemma 2.3:

i) If $-A + \frac{c}{b}\,\theta > \frac{(r-\theta)\theta}{k}$, then the steady-state qualifies as a saddle point.

ii) If $-A + \frac{c}{b}\,\theta < \frac{(r-\theta)\theta}{k}$, then the steady-state qualifies as an unstable node.

Proof: See Appendix B.

The saddle steady-state ensures that there is at least one path that converges to this point. The following Propositions show the solution to the system (2.12) and the optimal path.

Proposition 2.7: The solution to the system is given by:

$$\begin{cases} Y_M^t = C_1.e^{\varsigma_1 t} + C_2.e^{\varsigma_2 t} + \frac{kD}{Ak+B\theta} \\ U_M^t = C_1.\frac{A-\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_1}.e^{\varsigma_1 t} + C_2.\frac{A-\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_2}.e^{\varsigma_2 t} + \frac{-\theta D}{Ak+B\theta} \end{cases} \tag{2.14}$$

where $A = \frac{(r-\theta)c+2mk}{b}$, $B = (r - \theta - \frac{ck}{b})$, $D = \frac{(r-\theta)\bar{c}-\bar{\rho}k}{b}$, $\varsigma_1 > 0 > \varsigma_2$ are eigenvalues and C_1 and C_2 are constant.

Proof: See Appendix B.

Proposition 2.8: The optimal path for the monopolist is

$$\begin{cases} Y_M^t = C_2.e^{\varsigma_2 t} + \frac{kD}{Ak+B\theta} \\ U_M^t = C_2.\frac{A-\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_2}.e^{\varsigma_2 t} + \frac{-\theta D}{Ak+B\theta} \end{cases} \tag{2.15}$$

where constant C_2 is determined from initial conditions.

Proof: See Appendix B.

In the following I illustrate the optimal paths of quality and R&D investment for monopoly that approach the steady-state over time.

2.4.1.1. Illustration.

Figures 2.11 and 2.12 show the phase diagram of the dynamic system in case (i) where $\left(-A + \frac{c}{b}\,\theta\right) < 0$ and $\left(-A + \frac{c}{b}\,\theta\right) > 0$, respectively[13,14]. The dotted vertical and horizontal lines separate regions with negative R&D investment and/or quality from the region with positive R&D investment and/or quality. Points S and S' indicate the saddle steady-state. They are the intersection of loci $\dot{y}_M = 0$ and $\dot{u}_M = 0$. The loci $\dot{y}_M = 0$ and $\dot{u}_M = 0$ partition the space into 4 distinct regions. Region I is between loci $\dot{y}_M = 0$ and $\dot{u}_M = 0$ where $y_M > 0$ and $u_M > 0$; region II is above the line $\dot{y}_M = 0$ and $\dot{u}_M = 0$ where $y_M > 0$ and $u_M > 0$; region III is between loci $\dot{y}_M = 0$ and $\dot{u}_M = 0$ where u_M and y_M could be positive or negative; region IV is below the lines $\dot{y}_M = 0$ and $\dot{u}_M = 0$ where u_M and y_M could be positive or negative. The following Proposition shows the behaviour of the search engine in the neighbourhood of the saddle steady-state.

Proposition 2.9: The phase diagram for monopolist in the case of D < 0 and $\mathrm{Ak} + \mathrm{B}\theta < 0$ is characterised as:

Region I: $\dot{y}_M < 0, \dot{u}_M > 0$
Region II: $\dot{y}_M > 0, \dot{u}_M > 0$
Region III: $\dot{y}_M > 0, \dot{u}_M < 0$
Region IV: $\dot{y}_M < 0, \dot{u}_M < 0$

Proof: See Appendix B.

The small black arrows show the directions of paths in each respective region. The horizontal arrows indicate an increase or a decrease in the quality, whereas the vertical ones refer to a change in R&D investment. The red paths L_1 and L_1' in Figure 11 and L_2 and L_2' in Figure 12 approach the steady-state equilibrium over time while the blue ones move away from it. Figure 11 shows that monopoly by starting from $(y_M^0, u_M^0) = (1.6, 0.39)$ or $(y_M^0, u_M^0) = (0, 0.26)$ converges to the steady-state equilibrium. Figure 12 shows that if monopoly starts from $(y_M^0, u_M^0) = (1.82, 0.23)$ or $(y_M^0, u_M^0) = (0, 0.49)$, then there are optimal paths that converge to the steady-state equilibrium. If monopoly starts from other initial conditions, then it will not reach the equilibrium, and R&D investment and quality will not be at the optimal level. In Figure 2.11, steady-state is $(y_M^s, u_M^s) = (0.59, 0.31)$, and in Figure 2.12, it is $(y_M^s, u_M^s) = (0.84, 0.34)$. It reveals that when the growth of R&D investment decreases with the present stock of quality ($\left(-A + \frac{c}{b}\,\theta\right) < 0$), the quality and R&D investment at equilibrium is smaller than the case where the growth of R&D investment increases with the present stock of quality ($\left(-A + \frac{c}{b}\,\theta\right) > 0$).

[13] Parameter values are $\bar{c}$=1.5, k=1.7, $\theta = -0.9$, ρ= -0.9, τ=3, b=1, c=1.1, $\emptyset$=3.5, r=0.25, $f = 1$. In this case market share at the steady-state is equal to 0.69 and profit is 0.59.

[14] Parameter values are $\bar{c}$=1.5, k=1.7, $\theta = -0.7$, ρ= -0.9, τ=3, b=1, c=1.1, $\emptyset$=3.5, r=0.25, $f = 1$. In this case market share at the steady-state is equal to 0.98 and profit is 0.71.

Figure 2.11. Phase diagram of monopoly with saddle steady-state ($\left(-A + \frac{c}{b}\,\theta\right) < 0$).

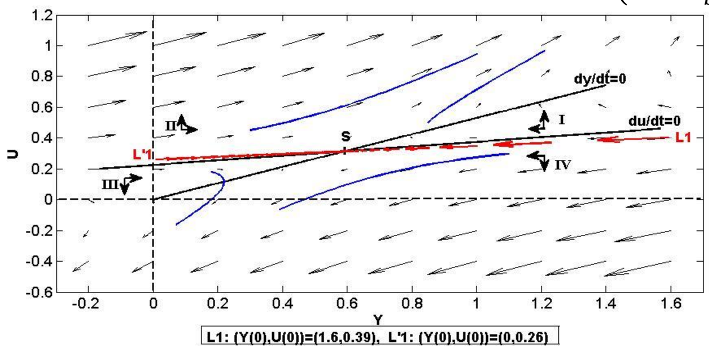


Figure 2.12. Phase diagram of monopoly with saddle steady-state ($\left(-A + \frac{c}{b}\,\theta\right) > 0$).

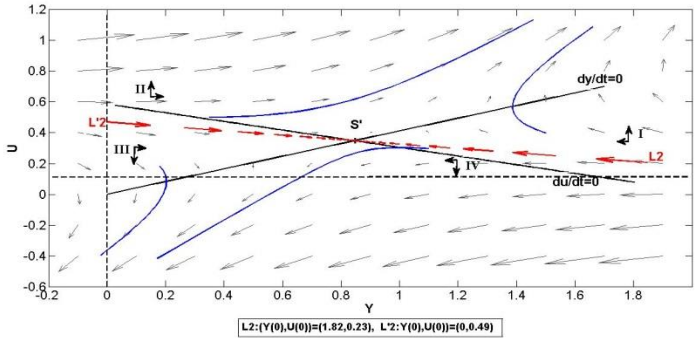


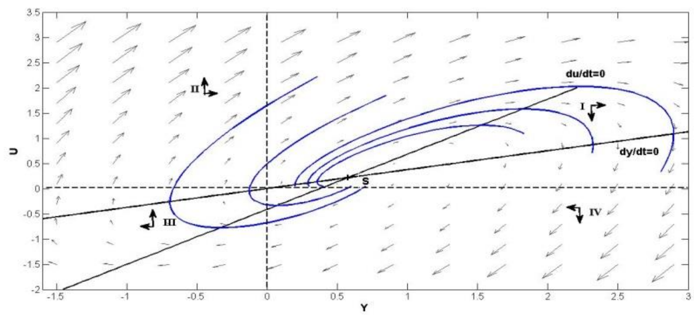
Figure 2.13 shows the behaviour of monopoly in the long term when the steady-state is an unstable node[15]. In this case, all paths point away from the equilibrium, and therefore, there is no stable path. The following proposition characterises the phase diagram of the unstable steady state.

Proposition 2.10: The phase diagram for monopolist in the case of $D > 0$ and $Ak + B\theta > 0$ is characterised as:

Region I: $\dot{y}_M > 0,\ \dot{u}_M < 0$
Region II: $\dot{y}_M > 0,\ \dot{u}_M > 0$
Region III: $\dot{y}_M < 0,\ \dot{u}_M > 0$
Region IV: $\dot{y}_M < 0,\ \dot{u}_M < 0$

Proof: See Appendix B.

Figure 2.13. Phase diagram of monopoly with unstable steady-state.



[15] Parameter values are $\bar{c}$=1, k=0.8, $\theta = -0.3$, τ =2, ρ= -0.1, b=1.2, c=1.1, $\emptyset$=2.2, r=0.8, f=1.

2.4.2. Comparative Statics.

Here I examine how the equilibrium steady-state reacts to changes in exogenous model's parameters (θ, k, r, b). Since the sign of derivatives respect to the mentioned parameters are ambiguous, I apply numerical simulation to study the comparative statics. I consider the range of parameters that yield positive *profit*, *investment cost* and *pay-off*[16]. Figure 2.14 shows the comparative statics in the monopoly case. The steady-state equilibrium increases with θ, k but decreases with b and r. Parameter $k > 0$ captures the effect of R&D investment and $\theta < 0$ captures the effect of stock of quality on the quality growth. If k or θ is increased, then investing in R&D is more effective or the stock of quality harms less the growth of quality, as a result the steady-state equilibrium is greater. The pay-off decreases with a higher discount rate, the lower advertising profit in future, the lower the incentives for the monopoly to invest in R&D. Therefore r affects negatively the equilibrium steady-state. Parameter b captures the convexity of the R&D investment cost. The greater b results in higher R&D investment cost that leads to the lower steady-state equilibrium. Table 2.1 contains the summary of the results.

Figure 2.14: Comparative statics in monopoly model.

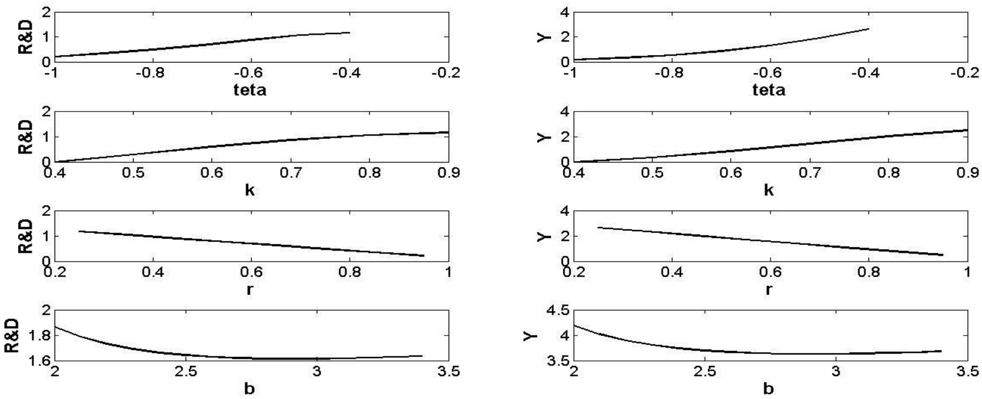


Table 2.1. Qualitative effects of some parameters on the steady state equilibrium.

Parameters	Steady-state equilibrium	
	y^s	u^s
θ	+	+
k	+	+
r	-	-
b	-	-

2.5. R&D Investment in Duopoly vs. Monopoly.

Here I impose the same initial conditions for duopoly and monopoly to compare R&D investment in those cases. Figure 2.15 shows the growth of R&D investment over time when $\theta < 0$ and

[16] Values of some interested parameters are: $0.4<k<0.9$, $-1<\theta<-0.4$, $0.25<r<0.95$, and $2.4<b<5$.

$(-A + \frac{c}{b}\theta) > 0$ and figure 2.16 shows the case when $\theta < 0$ and $(-A + \frac{c}{b}\theta) < 0$[17,18]. It is observed that monopolist invests less in R&D than search engines in the competitive environment. The reason for this result is that in the monopoly case, the search engine is not threatened by any rival so it invests in R&D to achieve its desire level of quality that maximises pay-off and after reaching the steady-state equilibrium, then it invests just enough to keep its quality at the desired level. In contrast, search engines in the duopoly market invest more in R&D in order to improve their quality to compete effectively.

Figure 2.15. Comparison of R&D investment in duopoly and monopoly models when $(-A + \frac{c}{b}\theta) > 0$.

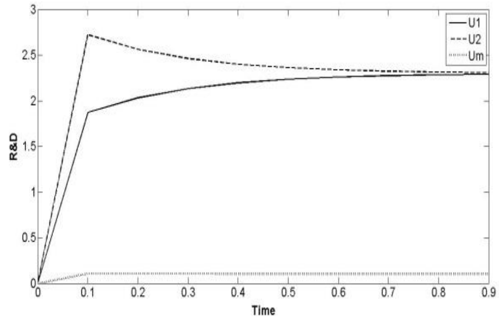
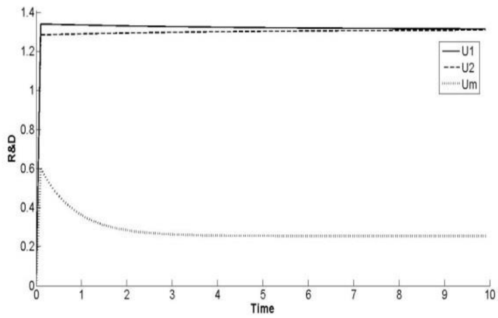


Figure 2.16. Comparison of R&D investment in duopoly and monopoly models when $\left(-A + \frac{c}{b}\theta\right) < 0$.



2.6. Conclusion.

In this chapter, I addressed the question of whether asymmetry between search engines tends to widen or narrow over time. I analysed a duopoly model in which search engines simultaneously invest in R&D to improve the quality of their search results. The model was built based on some facts observed in the online search market. I solved a differential duopoly model by considering open-loop strategies. I found that under some circumstances the low quality search engine can catch up its rival and gain market share. In particular, I designed four different scenarios and showed that asymmetry between search engines diminishes over time (in a process of catching up) when there is a saddle steady-stat. I further showed that for a sufficiently large discount rate that violated the condition of existence of saddle steady-state, the high quality search engine moves further ahead, in a process of monopolisation. I also explored and solved a monopoly model as a benchmark.

[17] Parameter values in Figure 2.15 are $\bar{c}$=1.5, k=1, $\theta = -0.5$, τ =3, ρ= -0.9, b=1, c=1.1, $\emptyset$=3.5, r=0.25, f=1, $u_1 = u_2 = u_M = 0$, $y = y_M = 0.3$.

[18] Parameter values in Figure 2.16 are $\bar{c}$=1.5, k=1.5, $\theta = -0.4$, τ =1, ρ= -0.5, b=1, c=0.5, $\emptyset$=1.5, r=0.25, f=1, $u_1 = u_2 = u_M = 0$, $y = y_M = 0.3$.

Analysis of the monopoly model indicated that there is optimal path of quality and R&D investment that converges to the steady-state equilibrium over time. Comparison of duopoly model and monopoly one revealed that monopolist invests less in R&D than search engines in the competitive environment. However, my analyses showed that a dominant search engine or monopolist had an incentive to invest in R&D and improve the quality of search results to keep the competitor out of the market. Regulators must be aware that any regulation that affects the search engine's future profitability has an impact on an incentive to invest in R&D and therefore on the quality of search results.

In this chapter I only focused on open-loop strategies, further research will examine closed-loop strategies where search engines' R&D investment decisions can react to each other over time.

2.7. Appendices.

Appendix A.

Proof of Proposition 2.1. To analyse the maximisation problem, it is useful to first define what is meant by open-loop strategies. Following literature (see, Reinganum (1982), Fershtman and Kamien (1987), Dockner (1988), Driskill and McCafferty (1989)), the open-loop strategies are defined as follows:

Definition1: The open-loop strategy space for firm i is:

$$S_i^{ol}=\{u_i(t,u_j^0,y^0)|u_i(t,u_j^0,y^0)\ is\ \ continuous\ function\ of\ time\ t\ for\ all\ t\in[0,\infty);i\neq j\}.$$

where $u_i(t,u_j^0,y^0)$ is a path of R&D investment of search engine i which depends on time, the initial R&D investment of search engine j, and initial quality gap. In fact, the open-loop strategy is path-strategy (Fershtman and Kamien, 1987). Open-loop Nash equilibrium for the game is a pair of open-loop strategies that maximises pay-off function.

Definition2: Open-loop Nash equilibrium solution for a dynamic game is a pair of open-loop strategies $(u_1^*,u_2^*)\in S_1^{ol}\text{X}\,S_2^{ol}$ such that for every $u_i\in S_i^{ol}$,

$$\Pi_i(u_i^*,u_j^*)\geq\Pi_i(u_i,u_j^*)\qquad\qquad i,j=1{,}2\ and\ i\neq j$$

where u_i^* is the optimal open-loop strategy for firm i. Having definition of open-loop Nash equilibrium, I form the Hamiltonian function and characterise individually optimal path of R&D investment. Search engine 1 maximises:

$$\max_{u_1^t}\int_0^\infty e^{-rt}[\bar{\rho}(y^t)^2+my^t+n-\left((\bar{c}-cy^t)u_1^t+b\frac{(u_1^t)^2}{2}\right)]dt$$

s.t.

$$\dot{y^t}=\theta y^t+k(u_1^t-u_2^t)$$

$$y^0=\text{y}(0)\ ,\ u_1(0)=u_1^0\ \text{ and } u_2(0)=u_2^0$$

and similarly, search engine 2 maximises:

$$\max_{u_2^t}\int_0^\infty e^{-rt}[\bar{\rho}(y^t)^2-my^t+n-\left((\bar{c}+cy^t)u_2^t+b\frac{(u_2^t)^2}{2}\right)]dt$$

s.t.

$$\dot{y}=\theta y^t+k(u_1^t-u_2^t)$$

$$\text{y}(0)=y^0,\ u_2(0)=u_2^0\ \text{and}\ u_1(0)=u_1^0$$

In order to obtain Nash equilibrium, I simultaneously solve the two optimisation problems. The corresponding Hamiltonian functions for search engines are qualified as:

$$H_1^t = \bar{\rho}(y^t)^2 + my^t + n - \left((\bar{c} - cy^t)u_1^t + b\frac{(u_1^t)^2}{2}\right) + \lambda_1^t(\theta y^t + k(u_1^t - u_2^t))$$

$$H_2^t = \bar{\rho}(y^t)^2 - my^t + n - \left((\bar{c} + cy^t)u_2^t + b\frac{(u_2^t)^2}{2}\right) + \lambda_2^t(\theta y^t + k(u_1^t - u_2^t))$$

where λ_i^t is the current value of the co-state variable associated with y^t. The first order condition and the co-state equation of Hamiltonian function related to search engine *i* is given by:

i) $\max_{u_i} H_i^t(y^t, u_i^t, \lambda_i^t) = H_i^t(y^t, u_i^*, \lambda_i^t)$

ii) $\dot{\lambda_i} = r\lambda_i^t - \frac{\partial H_i^*(y^t, \lambda_i^t)}{\partial y^t}$

The sufficient condition of the optimal path is that the co-state variable satisfies the transversality condition. This condition is the boundary condition for the final value of the co-state variable and is:

iii) $\lim_{t\to\infty}(e)^{-rt}\, \mathrm{H}_i(y^t, \lambda_i^t) = 0$, $\lim_{t\to\infty}(e)^{-rt}\, \lambda_i^t\, y^t = 0$

Conditions (i) – (iii) are necessary and sufficient conditions for existence of open-loop Nash equilibrium (Dockner, 1988). From condition (i), I get

$$u_1^t = \frac{1}{b}(k\lambda_1^t - (\bar{c} - cy^t)) \quad (2.a\text{-}1)$$

$$u_2^t = \frac{-1}{b}(k\lambda_2^t + (\bar{c} + cy^t)) \quad (2.a\text{-}2)$$

Hessian matrix of H_1 is:

$$\begin{bmatrix} \frac{\partial^2 H_1}{\partial u_1^2} & \frac{\partial^2 H_1}{\partial u_1 \partial y} \\ \frac{\partial^2 H_1}{\partial y \partial u_1} & \frac{\partial^2 H_1}{\partial y^2} \end{bmatrix} = \begin{bmatrix} -b & c \\ c & 2\bar{\rho} \end{bmatrix}$$

The leading principal minors of this matrix are:

$$\frac{\partial^2 H_1}{\partial u_1^2} = -b \;, \begin{vmatrix} \frac{\partial^2 H_1}{\partial u_1^2} & \frac{\partial^2 H_1}{\partial u_1 \partial y} \\ \frac{\partial^2 H_1}{\partial y \partial u_1} & \frac{\partial^2 H_1}{\partial y^2} \end{vmatrix} = -2b\bar{\rho} - c^2$$

The first minor is negative. As profit of each search engine is a concave function of the market share ($\rho < 0$), therefore, for sufficiently large b or sufficiently small $\bar{\rho}$, the second minor is positive. In this case, the Hessian is negative definite and payoff is jointly concave in terms of the quality gap and the R&D investment. In a similar way and under the same conditions, I also find that Hessian matrix of H_2 is negative definite. Therefore, the payoff is jointly concave in terms of quality and R&D investment. If u_i^* is an optimal control solution for search engine *i*, then the dynamic of the co-state variable for each search engine is as follows:

$$\dot{\lambda_1} = g_1\lambda_1 - g_2 y - g_3 \quad (2.a\text{-}3)$$

$$\dot{\lambda_2} = g_1\lambda_2 - g_2 y + g_3 \quad (2.a\text{-}4)$$

with $g_1 = (r - \theta - \frac{ck}{b})$, $g_2 = 2\bar{\rho} + \frac{c^2}{b}$, $g_3 =(m - \frac{c\bar{c}}{b})$. Equations 2.a-1 and 2.a-2 determine that u_i^* depends on y^t and λ_i^t, so the dynamic of R&D is:

$$\dot{u_1} = \frac{c}{b}\dot{y} + \frac{k}{b}\dot{\lambda_1} \tag{2.a-5}$$

$$\dot{u_2} = -\frac{c}{b}\dot{y} - \frac{k}{b}\dot{\lambda_2} \tag{2.a-6}$$

In order to find the Quality-R&D system for search engine 1, I have to obtain dynamic R&D investment in terms of the quality gap. From equation a-1, I immediately derive:

$$\lambda_1 = \frac{1}{k}(bu_1 + (\bar{c} - cy^t)) \tag{2.a-7}$$

By differentiate with respect to time, I get

$$\dot{\lambda_1} = \frac{b\dot{u_1} - c\dot{y}}{k} \tag{2.a-8}$$

Equating the recent expression of $\dot{\lambda_1}$ with co-state condition, equation 2.a-3, I have:

$g_1\lambda_1 - g_2 y - g_3 = \frac{b\dot{u_1} - c\dot{y}}{k}$ where $g_1 = (r - \theta - \frac{ck}{b})$, $g_2 = 2\bar{\rho} + \frac{c^2}{b}$, $g_3 =(m - \frac{c\bar{c}}{b})$. By substituting λ_1 from a-7, I get:

$$g_1 \frac{1}{k}\left(bu_1 + (\bar{c} - cy^t)\right) - g_2 y - g_3 = \frac{b\dot{u_1} - c\dot{y}}{k}.$$

Therefore,

$$\dot{u_1} = -\left(\frac{g_1 c + kg_2}{b}\right)y + g_1 u_1 + \frac{g_1\bar{c} - kg_3}{b} + \frac{c}{b}\dot{y}.$$

Consequently, the Quality-R&D system for search engine 1 is:

$$\begin{cases} \dot{y} \;=\; \theta y^t + \; k(u_1^t - u_2^t) \\ \dot{u_1} = -\left(\dfrac{g_1 c + kg_2}{b}\right)y + g_1 u_1 + \dfrac{g_1\bar{c} - kg_3}{b} + \dfrac{c}{b}\dot{y} \end{cases}$$

To simplify, I have:

$$\begin{cases} \dot{y} \;=\; \theta y^t + \; k(u_1^t - u_2^t) \\ \dot{u_1} = \left(-A + \frac{c}{b}\theta\right)y + \left(B + \frac{c}{b}k\right)u_1 - \frac{c}{b}ku_2^t + D \end{cases}$$

where $A = \left(\frac{g_1 c + kg_2}{b}\right)$, $B = g_1$ and $D = \frac{g_1\bar{c} - kg_3}{b}$.

I follow the same steps to find the Quality-R&D system for search engine 2. From equation 2.a-2, I get:

$$\lambda_2 = \frac{-1}{k}(bu_2 + (\bar{c} + cy^t)) \tag{2.a-9}$$

Differentiate λ_2 with respect to time, I have:

$$\dot{\lambda_2} = \frac{-b\dot{u_2} - c\dot{y}}{k} \tag{2.a-10}$$

Equating 2.a-10 with co-state condition, equation 2.a-4, I have:

$$g_1\lambda_2 - g_2 y + g_3 = \frac{-b\dot{u_2} - c\dot{y}}{k}$$

where $g_1 = (r - \theta - \frac{ck}{b})$ and $g_2 = 2\bar{\rho} + \frac{c^2}{b}$, $g_3 = (m - \frac{c\bar{c}}{b})$. By substituting λ_2 from 2.a-9, I get:

$$g_1(\frac{-1}{k}(bu_2 + (\bar{c} + cy^t))) - g_2 y + g_3 = \frac{-b\dot{u_2} - c\dot{y}}{k}.$$

Therefore,

$$\dot{u_2} = g_1 u_2 + \left(\frac{g_1 c + k g_2}{b}\right) y + \frac{g_1\bar{c} - k g_3}{b} - \frac{c}{b}\dot{y}.$$

The Quality-R&D system for search engine 2 is:

$$\begin{cases} \dot{y} = \theta y^t + k(u_1^t - u_2^t) \\ \dot{u_2} = g_1 u_2 + \left(\dfrac{g_1 c + k g_2}{b}\right) y + \dfrac{g_1\bar{c} - k g_3}{b} - \dfrac{c}{b}\dot{y} \end{cases}$$

In a simpler term, I have:

$$\begin{cases} \dot{y} = \theta y^t + k(u_1^t - u_2^t) \\ \dot{u_2} = \left(A - \frac{c}{b}\theta\right) y + \left(B + \frac{c}{b}k\right) u_2 - \frac{c}{b} k u_1^t + D \end{cases}$$

where $A = \left(\frac{g_1 c + k g_2}{b}\right)$, $B = g_1$ and $D = \frac{g_1\bar{c} - k g_3}{b}$.

■

Proof of Lemma 2.1. Steady state of system 2.3 is obtained by imposing the stationary condition: $\dot{y} = \dot{u_1} = 0$. Thus,

$$(y^s, u_1^s) = \left(\frac{k(B\theta u_2 + D\theta)}{\theta(Ak + B\theta)}, \frac{Aku_2 - D\theta}{Ak + B\theta}\right)$$

In a similar way, steady state of system 2.4 is:

$$(y^s, u_2^s) = \left(\frac{-k(B\theta u_1 + D\theta)}{\theta(Ak + B\theta)}, \frac{Aku_1 - D\theta}{Ak + B\theta}\right)$$

y^s yields:

$$y^s = \frac{k}{\theta}\left(\frac{B\theta u_2 + D\theta}{Ak + B\theta}\right) = \frac{-k}{\theta}\left(\frac{B\theta u_1 + D\theta}{Ak + B\theta}\right) \qquad (2.a\text{-}11)$$

It gives a condition whereas $u_1^s + u_2^s = \frac{-2D}{B}$. Under this condition, steady state of search engines 1 and 2 are computed by:

$$u_1^s = u_2^s = \frac{-D(2Ak + B\theta)}{B(2Ak + B\theta)} = \frac{-D}{B}.$$

By inserting $u_1^s = u_2^s$ in a-11, I get $y^s = 0$. Therefore, the steady-state is symmetric.

■

Proof of Lemma 2.2. In order to characterise the steady-state, I need to compute eigenvalues of systems 2.3 and 2.4. In this regard, Jacobean matrix associated with system 2.3 is

$$J_1(y^s, u^s) = \begin{bmatrix} \frac{\partial \dot{y}}{\partial y} & \frac{\partial \dot{y}}{\partial u_1} \\ \frac{\partial \dot{u}_1}{\partial y} & \frac{\partial \dot{u}_1}{\partial u_1} \end{bmatrix} = \begin{bmatrix} \theta & k \\ -A + \frac{c\theta}{b} & B + \frac{ck}{b} \end{bmatrix}$$

with trace and determinants:

Tr(J)= $\theta + B + \frac{c}{b}k$=r

Δ(J)=$Ak + B\theta$

The eigenvalues of the Jacobean matrix are:

$$\varsigma_{1,2} = \frac{r \pm \sqrt{r^2 - 4(Ak + B\theta)}}{2}.$$

In a similar way, the eigenvalues of the Jacobean matrix associated with system 2.4 are:

$$\varsigma'_{1,2} = \frac{r \pm \sqrt{r^2 - 4(Ak + B\theta)}}{2}.$$

As can be seen, eigenvalues of the two search engines are equal: $\varsigma_{1,2} = \varsigma'_{1,2}$. Under the existence of real root ($r^2 - 4(Ak + B\theta) > 0$), the first eigenvalue is always positive and the second one is negative when $Ak + B\theta < 0$. When eigenvalues have opposite sign, the steady-state qualifies as a saddle point. The condition $Ak + B\theta < 0$ can be rewritten with respect to the growth rate of R&D investment in terms of quality as: $\left(-A + \frac{cb}{\theta}\right) > \frac{(r-\theta)\theta}{k}$. It is straightforward to show that if $Ak + B\theta > 0$ ($\left(-A + \frac{cb}{\theta}\right) < \frac{(r-\theta)\theta}{k}$), then steady-state is qualified as an unstable node.

■

Proof of Proposition 2.2. Now, I solve the Quality-R&D system for each search engine. Recalling eigenvalues from proof of Lemma 2.2, I can obtain eigenvectors of the Jacobean matrix associated with system 2.3 as follows:

$$V_1 = (1, v_1)^T = (1, \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_1})^T, \qquad V_2 = (1, v_2)^T = (1, \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2})^T$$

In a similar way, the eigenvectors of the Jacobean matrix associated with system 2.4 are:

$$V'_1 = (1, v'_1)^T = (1, \frac{-A + \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma'_1})^T, \qquad V'_2 = (1, v'_2)^T = (1, \frac{-A + \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma'_2})^T$$

As the system has a constant particular solution (y^s, u^s) the general solution of system 2.3 can be written as:

$$\begin{cases} Y^t = C_1 e^{\varsigma_1 t} + C_2 e^{\varsigma_2 t} \\ U_1^t = C_1 \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_1} . e^{\varsigma_1 t} + C_2 \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} e^{\varsigma_2 t} - \frac{D}{B} \end{cases}$$

where C_1 and C_2 are constants.

In a same way, the solution of the dynamic system 2.4 is:

$$\begin{cases} Y^t = C_1 e^{\varsigma_1 t} + C_2 e^{\varsigma_2 t} \\ U_2^t = C_1 \frac{-A+\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_1} . e^{\varsigma_1 t} + C_2 \frac{-A+\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_2} e^{\varsigma_2 t} - \frac{D}{B} \end{cases}$$

where C_1 and C_2 are constants.

■

Proof of Proposition 2.3. The optimal path must satisfy the transversality conditions. In this regard, the optimal solution must be bounded where $\mathrm{C}_1 = 0$. Therefore, the optimal path for system 2.3 is

$$\begin{cases} \mathrm{Y}^\mathrm{t} = \mathrm{C}_2 \mathrm{e}^{\varsigma_2 \mathrm{t}} \\ \mathrm{U}_1^\mathrm{t} = \mathrm{C}_2 \frac{A-\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_2} \mathrm{e}^{\varsigma_2 \mathrm{t}} - \frac{\mathrm{D}}{\mathrm{B}} \end{cases}$$

and for system 4 is

$$\begin{cases} \mathrm{Y}^\mathrm{t} = \mathrm{C}_2 \mathrm{e}^{\varsigma_2 \mathrm{t}} \\ \mathrm{U}_2^\mathrm{t} = \mathrm{C}_2 \frac{A-\frac{c\theta}{b}}{B+\frac{ck}{b}-\varsigma_2} \mathrm{e}^{\varsigma_2 \mathrm{t}} - \frac{\mathrm{D}}{\mathrm{B}} . \end{cases}$$

The constant C_2 is indicated from the initial conditions $u_1(0)$, $u_2(0)$ and $y(0)$.

■

Proof of Proposition 2.4. In the case of $\theta > 0$, the condition $-A + \frac{c}{b}\theta < 0$ holds when $A > 0$. On the other hand, there is saddle steady-state when the condition $\left(-A + \frac{cb}{\theta}\right) > \frac{(r-\theta)\theta}{k}$ holds. Since $-A + \frac{c}{b}\theta < 0$, the parameter r must be smaller than θ to satisfy the existence of saddle steady-state. Under this condition A is negative that contradicts with $-A + \frac{c}{b}\theta < 0$.

■

Proof of proposition 2.5. By differentiating the steady state with respect to θ, I get:

$$\frac{\partial u^s}{\partial \theta} = \frac{k(\widetilde{\emptyset}\left(f+\frac{\rho}{2}\right)-\frac{c\bar{c}}{b})}{b(r-\theta-\frac{ck}{b})^2}$$

The sign of above derivative specifies with the sign of $k\left(\widetilde{\emptyset}\left(f+\frac{\rho}{2}\right)-\frac{c\bar{c}}{b}\right)$. At equilibrium $f+\frac{\rho}{2}$ is positive (from π_α^i = f+ $\rho\alpha_i^t > 0$ and $y^s = 0$, I obtain $\pi_\alpha^s = f + \frac{\rho}{2}$ that is positive). The sign of above derivative is positive when $\left(f+\frac{\rho}{2}\right) > \frac{c\bar{c}}{b\widetilde{\emptyset}}$. By differentiating the equilibrium R&D investment with respect to r, I get:

$$\frac{\partial u^s}{\partial r} = \frac{k(\frac{c\bar{c}}{b}-\widetilde{\emptyset}\left(f+\frac{\rho}{2}\right))}{b(r-\theta-\frac{ck}{b})^2}$$

If $\left(f+\frac{\rho}{2}\right) > \frac{c\bar{c}}{b\widetilde{\emptyset}}$, then $\frac{du^s}{dr} < 0$. In this case, if discount rate increases, equilibrium R&D investment decreases.

Derivative of u^s with respect to k is given by:

$$\frac{\partial u^s}{\partial k} = \frac{(r-\theta)(\widetilde{\emptyset}\left(f+\frac{\rho}{2}\right)-\frac{c\bar{c}}{b})}{b(r-\theta-\frac{ck}{b})^2}$$

The sign of above derivative is positive under three different conditions: 1) $\theta > 0, r > \theta$, and $\left(f+\frac{\rho}{2}\right) > \frac{c\bar{c}}{b\widetilde{\emptyset}}$, or 2) $> 0, r < \theta$, and $\left(f+\frac{\rho}{2}\right) < \frac{c\bar{c}}{b\widetilde{\emptyset}}$, or 3) $\theta < 0$, and $\left(f+\frac{\rho}{2}\right) > \frac{c\bar{c}}{b\widetilde{\emptyset}}$.

The derivative of u^s in terms of b is given by:

$$\frac{\partial u^s}{\partial b} = \frac{(\theta-r)^2\bar{c}+(\theta-r)k\widetilde{\emptyset}\left(f+\frac{\rho}{2}\right))}{b^2(r-\theta-\frac{ck}{b})^2}.$$

The sign of above derivative is negative under two different conditions: 1) $\theta > 0, \theta < r$, and $\left(f+\frac{\rho}{2}\right) > \frac{(\theta-r)\bar{c}}{k\widetilde{\emptyset}}$, or 2) $\theta < 0$ and $\left(f+\frac{\rho}{2}\right) > \frac{(\theta-r)\bar{c}}{k\widetilde{\emptyset}}$.

▪

Appendix B.

Proof of Proposition 2.6. In order to solve the dynamic optimisation problem, I form the Hamiltonian function:

$$H^t(y_M^t, u_M^t, \lambda^t) = \text{m}(y_M^t)^2 + \bar{\rho}\, y_M^t - ((\bar{c} - c y_M^t)u_M^t + b\frac{(u_M^t)^2}{2}) + \lambda^t\,(\theta y_M^t + k u_M^t)$$

Hamiltonian maximum principles state:

i) $\max_{u_M^t}\; H^t(y_M^t, u_M^t, \lambda^t) = H^t(y_M^t, u_M^*, \lambda^t)$

ii) $\dot{\lambda} = r\lambda^t - \frac{\partial H^*(y_M^t,\lambda^t)}{\partial y_M^t}$

iii) $\lim_{t\to\infty}(e)^{-rt}\, H(y_M^t, \lambda^t) = 0$, $\lim_{t\to\infty}(e)^{-rt}\,\lambda^t\, y_M^t = 0$

By differentiating Hamiltonian function with respect to u_M, I get:

$$u_M = \frac{1}{b}\,(k\lambda^t - (\bar{c} - c y_M^t)) \qquad (2.b\text{-}1)$$

Hamiltonian function is maximised at u_M for every (y_M, λ) when it is jointly concave in the state and control variables. To show this, I form the Hessian matrix with respect to the quality and R&D investment

$$\begin{bmatrix} \frac{\partial^2 H}{\partial u_M^2} & \frac{\partial^2 H}{\partial u_M \partial y_M^t} \\ \frac{\partial^2 H}{\partial y_M^t \partial u_M} & \frac{\partial^2 H}{\partial {y_M^t}^2} \end{bmatrix} = \begin{bmatrix} -b & c \\ c & 2m \end{bmatrix}$$

The leading principal minors of this matrix are:

$$\frac{\partial^2 H}{\partial u_M^2} = -b \text{ and } \begin{vmatrix} \frac{\partial^2 H}{\partial u_M^2} & \frac{\partial^2 H}{\partial u_M \partial y_M^t} \\ \frac{\partial^2 H}{\partial y_M^t \partial u_M} & \frac{\partial^2 H}{\partial {y_M^t}^2} \end{vmatrix} = -2bm - c^2$$

Given m is negative, for sufficiently large b or sufficiently small m, the Hamiltonian function is jointly concave in the quality and R&D investment. If u_M is an optimal control solution, then the dynamic of co-state variable is:

$$\dot{\lambda}=\tilde{r}\lambda^t - zy_M^t - \bar{\bar{\rho}} \tag{2.b-2}$$

where $\tilde{r} = (r - \theta - \frac{kc}{b})$, $z = \left(2m + \frac{c^2}{b}\right)$, $\bar{\bar{\rho}} = \bar{\rho} - \frac{c\bar{c}}{b}$. Equation 2.b-1 shows that u_M^* depends on the quality and co-state variable. Time derivative of optimal R&D is obtained by:

$$\dot{u}_M = \frac{c}{b}\dot{y}_M + \frac{k}{b}\dot{\lambda} \tag{2.b-3}$$

I can extract the co-state equation from 2.b-1 as follows:

$$\lambda_t = \frac{1}{k}(bu_M + (\bar{c} - cy_M^t)) \tag{2.b-4}$$

Taking derivative of 2.b-4, I have another expression for $\dot{\lambda}$:

$$\dot{\lambda} = \frac{b}{k}\dot{u}_M - \frac{c}{k}\dot{y}_M \tag{2.b-5}$$

Equating 2.b-5 with 2.b-2 and substituting λ^t from 2.b-4, I have $\dot{u}_M$ as

$$\dot{u}_M = \tilde{r}u_M^t + \frac{1}{b}[c\,\dot{y}_M - (\tilde{r}c + zk)y_M^t + \tilde{r}\bar{c} - \bar{\bar{\rho}}k]$$

In practice the Quality-R&D system follows two differential equations:

$$\begin{cases} \dot{y}_M = \theta y_M^t + ku_M^t \\ \dot{u}_M = \dfrac{-(\tilde{r}c + zk)}{b} y_M^t + \tilde{r}\,u_M^t + \dfrac{\tilde{r}\bar{c} - \bar{\bar{\rho}}k}{b} + \dfrac{c}{b}\ \dot{y}_M \end{cases}$$

To simplify, let's assume that $A = \frac{(\tilde{r}c+zk)}{b}$, $B = \tilde{r}$ and $D = \frac{\tilde{r}\bar{c}-\bar{\bar{\rho}}k}{b}$. So,

$$\begin{cases} \dot{y}_M = \theta y_M^t + ku_M^t \\ \dot{u}_M = \left(-A + \frac{c}{b}\theta\right) y_M^t + (\mathrm{B} + \frac{c}{b}\mathrm{k})u_M^t + D \end{cases}$$

▪

Proof of lemma 2.3. Stability of the steady-state is evaluated by Jacobean matrix of the Quality-R&D system. The Jacobean matrix of system 2.12 is given by:

$$J = \begin{bmatrix} \dfrac{\partial \dot{y}}{\partial y_M} & \dfrac{\partial \dot{y}}{\partial u} \\ \dfrac{\partial \dot{u}}{\partial y_M} & \dfrac{\partial \dot{u}}{\partial u} \end{bmatrix} = \begin{bmatrix} \theta & k \\ -A + \dfrac{c}{b}\theta & B + \dfrac{c}{b}k \end{bmatrix}$$

with trace and determinants:

$\mathrm{Tr}(J) = r$

$\Delta(J) = Ak + B\theta.$

The eigenvalues associated to the dynamic system are given by:

$$\varsigma_{1,2} = \frac{r \pm \sqrt{r^2 - 4(Ak + B\theta)}}{2}$$

If $r^2 - 4(Ak + B\theta) > 0$, then the eigenvalues have real roots. The first condition of positive steady-state shows that $\varsigma_1 > 0$ and $\varsigma_2 < 0$. Thus (y_M^s, u_M^s) is described as a saddle point. The second condition of the positive steady-state shows that the real ς_1 is positive. In order to have a saddle point, ς_2 must be negative. To show this, consider the following procedure. For having $\varsigma_2 < 0$, the term $r - \sqrt{r^2 - 4(Ak + B\theta)}$ must be negative. Evaluating the sign of $r - \sqrt{r^2 - 4(Ak + B\theta)}$ shows that it is negative when $(Ak + B\theta) < 0$ which contradicts the second condition of positive steady-state where $Ak + B\theta > 0$. Consequently, both eigenvalues are positive, and steady-state is an unstable node. Note that the condition $Ak + B\theta < 0$ can be rewritten as $\left(-A + \frac{cb}{\theta}\right) > \frac{(r-\theta)\theta}{k}$.

∎

Proof of Proposition 2.7. Solving the Quality-R&D system, I need to calculate the eigenvalues and eigenvectors. Recalling eigenvalues from proof of Lemma 2.3, I get eigenvectors as follows:

$$V_1 = (1, v_1)^T = \left(1, \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_1}\right)^T, \qquad V_2 = (1, v_2)^T = \left(1, \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2}\right)^T.$$

Therefore, the general solution of the system is given by:

$$\begin{cases} Y_M^t = C_1 . e^{\varsigma_1 t} + C_2 . e^{\varsigma_2 t} + \frac{kD}{Ak + B\theta} \\ U_M^t = C_1 . \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_1} . e^{\varsigma_1 t} + C_2 . \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} . e^{\varsigma_2 t} + \frac{-\theta D}{Ak + B\theta} \end{cases}$$

where C_1 and C_2 are constants.

∎

Proof of Proposition 2.8. Imposing the transversality condition needs to $C_1 = 0$. Therefore, the optimal path for system 2.12 is

$$\begin{cases} Y_M^t = C_2 . e^{\varsigma_2 t} + \frac{kD}{Ak + B\theta} \\ U_M^t = C_2 . \frac{A - \frac{c\theta}{b}}{B + \frac{ck}{b} - \varsigma_2} . e^{\varsigma_2 t} + \frac{-\theta D}{Ak + B\theta} \end{cases}$$

The constant C_2 is indicated from the initial conditions.

∎

Proof of proposition 2.9. In order to study the behaviour of the search engine, I analyse the sign of $\dot{y_M}$ and $\dot{u_M}$ in either side of the equilibrium lines in Figures 2.11 and 2.12. The equilibrium lines are:

$$u_M = \frac{-\theta}{k} . y_M \qquad (\dot{y_M} = 0)$$

$$y_M = -\left(\frac{B + \frac{ck}{b}}{-A + \frac{c\theta}{b}} u_M + \frac{D}{-A + \frac{c\theta}{b}}\right) \qquad (\dot{u} = 0)$$

Region I:

$u_M < \frac{-\theta}{k} . y_M$ implying $\dot{y_M} < 0$ hence y_M is falling.

$y_M < -(\frac{B+\frac{ck}{b}}{-A+\frac{c\theta}{b}} u_M + \frac{D}{-A+\frac{c\theta}{b}})$ implying $\dot{u_M} > 0$ hence u_M is rising.

Region II:

$u_M > \frac{-\theta}{k} . y_M$ implying $\dot{y_M} > 0$ hence y_M is rising.

$y_M < -(\frac{B+\frac{ck}{b}}{-A+\frac{c\theta}{b}} u_M + \frac{D}{-A+\frac{c\theta}{b}})$ implying $\dot{u_M} > 0$ hence u_M is rising.

Region III:

$u_M > \frac{-\theta}{k} . y_M$ implying $\dot{y_M} > 0$ hence y_M is rising.

$y_M > -(\frac{B+\frac{ck}{b}}{-A+\frac{c\theta}{b}} u_M + \frac{D}{-A+\frac{c\theta}{b}})$ implying $\dot{u_M} < 0$ hence u_M is falling.

Region IV:

$u_M < \frac{-\theta}{k} . y_M$ implying $\dot{y_M} < 0$ hence y_M is falling.

$y_M > -(\frac{B+\frac{ck}{b}}{-A+\frac{c\theta}{b}} u_M + \frac{D}{-A+\frac{c\theta}{b}})$ implying $\dot{u_M} < 0$ hence u_M is falling.

■

Proof of proposition 2.10. I follow similar steps as proof of Proposition 2.9.

Region I:

$u_M > \frac{-\theta}{k} . y_M$ implying $\dot{y_M} > 0$ hence y_M is rising.

$y_M > -(\frac{B+\frac{ck}{b}}{A+\frac{c\theta}{b}} u_M + \frac{D}{A+\frac{c\theta}{b}})$ implying $\dot{u_M} < 0$ hence u_M is falling.

Region II:

$u_M > \frac{-\theta}{k} . y_M$ implying $\dot{y_M} > 0$ hence y_M is rising.

$y_M < -(\frac{B+\frac{ck}{b}}{A+\frac{c\theta}{b}} u_M + \frac{D}{A+\frac{c\theta}{b}})$ implying $\dot{u_M} > 0$ hence u_M is rising.

Region III:

$u_M < \frac{-\theta}{k} . y_M$ implying $\dot{y_M} < 0$ hence y_M is falling.

$y_M < -(\frac{B+\frac{ck}{b}}{A+\frac{c\theta}{b}} u_M + \frac{D}{A+\frac{c\theta}{b}})$ implying $\dot{u_M} > 0$ hence u_M is rising.

Region IV:

$u_M < \frac{-\theta}{k} . y$ implying $\dot{y_M} < 0$ hence y_M is falling.

$y > -(\frac{B+\frac{ck}{b}}{A+\frac{c\theta}{b}} u_M + \frac{D}{A+\frac{c\theta}{b}})$ implying $\dot{u_M} < 0$ hence u_M is falling.

■

Chapter 3

The Single Euro Payments Area (SEPA) and The Banking Industry:

Discriminatory Pricing vs. Non-Discriminatory Pricing

3.1. Introduction.

The growth of international trade, cross-border e-commerce, and migration show that cross-border retail payment[19] is increasingly important in the last century. Many businesses serve clients abroad and purchase goods from international suppliers; many people make online purchases from international sellers, and migrants send money to their families in their home country; government agencies purchase from international suppliers or pay international aids. In Europe, cross-border payments have not been easy as domestic ones. For instance, an individual in Spain could not authorise a direct debit[20] by a German company (to pay a bill, receive a salary, etc.) unless he had a bank account in Germany. A business needed to maintain different bank accounts in the European countries in which it operated in order to conform to their instructions. Moreover, the price of cross-border payment was higher than domestic one.

The European Commission (henceforth EC), European Payment Council (henceforth EPC), and the European Central Bank (henceforth ECB) have debated that the source of customers' problems for making a cross-border payment in Europe was the incompatibility of domestic payment systems between European countries. Accordingly, the EPC enforced the Single Euro Payments Area (henceforth SEPA) project towards the retail payment market in Europe that supported by the EC and the ECB. The mission of the SEPA project was to apply principles in which all non-cash euro payments are treated in accordance with the same rights and obligations irrespective of their location. In particular, the intention was to overcome the problem of incompatibility of national payment systems across Europe and implement uniform pricing for domestic and cross-border payments. In fact, SEPA has created one union-wide retail payment market in the euro area. SEPA is identified as

[19] Cross-border retail payment is a term referring to the transfer of low value of funds between at least two different countries; for instance, a retail payment from Spain to Germany or from the United Kingdom to France is regarded as a cross-border payment.

[20] Direct debit is an instruction from the payer to his bank in order to pay his debt. The payer authorizes payee to collect money from his account by giving advanced notice of the amounts and dates of collection.

the infrastructural project[21] that consolidates[22] payment services across Europe. Payment service providers such as banks were responsible for implementing SEPA (because banks are important owners and users of the payment systems) which required the adoption of common standards and rights at significant cost. Hasan et al. (2012) explain that payment services play a vital role in the bank's revenue. In 2015, the estimated revenue for European banks from executing payment was about a quarter of total European retail banking revenue (Deloitte, 2015). Given the important role of the payment system in the banking industry, I focus my attention on banks as a proxy for payment service providers.

Compliance with SEPA has resulted in fundamental changes in the payment system in Europe. Thus, it is of great importance to analyse the consequences of this policy. In this regard, the main objective of this chapter is to address the question of how uniform pricing with respect to harmonisation of payment systems affects competition between European banks in the retail payment market. Analytical studies on this research question are almost scarce. In this regard, the purpose of the present chapter is to make a contribution to this rather undiscovered area.

To analyse the potential effects of SEPA, it is essential to consider the prevailing conditions prior to SEPA project. In this chapter, pre-SEPA is considered as a period in which payment systems are diversified across countries and banks are allowed to discriminate between price of domestic and cross-border payments. Post-SEPA refers to a period in which banks complied with the SEPA system and applied the uniform pricing for making domestic and cross-border payments.

Given this generalised framework, I extend the duopoly model by Laffont et al. (1998a, b) (henceforth LRT model) who provide a theoretical framework for the telecommunication market, to study competition between two asymmetric banks, in terms of capital, under non-linear pricing and in the presence of economies of scale. The large bank is defined as a bank with large capital compared to a small bank with low capital. The capital is intended versus the labour and is referred here to transaction technologies and modernisation initiatives by banks. The adoption of modernisation such as online payment services and mobile bank involves a gradual reduction in banks costs, particularly labour costs (see, Humphrey et al. (2006), Columba (2009), Hasan et al. (2012), Aliha et al. (2017)). Therefore, the large bank with greater capital is cost-efficient. Study of competition between two asymmetric banks is motivated by the entrance of Neobanks and FinTech companies (technology firms that focus on financial products and services) into this market that intensify competition between banks in terms of transaction technologies such as digitalisation. The non-linear pricing consists of two prices: a fixed fee that is a subscription fee and a transaction price to make a payment that may depend on whether the payment is domestic or cross-border. Kokkola (2010) among others states that economies of scale are one of the main features of the banking industry since they allow banks to recover their high cost of investment in infrastructure. Humphrey (2009) estimates the scale economies among 11 European countries like Germany, France, U.K, Spain, Netherlands, Italy, Belgium, Sweden, Finland, Norway, and Denmark over 1987-2004. He finds that banks in the payment market are acting under economies of scale. Beccalli, Anolli, and Borell (2015) study the existence of economies of scale for 103 European banks from 2000 to 2011. They find that there are

[21] Following the European Payments Council (2009), the infrastructure is defined as '*the technology delivery system and network entity that supports a payment scheme*'.

[22] So far, consolidation of payment services means two or more national services acting based on one standard and rule but not the merging of national markets.

economies of scale among different banks, and they are significantly large for the largest banks. In this regard, I analyse competition between banks under the existence of economies of scale.

The major difference between the model of this chapter and the LRT model is the definition of the cost function. In the framework of the LRT model, it is considered that the two networks have the same cost structures and fixed marginal cost. Here, I consider that two banks have different marginal costs and the large bank is cost-efficient due to a larger capital level. Based on the existing work of Humphrey et al. (2003), Schmiedel (2007), and Mermelstein *et al.* (2019), I build the cost function associated with payment processing by taking into account transaction volumes, capital and economies of scale. Besides, I introduce the infrastructural change as a result of compliance with SEPA through the cost functions. In particular, in pre-SEPA, the domestic payment systems are incompatible. This feature is captured by considering different marginal costs depending on payment termination: the domestic transaction cost is lower than the cross-border one since the latter includes connectivity cost to a third party. While, in post-SEPA, the compatibility between payment systems across countries implies the same costs per transaction for domestic and cross-border payments. However, in post-SEPA, banks have to make substantial investments to adopt the common standards required by this project for credit transfers, direct debits, and payment cards. I consider this cost as a fixed adjustment cost. Since payment cards have main inherent differences with credit transfers and direct debits, my model focuses on the account to account transactions without cards. For the sake of tractability, I take a narrower view of the cost functions introduced by Mermelstein *et al.* (2019) and only focus on the case where the marginal cost is constant in terms of the transaction volume.

My analysis stands in two phases: pre-SEPA with price discrimination and post-SEPA with uniform pricing in terms of payment destination. In this setup, I analyse the impacts of SEPA on competition and welfare by comparing pre-SEPA with post-SEPA. Given economies of scale, I start the analysis in the symmetric case where the two banks have the same level of capital. Comparison of the results in pre- and post-SEPA shows that symmetric banks could not take advantage of SEPA, but SEPA would be beneficial for the customers because of the lower transaction prices. Welfare would improve in post-SEPA when increasing transaction volumes can offset the fixed adjustment cost. Then, I analyse the impacts of SEPA in the asymmetric case. The main result is that the transaction pattern affects the competition between banks in post-SEPA which is consistent with Leibbrandt (2010) and Schaefer (2008). I show that when the transaction pattern is dominated by the domestic market, then competition between banks is less intense in post-SEPA. I further show that consumer surplus improves in post-SEPA because banks offer a higher net surplus to customers by setting the uniform pricing. The effect of SEPA on welfare depends on the amount of fixed adjustment cost. If this cost is sufficiently small, then welfare improves in post-SEPA. On further analysis, I consider the case where economies of scale are improved in post-SEPA. It is motivated by empirical evidence that the harmonisation and standardisation of national payment systems are likely to foster economies of scale in the payment market in Europe (see, Bolt and Humphrey (2007), Beijnen and Bolt (2009)). The results show that if economies of scale improve, then SEPA intensifies competition between banks. This result is in line with the EC expectation about the effect of SEPA on competition between banks.

The rest of the chapter is organised as follows. Section 3.2 generally describes SEPA project and reviews some related literature. The structure of the models in pre- and post-SEPA are laid out in Section 3.3. Section 3.4 analyses competition in pre- and post-SEPA. The comparisons of pre-SEPA with post-SEPA are shown in Section 3.5. Conclusion is presented in Section 3.6. Appendix gathers proofs.

3.2. Implementation of SEPA and Related Literature.

Before the introduction of SEPA, each European country was served by its own domestic payment system that was created under the national rules and standards, and therefore was incompatible among countries. For example, there was ‘Iberpay’ payment system in Spain, ‘Vocalink’ in the United Kingdom, and ‘Wordline’ in France. Therefore, a third-party like a correspondent bank was required to link domestic payment systems in order to make a cross-border payment, i.e. the correspondent bank provided international transaction services on behalf of the domestic payment systems. One exception was that if there was a bilateral agreement between banks to execute payments through a single payment system, then the third party was not needed. However, few banks could afford to retain such agreement since it depended on the transaction volumes between the two banks in two different countries (Krarup, 2019).

Figure 3.1 shows the process of a cross-border payment in pre-SEPA. Payer’s and payee’s banks are located at two different countries namely country A and country B. A payer is an individual (or a business, or a government agency) who gives the payment order to his bank and allows them to make a payment from his account. A payee is a beneficiary (could be an individual or a business or a government agency) who has received a fund to his account. The payer’s bank receives a payment order. It then transfers information to the domestic payment system. The payment system settles the payment order based on domestic rules and technical standards. Then, the payment order goes to the correspondent bank in country A. If the fund needs to convert to the local currency, it is sent to the second correspondent bank in country B. Ultimately, the fund transfers to the payee’s bank via the domestic payment’s system of country B.

Figure 3.1.Cross-border payment processes in pre-SEPA.

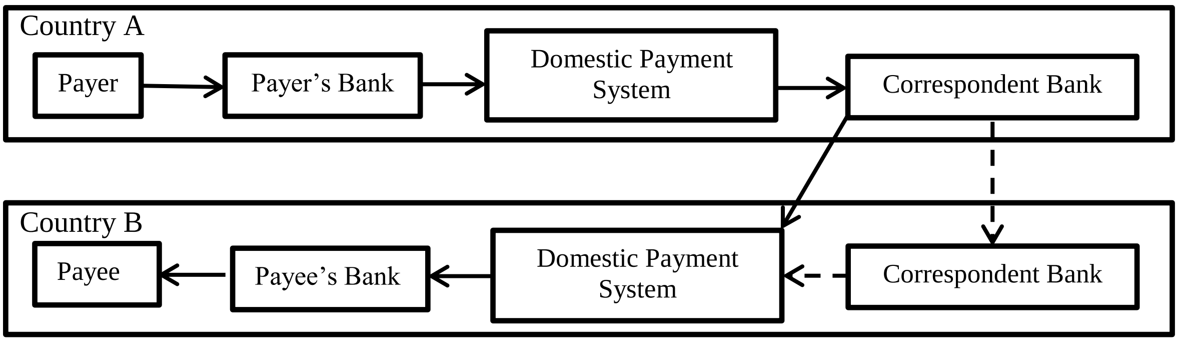
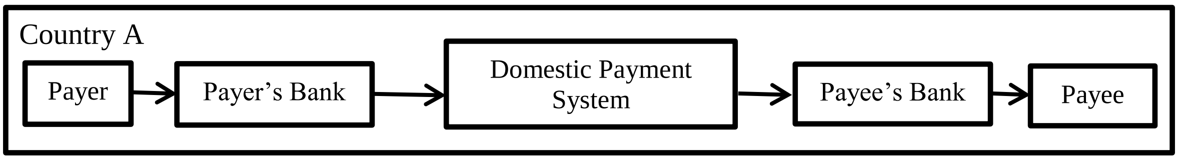


Figure 3.2 shows the process of a domestic payment in pre-SEPA. The payer’s and payee’s banks are located in the same country (for instance, country A) and the payment executes through the domestic payment system without involving any third-party.

Figure 3.2. Domestic payment processes in pre-SEPA.



In pre-SEPA, the price of a cross-border payment was significantly higher than a domestic one. The EC and ECB argued that the price discrimination was due to the complexity of the cross-border payment systems. Moreover, the EC found that the price of cross-border payments varied significantly across European countries. The evidence provided by the EC in 2001 shows that the price of transferring €100 from Luxembourg to another European country was €9.58, from Germany was €11.93, from Spain was €20.56, and from Portugal was €31.04 (EC's survey IP/01/992, 2001). From the EC point of view, the price diversification was problematic because it prevented an integrated market in Europe.

To overcome these problems, the first attempt after the introduction of the physical Euro as a single (cash) payment instrument across Europe was to enforce banks to charge the same transaction prices for domestic and cross-border payment up to €12,500, in 2002 (Regulation (EC) No.2560/2001). This regulation covered cross-border credit transfer and cross-border electronic payment. In 2007, the EC expanded the scope of uniform pricing for cross-border direct debit (Directive 2007/64/EC). In 2009, the uniform pricing regulation was enlarged to execute up to €50,000 (Regulation (EC) No.924/2009). The adoption of uniform pricing was an important step in reaching SEPA. The next step was to overcome the problem of diversity of the national payment systems, such as different standards, technologies, and rules across countries and form an integrated financial market in Europe to simplify the non-cash payment. In this regard, the last important stage of adopting SEPA was to implement the regulation (EC) No.260/2012 of the Commission and European Parliament. This regulation established the technical and business requirements for direct debit and credit transactions and cancelled €50,000 ceiling. All banks were obliged to comply with SEPA. They must adopt the common standards and rights that come with a significant cost. Based on the definition of the ECB (2009) 'SEPA is an area, in which consumers, companies and other economic actors will be able to make and receive payments in euro, whether within or across national borders, with the same basic conditions, rights and obligations, regardless of their location'[23,24]. Under the SEPA system, there is no difference between domestic and cross-border euro payments; all euro payments in the SEPA zone are treated like domestic ones. All banks are obliged to make cross-border payment as cheap and easy as a domestic one (ECB, 2009). Figure 3.3 shows domestic and cross-border payments are executed under a single system in post-SEPA.

The scope of influence of SEPA was extensive, so that retail payment market, every individual, business, and government agency in the euro area were affected by this project. In post-SEPA, customers rely on one bank account to make cashless euro payments to any payee under the same conditions, regardless of their location in the SEPA zone. It enables them to pay and receive funds from other SEPA countries without any extra costs when they travel, study, work, purchase goods and services. Businesses can integrate different bank accounts among different European countries into a unique one, thus they may be able to save cost and time for making payments. In general, SEPA provides better payment services since payments are executed within a certain time, the costs of making payments are clear and there is no hidden fees (banks are not allowed to make any deficit of the transferred amount), and payments are safe through SEPA via IBAN and BIC[25].

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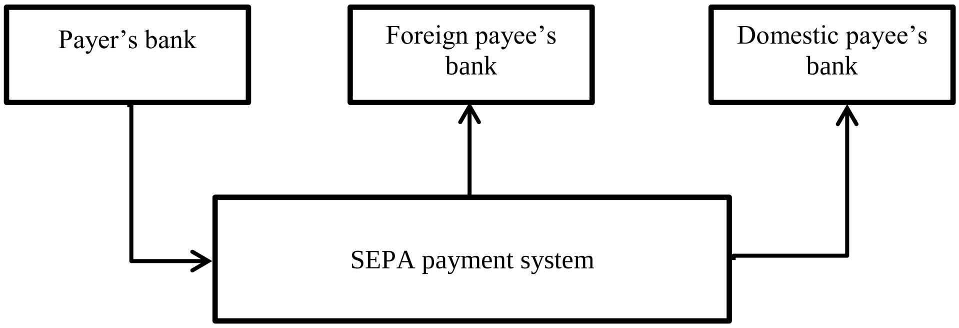
[23] SEPA consists of 34 countries which are 28 member states of the European Union and 6 other territories: Iceland, Monaco, Switzerland, Liechtenstein, Norway and San Marino. Some countries such as the UK, Sweden, Denmark, Switzerland, among others, that are located in SEPA but their economy is non-Euro based are obliged to comply with SEPA.

[24] ECB quotations (2009, page 7).

[25] IBAN is an abbreviation of 'International Bank Account Number' which is a single standard for identifying and validating an account with a bank in Europe. A single bank identifier entails 'Bank Identifier Code (BIC)' that is also called Swift code. By BIC, European and international payment orders automatically reach the right bank and branch.

Figure 3.3. Domestic and cross-border payment processes in post-SEPA.



Although the analytical literature related to my research question is scarce, there are several studies that attempt to enhance understanding of the opportunities and costs of SEPA for customers and banks. These studies apply different methodologies. Some of them have examined the effects of SEPA from a theoretical or empirical standpoint, while others are interview-based studies.

Leibbrandt (2010) studies the effect of compatibility of Europe's payment systems on bank competition and welfare. He assumes that there are two equal sized countries served by two banks, one in each country. Moreover, he supposes that banks do not make price discrimination based on termination and that the marginal cost of a payment execution is zero. He considers the case where the two banks compete in two stages: in the first stage, they decide to comply or not with the compatible system, and in the second stage, they compete on prices. Results show that the transaction patterns have the main role in bank's desire to choose the compatible system, i.e. if the transaction patterns are dominated by domestic transactions, banks maintain the incompatible system to avoid migration costs. In contrast, if this cost is zero, then banks make more profit with the compatible system than with the incompatible system but consumer surplus is lower due to higher prices charged by banks.

In another work, Schaefer (2008) studies the economic effect of SEPA project on the banking industry and welfare. He applies a spatial bank competition model between two banks and focuses on the cost implications to study SEPA-effects on welfare. From an analytical perspective, he considers the choice of adopting SEPA by comparing two cases: 'high initial investment cost and low cost of cross-border payment' against 'low or zero investment cost and high cost of cross-border payment'. From the results, he suggests that adopting SEPA may be welfare-enhancing if the initial investment cost reduces or the share of the cross-border payment is high enough to cover this cost. He also finds welfare-enhancing due to intensifying cross-border competition between banks through reducing entry barriers. He extends his model by considering the entrance of a foreign bank with the cost advantage. He concludes that in spite of the increasing welfare, without public intervention, banks would not adopt SEPA since they suffer a considerable adjustment cost.

In a complementary work, Kemppainen (2008) evaluates economic effects of SEPA in a spatial competition model in the debit card market. He considers two countries covered by two incompatible payment networks in pre-SEPA and compatible in post-SEPA. In pre-SEPA, customers only can use their cards in their home network, while they can use their cards both in home and foreign networks in post-SEPA. The model is built based on some SEPA elements such as the increased number of customers in demand-side and the SEPA adjustment cost in supply-side. The results show that SEPA causes an increase in prices, larger network size, and greater consumer surplus. Conversely, profit and welfare increase if SEPA adjustment cost is ignored. Furthermore, the model reveals that SEPA is not enough to lead to a fully competitive market.

However, these studies do not further discuss price setting in pre- and post-SEPA. This chapter contributes to this strand of literature by focusing on price setting and cost efficiency due to the consolidation of national payment systems to analyse the effects of SEPA on competition between banks, consumer surplus and welfare.

In the empirical work, Todorovic, Sedlarevic and Tomic (2017) evaluate the effects of SEPA on the performance of the banking industry among 17 European countries in the period 2002-2012. They find that benefits of SEPA cannot cover its costs in the short term, while in the long term, SEPA will improve the performance of the banking industry.

A number of other contributions assess the economic impact of SEPA by focusing on survey- and interview-based studies. The analysis undertaken by Schmiedel (2007) provides insights into the economic impact of SEPA. In particular, he studies benefits and costs of SEPA for the banking industry. For this purpose, he applies a questionnaire and interview-based fact-finding exercise from the ECB. He finds that in the long term when national systems are completely replaced with the SEPA system, the cost of banks will decline because of potential economies of scale and scope. Furthermore, the revenue of banks will be affected by increasing competition as entry barriers in the market. In 2014, the EC asked PWC group to provide a report related to benefits and opportunities of SEPA for stakeholders such as banks, companies, and customers. In an interview-based study, the PWC group states that companies and customers take advantage of SEPA at the expense of banks. In this study, it considers three categories of banks namely global bank that has global operations, regional bank that has regional operations and local bank that consists of smaller domestic banks. The results show that the local bank may have less opportunity to benefit from SEPA while the global and regional banks can attract more transaction volumes and make an additional profit in post-SEPA. The reason is that the local bank operates on a smaller scale than other banks and therefore would not afford to cover the SEPA cost.

3.3. Model Specification.

In this section, I describe the structure of the model in the presence of economies of scale. I first characterise pre-SEPA and then post-SEPA phases. In pre-SEPA, the domestic payment systems are diversified across European countries and banks charge different transaction prices for making domestic and cross-border payments. In post-SEPA, the domestic payment systems are homogeneous across countries and banks charge the same transaction prices for making domestic and cross-border payments.

I consider a country located in the SEPA zone that is served by two asymmetric banks, a large bank with a large level of capital and a small bank with a small level of capital indexed by $i \neq j \in \{l, s\}$, that offer payment services. Customers located in this country subscribe only to one bank to conduct domestic and/or cross-border payments. I assume that customers are homogeneous and uniformly distributed on the segment [0, 1]. Banks are located at either extreme; w.l.o.g. I assume that the large bank is located at 0 and the small bank is located at 1. Moreover, I suppose that the two banks serve all customers, that is, there is full coverage.

3.3.1. Pre-SEPA Phase.

Three-part tariff. To handle a payment, each bank charges three-part tariff $T_i = \{f_i, p_i, \hat{p}_i\}$, where f_i is a fixed fee (or subscription fee), p_i is a domestic transaction price for each inter-bank payment inside the country and $\hat{p}_i$ is a cross-border transaction price for each inter-bank payment to another country located in the SEPA zone. To simplify the analysis, I assume that intra-bank transactions are free of charge. Banks are allowed to charge different transaction prices based on the payment destination, i.e. the transaction price for a domestic payment can differ from a cross-border payment: $p_i \neq \hat{p}_i$. The non-linear pricing scheme is motivated by the European Union (EU) report on retail financial services in 2009[26]. The study assesses the level of bank fees for 224 banks across the EU-27 including basic annual fees (e.g., package fees and account maintenance charges), account fees (e.g., over-the-counter transactions, accounts' movements, internet and phone banking, etc.), credit transfer charges (e.g., reception and transmission of credit transfers, standing orders including setup, modification and closure, etc.), direct debit charges (e.g., fees for setting up direct debits, sending and closure), among others. Accordingly, in my terminology, fixed fees refer to annual fees and transaction prices refer to credit or debit transfer charges. For the sake of tractability, I assume that all inter-bank transactions have the same size, but volumes or number of transactions do depend on transaction prices. The total volume of transaction is $Q_i = (q_i + \hat{q}_i)$, where q_i is the domestic transaction volume and $\hat{q}_i$ is the cross-border transaction volume at bank i[27,28,29]. Moreover, I assume that banks access to sufficient funds in order to execute payments.

Individual demand. The customer's problem is to maximise utility $u(q_i, \hat{q}_i) = \omega.(q_i + \hat{q}_i) - \frac{({q_i}^2 + \hat{q}_i^2)}{2} + \vartheta_0$ where $i \in \{l, s\}$, $\omega > 0$ and ϑ_0 is the fixed surplus from being connected to either bank. Suppose ϑ_0 is large enough that customers always choose to have a bank account. The individual payment demands are given by $\frac{\partial u}{\partial q_i} = p_i$ and $\frac{\partial u}{\partial \hat{q}_i} = \hat{p}_i$ which result in $q(p_i) = \omega - p_i$ and $\hat{q}(\hat{p}_i) = \omega - \hat{p}_i$. The parameter ω is the maximum amount customers would be willing to pay in order to make a payment. The indirect utility of payment or customer's variable net surplus is $V(p) = \max_q u(q) - p.q$, yielding

$$V(P) = \frac{(\omega - p)^2}{2}$$

where $V(p_i)$ is the domestic surplus and $V(\hat{p}_i)$ is the cross-border surplus. The derivative of indirect utility with respect to the transaction price is $\frac{\partial V}{\partial p} = -q$; the indirect utility strictly decreases with the transaction price. Without price discrimination, the surplus equals $V = (\omega - p)^2$.

Market share. Banks offer payment services that are horizontally differentiated á la Hotelling and there is full coverage, i.e., each bank can offer its services to all customers. The net surplus offered by bank i is:

$$w_i = V(p_i) + V(\hat{p}_i) - f_i$$

with $i \in \{l, s\}$.Then, the net utility that a customer located at x derives from subscribing to bank i is:

$$U_i = w_i - \tau|x - x_i|$$

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[26] See European Commission 2009, EU report on retail financial services: fact sheet, MEMO/09/402.

[27] Equivalently, one could assume that each customer makes one transaction of size q.

[28] Since card payment network is not the main focus of this paper, I omit the role of interchange fees that are paid for interconnection by a bank to its rival in a card payment. The role of interchange fees in the banking industry is discussed in chapter 4.

[29] In the credit transfer, the payer pays the interest rate to its lender. Since this fee has no role on transaction price, I omit it which allows me to focus on the comparison between pre-SEPA and post-SEPA.

Parameter τ is product differentiation. Banks differentiate themselves through service quality since they provide similar set of services. Delivering better customer services such as problem solving ability of staff, convenience, accessibility, and reliability improve customers' satisfaction (Novokreshchenova et al., 2016; Pirzada et al., 2014). Customers subscribe to a bank from which they obtain a higher net utility. Since $x_l = 0$ and $x_s = 1$, a customer located at x is indifferent to subscribe to the large or small bank if and only if

$$w_l - \tau x = w_s - \tau(1 - x).$$

The term τx is the transportation cost of going to the large bank and $\tau(1 - x)$ is the transportation cost of going to the small bank. Transportation cost is used here as a means to capture product differentiation. Solving for x, I obtain the market share of the large bank as follows:

$$\alpha_l = \frac{1}{2} + \sigma(w_l - w_s) \tag{3.1}$$

Parameter $\sigma = \frac{1}{2\tau} > 0$ is the degree of substitutability between the two banks. Since there is full participation (i.e., each customer subscribes to one bank), the market share of the small bank is $\alpha_s = 1 - \alpha_l$. In a symmetric equilibrium with $w_l = w_s$, the market share equals $\frac{1}{2}$.

Consumer surplus. Consumer surplus is determined by

$$CS = \alpha_l w_l + \alpha_s w_s - \frac{\tau}{2}(\alpha_l^2 + \alpha_s^2) \tag{3.2}$$

The term $\frac{\tau}{2}(\alpha_l^2 + \alpha_s^2)$ is the customer disutility from not being able to subscribe to his preferred services.

Cost function. By following Humphrey et al. (2003) and Schmiedel (2007), I consider that banks incur two types of costs to execute a payment: *'Distribution/Maintenance Cost'* (as a fixed cost) and *'Processing Cost'* (as a variable cost).

Distribution/Maintenance Cost. Banks incur the fixed cost, $\bar{c}$, to serve each customer. This cost covers all the costs which are not directly linked to a transaction but are necessary to its execution[30].

Processing Cost. The empirical work of Humphrey et al. (2003) determines that processing cost depends on transaction technologies, economies of scale and transaction volumes. In order to introduce those factors in the model, I adopt the cost function proposed by Mermelstein *et al.* (2019). In my model, capital captures the transaction technologies adopted by banks such as online payment services and mobile banks. In pre-SEPA, each country has a national payment system with particular requirements in terms of technology, standards, and services. Banks use different methods to execute domestic and cross-border payments[31]. As a result, the processing cost of each payment depends on its destination. In this regard, there are two kinds of processing costs: the cost of the domestic payment ($C(q_i)$) and the cost of the cross-border payment ($\hat{C}(\hat{q}_i)$). From this perspective, processing costs are defined as follows:

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[30] Based on the directive (EU) 2015/849 of the European Parliament and Council on the prevention of the use of the financial system for the purposes of money laundering or terrorist financing, banks have to monitor accounts.
[31] For more details see Park (2006).

$$C(q_i) = \frac{q_i^{(\frac{1}{(1-\beta)\theta})}}{k_i^{\frac{\beta}{(1-\beta)}}}$$

$$\hat{C}(\hat{q}_i) = \frac{\hat{q}_i^{\left(\frac{1}{(1-\beta)\theta}\right)}}{k_i^{\frac{\beta}{(1-\beta)}}} + z\hat{q}_i.$$

The marginal costs of the domestic and cross-border payments are thus given by:

$$c(q_i) = \frac{1}{(1-\beta)\theta} \frac{q_i^{(\frac{1}{(1-\beta)\theta})-1}}{k_i^{\frac{\beta}{(1-\beta)}}} \quad (3.3)$$

$$\hat{c}(\hat{q}_i) = \frac{1}{(1-\beta)\theta} \frac{\hat{q}_i^{\left(\frac{1}{(1-\beta)\theta}\right)-1}}{k_i^{\frac{\beta}{(1-\beta)}}} + z \quad (3.4)$$

with $i \in \{l, s\}$. Parameter $\theta > 1$ represents economies of scale, $\beta \epsilon\ (0,1)$ is the capital share ($(1-\beta)$ is the labour share)[32], k_i is the capital owned by bank i to settle a payment, and q_i and $\hat{q}_i$ are transaction volumes. Remind that the large bank is cost-efficient due to having a larger capital level (developed transaction technologies). The parameter z shows the connectivity cost to execute a cross-border payment. It is worth noting that if there is a bilateral agreement between banks in order to execute payments through one payment system, then $z = 0$, which means that the domestic and cross-border payments execute in the same ways. In this case, the third party does not have any role and there is no problem with incompatible systems. As long as the main concern of the present chapter is to analyse the effect of harmonisation of payment systems through SEPA, I consider the case with $z > 0$.

Profit function. Under the price discrimination, bank i's profit is given by:

$$\Pi_i = \alpha_i[p_i q_i - C_i + \hat{p}_i \hat{q}_i - \hat{C}_i + f_i - \bar{c}] \quad (3.5)$$

The profit consists of two parts: the profit from the execution of payments and the profit from the fixed fee.

Welfare. Welfare is defined as follows:

$$W = \Pi_l + \Pi_s + CS \quad (3.6)$$

3.3.2. Post-SEPA Phase.

[32] The variable cost function comes from the Cobb-Douglas production function $F(K, L) = K^{\beta\theta} L^{(1-\beta)\theta}$: the share of output that comes from labour is $(1-\beta)$ while the share of output that comes from capital is the constant β.

Two-part tariff. In post-SEPA, banks are constrained to set uniform pricing, i.e. they must charge the same price for domestic and cross-border payments. Therefore, each bank sets two-part tariff $\tilde{T}_i = \{\tilde{f}_i, \tilde{p}_i\}$ where $\tilde{f}_i$ is a fixed fee (or subscription fee) and $\tilde{p}_i$ is a transaction price for each transaction regardless of its destination.

Individual demand. Following similar steps as in pre-SEPA case, total individual demand function in post-SEPA can be written as

$$\tilde{q}_i = 2(\omega - \tilde{p}_i) = 2q(\tilde{p}_i)$$

which is twice the domestic payment at price $\tilde{p}_i$. Under uniform pricing, the indirect utility of payment or consumer's variable net surplus is $\tilde{V}(\tilde{p}) = \max_{\tilde{q}} u(\tilde{q}) - \tilde{p}.\tilde{q}$, yielding

$$\tilde{V}(\tilde{p}) = (\omega - \tilde{p})^2$$

where $\frac{\partial \tilde{V}}{\partial \tilde{p}} = -\tilde{q}$.

Market share. It is as pre-SEPA case where:

$$\widetilde{w}_i = \tilde{V}(\tilde{p}_i) - \tilde{f}_i$$

with $\tilde{V}(\tilde{p}_i) = \frac{\tilde{q}_i^2}{4} = q_i^2$. The net utility of customer x from subscribing to bank i is:

$$\widetilde{U}_i = \widetilde{w}_i - \tau|x - x_i|$$

where $i \in \{l, s\}$ and $x_l = 0$ and $x_s = 1$. The market share is given by the location of the customer that is indifferent between the two banks:

$$\widetilde{w}_l - \tau x = \widetilde{w}_s - \tau(1 - x)$$

Consequently,

$$\tilde{\alpha}_l = \frac{1}{2} + \sigma(\widetilde{w}_l - \widetilde{w}_s) \tag{3.7}$$

As before, parameter $\sigma = \frac{1}{2\tau}$ is the degree of substitutability between two banks. Under full coverage assumption, market shares add up to unity: $\tilde{\alpha}_s = 1 - \tilde{\alpha}_l$.

Consumer surplus. Consumer surplus is as in (3.2).

Cost function. The consolidation of national payment systems in post-SEPA leads to a change in the cost structure of each bank. The following categories are distinguished:

Fixed Adjustment Cost. Banks incur a fixed adjustment cost to comply with SEPA, F. This cost is due to the technology investments required for SEPA such as the cost associated with updating and upgrading to new technologies. To simplify the analysis, I assume that this cost is the same for both large and small banks.

Distribution/Maintenance Cost. As pre-SEPA, serving a customer involves a fixed cost, $\bar{c}$.

Processing Cost. In post-SEPA, the payment systems are compatible across countries leading to the same processing costs per transaction regardless of termination (Bolt and Humphrey, 2007). The processing cost of each payment is defined as:

$$\tilde{C}(\tilde{q}_i) = \frac{\tilde{q}_i^{\left(\frac{1}{(1-\beta)\theta}\right)}}{k_i^{\frac{\beta}{(1-\beta)}}}.$$

The marginal cost is thus given by:

$$\tilde{c}(\tilde{q}_i) = \frac{1}{(1-\beta)\theta}\frac{\tilde{q}_i^{\left(\frac{1}{(1-\beta)\theta}\right)-1}}{k_i^{\frac{\beta}{(1-\beta)}}}. \quad (3.8)$$

Equation 3.8 shows the cost of cross-border payment equals domestic one, i.e. the cost of cross-border payment is decreased since there is no connectivity cost, $z = 0$.

Profit function. In post-SEPA, bank i profit is:

$$\widetilde{\Pi}_i = \tilde{\alpha}_i[\tilde{p}_i\tilde{q}_i - \tilde{C}_i + \tilde{f}_i - \bar{c}] - F \quad (3.9)$$

where F is the fixed adjustment cost. Again the profit consists of profit from the execution of payments and fixed fees.

*Welfar*e. Welfare in post-SEPA is given by (3.6).

3.4. Non-Linear Price Competition.

This section provides a general analysis of non-linear price competition in pre- and post-SEPA.

3.4.1.Competition in Pre-SEPA.

In pre-SEPA, each bank maximises its profit by optimally setting $T_i = \{f_i, p_i, \hat{p}_i\}$. By following the lines of Laffont *et al*. (1998), I analyse the case where banks compete in prices, $p_i, \hat{p}_i$, and w_i rather than in $p_i, \hat{p}_i$, and f_i due to the one-to-one relationship between w_i and f_i. By solving systems $\frac{\partial \Pi_i}{\partial p_i} = 0$ and $\frac{\partial \Pi_i}{\partial \hat{p}_i} = 0$ for p_i and $\hat{p}_i$ from equation 3.5, I get:

$$p_i^* = c_i \quad (3.10)$$

$$\hat{p}_i^* = \hat{c}_i \quad (3.11)$$

Equations 3.10 and 3.11 show that banks set transaction prices at the marginal costs and consequently, make price discrimination for domestic and cross-border payments in pre-SEPA. Note that the marginal cost is a function of price, so equations define implicitly optimal transaction prices: it can be easily shown that $p_i^* = c_i$ and $\hat{p}_i^* = \hat{c}_i$ have the unique solution (see proof of Proposition 3.1 in Appendix). The optimal fixed fee, market share, and profit are characterised in the following Proposition.

Proposition 3.1. In pre-SEPA, at the equilibrium, transaction prices equal marginal costs, $p_i^* = c_i$ and $\hat{p}_i^* = \hat{c}_i$, and the fixed fee, market share, and profit of each bank equal:

$$f_i^* = \frac{1}{2\sigma} + \frac{1}{6}[(q_i^2 + \hat{q}_i^2) - (q_j^2 + \hat{q}_j^2)] - \frac{1}{3}[2n_i(q_i^\rho + \hat{q}_i^\rho) + n_j\left(q_j^\rho + \hat{q}_j^\rho\right)] + \bar{c} \quad (3.12)$$

$$\alpha_i^* = \frac{1}{2} + \frac{\sigma}{6}[(q_i^2 + \hat{q}_i^2) - (q_j^2 + \hat{q}_j^2)] + \frac{\sigma}{3}[n_i(q_i^\rho + \hat{q}_i^\rho) - n_j(q_j^\rho + \hat{q}_j^\rho)] \quad (3.13)$$

$$\Pi_i^* = \alpha_i^*[n_i(q_i^\rho + \hat{q}_i^\rho) + f_i^* - \bar{c}] \quad (3.14)$$

with $i \in \{l, s\}$, $n_i = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_i^{\frac{\beta}{(1-\beta)}}}$, $n_j = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_j^{\frac{\beta}{(1-\beta)}}}$, and $\rho = \left(\frac{1}{(1-\beta)\theta}\right)$.

Proof: See Appendix.

Note that setting fixed fees, market share, and thus making profit depend on the degree of substitutability between banks. In the extreme case where σ tends to zero (for instance, the high degree of differentiation in quality of services offered by banks), banks' fixed fees tend to infinite and the market is split equally given the full participation assumption. Competition in fixed fees is thus intensified as σ increases, i.e. as the degree of substitutability increases. In this case, a bank with greater transaction volumes than its rival has a greater market share.

Parameter ρ plays an important role in setting the fixed fee by banks, their market share, and profit. This parameter determines the type of the cost function in terms of the transaction volume (see equations 3, 4 and 8): $\rho > 1$ shows that marginal costs increase with transaction volume, $\rho = 1$ shows that marginal costs are constant in terms of transaction volume, and $\rho < 1$ shows that marginal costs decrease with transaction volume.

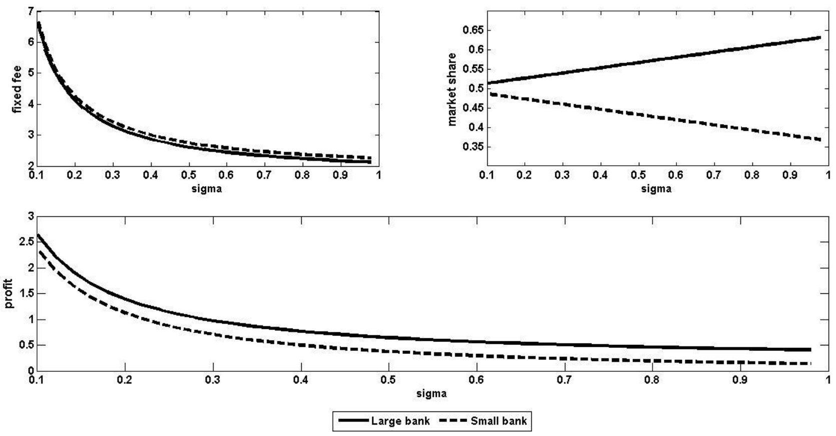
When $\rho > 1$, the fixed fee of bank i decreases with its own transaction volumes if q_i and $\hat{q}_i$ are greater than $\left(\frac{k_i^{\frac{\beta}{(1-\beta)}}}{2\rho(\rho-1)}\right)^{\frac{1}{\rho-2}}$, while its market share always increases with q_i and $\hat{q}_i$. In this case, the profit of bank i increases with q_i and $\hat{q}_i$ if the increasing market share has a dominant effect. When $\rho = 1$, f_i^* increases with q_i and $\hat{q}_i$. In this case, the bank with greater transaction volumes sets a higher fixed fee, gains a higher market share than the rival, and earns more profit. If $\rho < 1$, then the fixed fee of bank i increases with q_i and $\hat{q}_i$. Market share of bank i increases with its own transaction volumes when q_i and $\hat{q}_i$ are smaller than $\left(\frac{k_i^{\frac{\beta}{(1-\beta)}}}{\rho(1-\rho)}\right)^{\frac{1}{\rho-2}}$. Under this condition, the profit of bank i increases with q_i and $\hat{q}_i$. The reason is that increasing transaction volumes leads to a decrease in marginal costs and consequently prices. Banks by setting high fixed fees extract some parts of surplus they offered through lower prices to customers resulting in lower net surplus offered to customers. If the transaction volumes are greater than the boundary condition, then bank i loses market share as long as the net surplus is low.

Consider one special case where ρ tends to zero (marginal cost is zero). In this case, the domestic transaction price equals zero but the cross-border one equals z. In this case, banks compete on fixed fees. The profit is given by:

$$\Pi_i^* = \alpha_i^*\left[\frac{-2}{k_i^{\frac{\beta}{(1-\beta)}}} + f_i^* - \bar{c}\right]$$

where $f_i^* = \frac{1}{2\sigma} + \frac{2}{3}\left(\frac{2}{k_i^{\frac{\beta}{(1-\beta)}}} + \frac{1}{k_j^{\frac{\beta}{(1-\beta)}}}\right) + \bar{c}$ and $\alpha_i^* = \frac{1}{2} + \frac{\sigma}{3}\left(\frac{-2}{k_i^{\frac{\beta}{(1-\beta)}}} + \frac{2}{k_j^{\frac{\beta}{(1-\beta)}}}\right)$. The large bank sets smaller fixed fee because of higher k_i and has greater market share than the small bank. Increasing asymmetry between banks leads to the large bank makes more profit when σ is sufficiently small: for sufficiently small σ, the sign of $\frac{\partial \Pi_l^*}{\partial k_l} = \frac{2\beta\sigma}{3(1-\beta)k_l^{\frac{\beta}{(1-\beta)}+1}}\left(\frac{-4}{3k_l^{\frac{\beta}{(1-\beta)}}} + \frac{4}{3k_s^{\frac{\beta}{(1-\beta)}}} + \frac{1}{\sigma} - \bar{c}\right)$ is positive. It shows that when the product differentiation is high, then the large bank makes more profit because of higher k_i. Figure 3.4 shows this extreme case: the fixed fee, market share, and profit are plotted as a function of σ[33]. If the degree of substitutability between banks is large, then the large bank sets smaller fixed fee than the small bank. As a result, more customers join the large bank and consequently the large bank gains more market share. The profit of banks decreases with σ, which is due to the higher degree of competition in the market.

Figure 3.4. Behaviour of asymmetric banks when $\rho = 0$ in pre-SEPA.



3.4.2. Competition in Post-SEPA.

Under uniform pricing, each bank maximises its profit by optimally setting two-part tariff $(\tilde{f}_i, \tilde{p}_i)$. Given the one-to-one relationship between $\tilde{f}_i$ and $\tilde{w}_i$, I solve $\frac{\partial \tilde{\Pi}_i}{\partial \tilde{p}_i} = 0$ for $\tilde{p}_i$ from equation 3.9 and obtain:

$$\tilde{p}_i^* = \tilde{c}_i \qquad (3.15)$$

Equation 3.15 shows that banks set the transaction price at the marginal cost in post-SEPA. The following Proposition characterises the fixed fee, market share, and profit of bank i at the equilibrium.

Proposition 3.2. In post-SEPA, at the equilibrium, the transaction price equals marginal cost, $\tilde{p}_i^* = \tilde{c}_i$, and the fixed fee, market share, and profit for each bank equal:

[33] Parameter values are $\omega = 3, z = 0.1, k_l = 6, k_s = 2, \bar{c} = 0.2, \beta = 0.2$.

$$\tilde{f}_i^* = \frac{1}{2\sigma} + \frac{1}{3}[\frac{(\tilde{q}_i^2 - \tilde{q}_j^2)}{4} - \left(2n_i\tilde{q}_i^{\rho} + n_j\tilde{q}_j^{\rho}\right)] + \bar{c} \quad (3.16)$$

$$\tilde{\alpha}_i^* = \frac{1}{2} + \frac{\sigma}{3}[\frac{(\tilde{q}_i^2 - \tilde{q}_j^2)}{4} + n_i\tilde{q}_i^{\rho} - n_j\tilde{q}_j^{\rho}] \quad (3.17)$$

$$\tilde{\Pi}_i^* = \tilde{\alpha}_i^*[n_i\tilde{q}_i^{\rho} + \tilde{f}_i^* - \bar{c}] - F \quad (3.18)$$

with $n_i = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_i^{\frac{\beta}{(1-\beta)}}}$, $n_j = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_j^{\frac{\beta}{(1-\beta)}}}$, and $\rho = \left(\frac{1}{(1-\beta)\theta}\right)$.

Proof: See Appendix.

Similar to pre-SEPA, parameter ρ plays an important role in the analysis. When $\rho > 1$, the fixed fee of bank i in post-SEPA decreases with its own transaction volume if $\tilde{q}_i$ is grater than $(\frac{k_i^{\frac{\beta}{(1-\beta)}}}{4\rho(\rho-1)})^{\frac{1}{\rho-2}}$, while its market share always increases with $\tilde{q}_i$. If increasing market share with $\tilde{q}_i$ is larger than decreasing fixed fee, then profit of bank i increases with $\tilde{q}_i$. When $\rho = 1$, the fixed fee of bank i and its market share increase with $\tilde{q}_i$, and bank i earns more profit. If $\rho < 1$, then fixed fee increases with $\tilde{q}_i$, and its market share increases with its transaction volume when $\tilde{q}_i$ is smaller than $(\frac{k_i^{\frac{\beta}{(1-\beta)}}}{4\rho(1-\rho)})^{\frac{1}{\rho-2}}$. Under this condition, the profit of bank i increases with $\tilde{q}_i$.

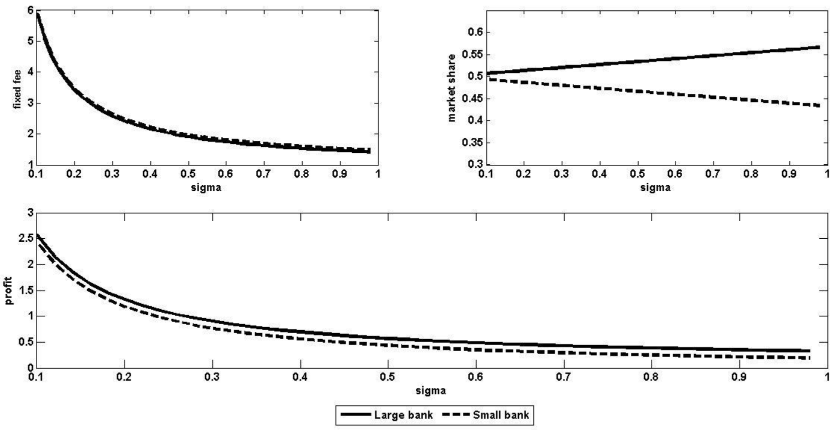
Consider $\rho = 0$ (marginal cost is zero), the profit is:

$$\tilde{\Pi}_i^* = \tilde{\alpha}_i^*[\frac{-1}{k_i^{\frac{\beta}{(1-\beta)}}} + \tilde{f}_i^* - \bar{c}] - F$$

with $\tilde{f}_i^* = \frac{1}{2\sigma} + \frac{1}{3}(\frac{2}{k_i^{\frac{\beta}{(1-\beta)}}} + \frac{1}{k_j^{\frac{\beta}{(1-\beta)}}}) + \bar{c}$ and $\tilde{\alpha}_i^* = \frac{1}{2} + \frac{\sigma}{3}(\frac{-1}{k_i^{\frac{\beta}{(1-\beta)}}} + \frac{1}{k_j^{\frac{\beta}{(1-\beta)}}})$. Similar to pre-SEPA, banks compete on fixed fees when $\rho = 0$. If asymmetry between banks increases, then the profit of the large bank increases with k_l when σ is sufficiently small. Figure 3.5 shows the behaviour of asymmetric banks at equilibrium as a function of σ in post-SEPA[34]. Similar to pre-SEPA, in this case, the large bank sets smaller fixed fee and has greater market share than the small bank.

[34] Parameter values are $\omega = 3, k_l = 6, k_s = 2, \bar{c} = 0.2, \beta = 0.2, F = 0$.

Figure 3.5. Behaviour of asymmetric banks when $\rho = 0$ in post-SEPA.



The purpose of this chapter is to study the effect of SEPA on competition between banks. When $\rho = 0$, the comparison between pre-SEPA and post-SEPA shows that the large bank loses market share but the small bank gains market share in post-SEPA. In other words, the SEPA project intensifies competition between banks when $\rho = 0$. When $\rho > 0$, the comparison is complicated because for values of ρ different from 0, marginal costs take different functional forms in terms of transaction volumes as follows.

$$c_i = \rho k_i^{1-\rho\theta} q_i^{\rho-1},\ \hat{c}_i = \rho k_i^{1-\rho\theta} \hat{q}_i^{\rho-1} + z,\ \tilde{c}_i = \rho k_i^{1-\rho\theta} \tilde{q}_i^{\rho-1} \qquad i \in \{l, s\}$$

For instance, if $\rho = 2$, then marginal costs are a linear function of transaction volumes as $c_i = 2k_i^{1-2\theta} q_i$, $\hat{c}_i = 2k_i^{1-2\theta}\hat{q}_i + z$,and $\tilde{c}_i = 2k_i^{1-2\theta}\tilde{q}_i$. In another example, if $\rho = 0.5$, then marginal costs are a nonlinear function of transaction volumes as $c_i = 0.5k_i^{1-0.5\theta} q_i^{-0.5}$, $\hat{c}_i = 0.5k_i^{1-0.5\theta}\hat{q}_i^{-0.5} + z$, and $\tilde{c}_i = \rho 0.5k_i^{1-0.5\theta}\tilde{q}_i^{-0.5}$. The diversity of marginal cost functions leads to obtain multiple solutions for transaction prices which complicate the analysis. To keep the model tractable, I take a narrower view and only focus on the case where $\rho = 1$. In this case, $\rho = 1$ ($\theta = \frac{1}{1-\beta}$), the marginal costs are constant in terms of the transaction volumes. This assumption still captures the existence of the economies of scale[35].

$$c_i = k_i^{1-\theta},\ \hat{c}_i = k_i^{1-\theta} + z,\ \tilde{c}_i = k_i^{1-\theta} \qquad i \in \{l, s\}$$

3.5. Pre-SEPA vs. Post-SEPA.

This section analyses effects of SEPA on competition between banks and welfare when $\rho = 1$. Then, I expand analysis by considering the case where θ tends to infinity and study effects of economies of scale on equilibrium.

3.5.1. Comparison between pre-SEPA and post-SEPA when $\theta = \frac{1}{1-\beta}$ ($\rho = 1$).

[35] When $\rho = 1$, the average total cost ($\frac{C_i+\bar{c}}{q}$) decreases with transaction volumes and the average variable cost equals marginal cost ($\frac{\partial C_i}{\partial q} = c_i$).

When marginal costs are constant in terms of the transaction volumes, then the optimal transaction prices are given by:

$$p_i^* = k_i^{1-\theta}, \hat{p}_i^* = k_i^{1-\theta} + z, \ \tilde{p}_i^* = k_i^{1-\theta} \qquad i \in \{l, s\} \tag{3.19}$$

It notes that the optimal transaction prices decrease with the capital level since $\theta > 1$. This means that the large bank sets lower transaction prices than the small bank in pre- and post-SEPA. Comparison of optimal prices in pre-SEPA with post-SEPA shows that the transaction price in post-SEPA equals the domestic transaction price in pre-SEPA (owing to the same marginal cost) and smaller than the cross-border transaction price in pre-SEPA: $p_i^* = \tilde{p}_i^* < \hat{p}_i^*$. In other words, SEPA affects the cross-border transaction prices but not domestic ones. Since transaction prices are set at marginal costs, banks earn zero profit from the execution of payments but they earn positive profit from the fixed fees. To gain our understating regarding the effect of SEPA on banks and customers, I start with the symmetric case as a benchmark and then expand my analysis to the asymmetric case.

Symmetric banks:

In the symmetric case, the two banks have the same level of capital ($k_l = k_s = k$) and market share equals $\frac{1}{2}$ ($\alpha^* = \tilde{\alpha}^* = \frac{1}{2}$), the optimal transaction prices are

$$p^* = \tilde{p}^* = k^{1-\theta} < \hat{p}^* = k^{1-\theta} + z.$$

From equations 3.12 and 3.16, it is obtained that the fixed fee in post-SEPA equals pre-SEPA with

$$f^* = \tilde{f}^* = \frac{1}{2\sigma} + \bar{c}.$$

It shows that SEPA has no effect on the fixed fee in the symmetric case.

The profit of banks in pre- and post-SEPA are given by $\Pi^* = \frac{1}{4\sigma}$ and $\tilde{\Pi}^* = \frac{1}{4\sigma} - F$, respectively. For each $F > 0$, SEPA results in lower profit for banks. In contrast, SEPA favours customers in the symmetric case since

$$CS^* = \frac{q^2 + \hat{q}^2}{2} - \left(\bar{c} + \frac{5}{8\sigma}\right) < \widetilde{CS}^* = q^2 - \left(\bar{c} + \frac{5}{8\sigma}\right).$$

Observes that in post-SEPA customers take advantage of lowering transaction prices while banks must bear the fixed adjustment cost. The reason is that the harmonisation of the national payment systems in post-SEPA leads to decrease cross-border transaction prices, thus, the transaction volumes are greater in post-SEPA than pre-SEPA ($q^2 > \frac{q^2+\hat{q}^2}{2}$). Consequently, consumer surplus is greater in post-SEPA than pre-SEPA. The effect of SEPA on welfare depends on the value of F. Welfare may improve in post-SEPA when the gain in consumer surplus offsets the bank's fixed investments.

Asymmetric banks:

Here, I analyse the effect of SEPA on asymmetric banks with $k_l > k_s$. In order to compare the results in pre- and post-SEPA, I recall $\tilde{q}_i^2 = 4q_i^2$. The next Proposition establishes the relationship between tariffs of the large bank and the small bank in pre- and post-SEPA.

Proposition 3.3. For $\rho = 1$ and $k_l > k_s$, at the equilibrium I have

In pre-SEPA:

(i) $p_l^* < p_s^*,\ \hat{p}_l^* < \hat{p}_s^*$ but $f_l^* > f_s^*$ where

$$f_i^* = \frac{1}{2\sigma} + \frac{(q_i^2+\hat{q}_i^2)-(q_j^2+\hat{q}_j^2)}{6} + \bar{c} \quad i \neq j \in \{l, s\}$$

and f_i^* increases with k_i but decreases with k_j.

In post-SEPA:

(ii) $\tilde{p}_l^* < \tilde{p}_s^*$ but $\tilde{f}_l^* > \tilde{f}_s^*$ where

$$\tilde{f}_i^* = \frac{1}{2\sigma} + \frac{\left(q_i^2-q_j^2\right)}{3} + \bar{c} \quad i \neq j \in \{l, s\}$$

and $\tilde{f}_i^*$ increases with k_i but decreases with k_j.

Proof. See Appendix.

The comparison of tariffs between pre- and post-SEPA shows that the large bank sets its transaction prices below the small bank, while the small bank sets its fixed fee below the large bank. This is due to the trade-off between transaction prices and fixed fees, so that where the transaction prices are low, the fixed fee is high and vice versa. The reason is that transaction prices are set at marginal costs so as to maximise consumer surplus, which banks then extract through the fixed fee. Since the large bank has a lower marginal cost, its transaction price is lower and its fixed fee is larger than that of the small bank. Proposition 3.3 shows that when asymmetry between banks increases, the large bank increases its fixed fee. The reason is that increasing asymmetry between banks makes the large bank relatively more efficient and consequently allows it to set lower transaction prices and a higher fixed fee. In contrast, if asymmetry between banks decreases then the competitive advantage of the large bank diminishes, and the difference between fixed fees becomes smaller.

Next, I discuss market shares. By inserting the optimal transaction prices and fixed fees into equations 3.13 and 3.17, I get the market share of bank *i* in pre- and post-SEPA, which are respectively:

$$\alpha_i^* = \frac{1}{2} + \sigma\left(\frac{(q_i^2+\hat{q}_i^2)-(q_j^2+\hat{q}_j^2)}{6}\right) \qquad (3.20)$$

$$\tilde{\alpha}_i^* = \frac{1}{2} + \sigma\left(\frac{q_i^2-q_j^2}{3}\right) \qquad (3.21)$$

with $i \neq j \in \{l, s\}$. The above equations point that for each $0 < \sigma \leq 1$ the large bank with greater transaction volumes has greater market share than the small bank in pre- and post-SEPA. The difference between market shares of the large bank and the small bank increases with σ, the less differentiated the products are. A closer look at Proposition 3.3 and equations 3.20 and 3.21 tells us that $\alpha_i^* = \sigma[f_i^* - \bar{c}]$ and $\tilde{\alpha}_i^* = \sigma[\tilde{f}_i^* - \bar{c}]$. Next, I use this relationship to determine the profit of banks in pre- and post-SEPA.

Proposition 3.4. At the equilibrium, the large bank has greater market share and earns more profit than the small bank in pre- and post-SEPA:

$$\Pi_i^* = \frac{1}{\sigma}\alpha_i^{*2}$$

$$\widetilde{\Pi}_i^* = \frac{1}{\sigma}\tilde{\alpha}_i^{*2} - F$$

with $\alpha_i^* = \sigma[f_i^* - \bar{c}]$ and $\tilde{\alpha}_i^* = \sigma[\tilde{f}_i^* - \bar{c}]$.

Proof. See Appendix.

Since transaction prices are set at marginal costs, banks earn profit from fixed fees in pre- and post-SEPA. As f_i^* increases with q_i and $\hat{q}_i$ but decreases with q_j and $\hat{q}_j$, the bank with greater transaction volumes earns more profit than the rival. Moreover, similar to the effect of σ on market share of banks, the difference between profits of banks increases with σ.

Let's define $\varphi = \frac{\hat{q}_l+\hat{q}_s}{q_l+q_s}$, the ratio of cross-border transaction volumes to domestic ones. This expression is important in my analysis since it measures asymmetry between the two phases. Corollary 3.1 summarises the comparison of the performance of banks in pre- and post-SEPA.

Corollary 3.1. For $k_l > k_s$ and given θ, SEPA results in $\tilde{p}_i^* = p_i^* < \hat{p}_i^*$ with $i \epsilon \{l, s\}$, then

i) The large bank (small bank) sets higher (lower) fixed fee in post-SEPA than pre-SEPA as $\varphi < 1$.

ii) Given $\varphi < 1$, the large bank (small bank) has greater (lower) market share and consequently makes more profit in post-SEPA than pre-SEPA with sufficiently small F.

Proof: See Appendix.

Corollary 3.1 shows that the transaction volume pattern plays an important role in determining the effects of SEPA on competition between banks. In my analysis, φ is always lower than one. It shows that the share of cross-border transaction volumes is smaller than the domestic ones since the domestic transactions are cheaper than the cross-border ones. This is consistent with Leibbrandt (2010) who explains that the share of cross-border transactions is significantly lower than domestic ones for most countries, and it is around 1-2%. The data provided by the ECB statistics shows that in 2018, in Germany the share of cross-border payment was 3%, in Spain was 1.2%, in Italy was 0.2%, and in Portugal was 0.01%. Under this transaction volume pattern, the large bank gains market share in post-SEPA since the marginal cost advantage of the large bank reinforces the differences between banks. Thus, competition between banks is less intense in post-SEPA and for sufficiently small F, the large bank makes more profit than pre-SEPA.

At the equilibrium, consumer surplus in pre- and post-SEPA are:

$$CS^* = \alpha_l^*\left(\frac{q_l^2 + \hat{q}_l^2}{2}\right) + \alpha_s^*\left(\frac{q_s^2 + \hat{q}_s^2}{2}\right) - \frac{5}{4\sigma}\left(\alpha_l^{*2} + \alpha_s^{*2}\right) - \bar{c}$$

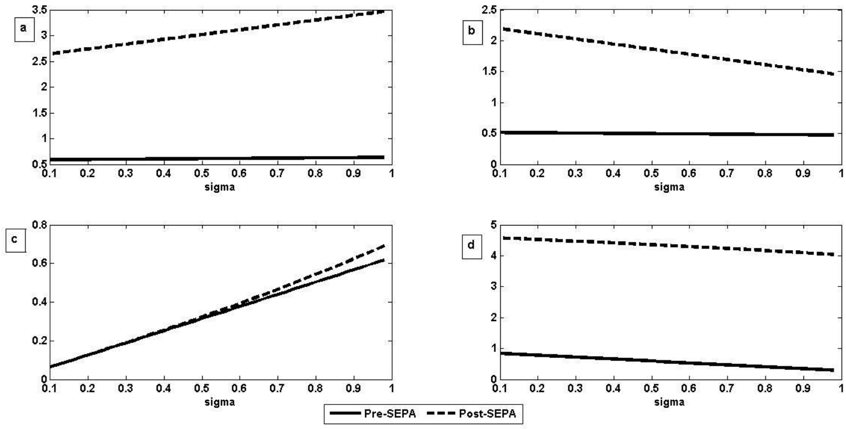
$$\widetilde{CS}^* = \tilde{\alpha}_l^*\tilde{q}_l^2 + \tilde{\alpha}_s^*\tilde{q}_s^2 - \frac{5}{4\sigma}\left(\tilde{\alpha}_l^{*2} + \tilde{\alpha}_s^{*2}\right) - \bar{c}$$

Figure 3.6 illustrates consumer surplus in pre- and post-SEPA as a function of σ[36]. Figure 3.6-a

[36] Parameter values are $\omega = 2, z = 0.1, k_l = 4, k_s = 2, \bar{c} = 0.2, \theta = 1.1$

shows the net surplus offered by the large bank, Figure 3.6-b shows the net surplus offered by the small bank, Figure 3.6-c shows the customer disutility, and Figure 3.6-d shows the accumulation of three former figures that is total consumer surplus. In pre-SEPA, when σ increases, the net surpluses offered by the large bank and the small bank do not change significantly, but the consumer disutility increases. Therefore consumer surplus decreases with σ in pre-SEPA. In post-SEPA, the situation is somewhat different. The net surplus offered by the large bank increases with σ but the net surplus offered by the small bank decreases. Similar to pre-SEPA, the consumer disutility increases with σ. As a result, consumer surplus decreases with σ. Comparison of consumer surplus (Figure 3.6-d) in pre- and post-SEPA shows that SEPA results in greater consumer surplus. The two banks offered greater net surplus in post-SEPA than pre-SEPA but the consumer disutility is almost the same as pre-SEPA. Consequently, consumer surplus improves in post-SEPA.

Figure 3.6. Components of consumer surplus in pre- and post-SEPA.



Welfare in pre- and post-SEPA are:

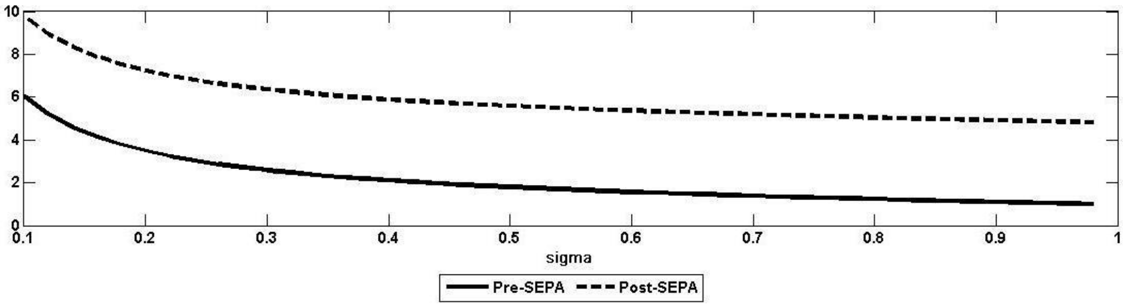
$$W^* = \alpha_l^* \left(\frac{q_l^2 + \hat{q}_l^2}{2}\right) + \alpha_s^* \left(\frac{q_s^2 + \hat{q}_s^2}{2}\right) - \frac{1}{4\sigma}\left(\alpha_l^{*2} + \alpha_s^{*2}\right) - \bar{c}$$

$$\widetilde{W} = \tilde{\alpha}_l^* \tilde{q}_l^2 + \tilde{\alpha}_s^* \tilde{q}_s^2 - \frac{1}{4\sigma}\left(\tilde{\alpha}_l^{*2} + \tilde{\alpha}_s^{*2}\right) - \bar{c} - 2F$$

Figure 3.7 illustrates welfare in pre- and post-SEPA[37]. When the fixed adjustment cost is sufficiently small, then welfare improves in post-SEPA since consumer surplus improves. If the fixed adjustment cost is large, then welfare decreases in post-SEPA and can be even negative. In this case, both banks lose profit since they are not enabled to cover this cost. Literature has estimated various amounts for the fixed adjustment cost. For instance, the ECB (2019) estimated this cost at around GBP 10.2 billion or €15.3 billion; Boston Consulting Group (2006) estimated this cost around €5 billion. In contrast, PWC group estimated the net annual saving by banks is €5.9 billion without considering the fixed adjustment cost for the period 2014-2020. Thus, if the fixed adjustment cost is depreciated over some years, then SEPA may be profitable for banks. In this case, welfare would improve in post-SEPA.

[37] Parameter values are $\omega = 2, z = 0.1, k_l = 4, k_s = 2, \bar{c} = 0.2, \theta = 1.1$

Figure 3.7. Welfare comparison in pre- and post-SEPA.



In the following, I study how the performance of banks changes when economies of scale improve.

3.5.2. Impact of Economies of Scale.

Concerning the economies of scale, I have assumed that it was the same in pre- and post-SEPA. Following literature, economies of scale are likely to foster as a consequence of SEPA. Bolt and Humphrey (2007) and Beijnen and Bolt (2009) state that economies of scale are expected to improve in post-SEPA as a result of spurring consolidation among European payment systems. Because $\theta = \frac{1}{1-\beta}$, in my model the higher economies of scale are achieved when the capital share is relatively larger than the labour share. It leads to a reduction in the marginal costs. McKinsey (2005) points out that SEPA would lead to fostering economies of scale by 25% in some European countries. For sufficiently large economies of scale, pre-SEPA domestic transaction prices and post-SEPA transaction prices equal zero, $p_i^* = \tilde{p}_i^* = 0$, since the marginal cost tends to zero. But the cross-border transaction price in pre-SEPA equals z which is the connectivity cost to execute the cross-border payment. In the symmetric case, fostering economies of scale has no effect on banks' profitability, but it results in increasing consumer surplus since there are more transaction volumes in post-SEPA than pre-SEPA. The following Corollary establishes the effect of improving economies of scale on the equilibrium in the asymmetric case.

Corollary 3.2. An increase in economies of scale as a consequence of SEPA results in

1- Diminishing asymmetry between banks; for sufficiently large economies of scale the two banks will have the same market share and earn equal profit.
2- Consumer surplus converges to a certain amount.

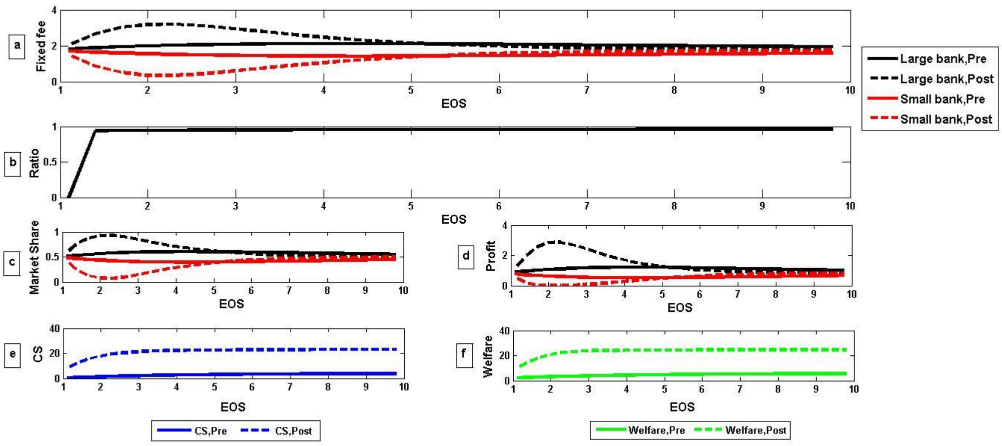
Proof: See Appendix.

The above results are illustrated by means of numerical simulations in Figure 3.8[38]. Here, the equilibria are plotted as a function of economies of scale. I shall further simplify the analysis by assuming that the fixed adjustment cost is arbitrarily set to zero as it does not affect the optimal transaction prices, thus $F = 0$. If this cost is larger than zero, then profit and welfare in post-SEPA will decrease accordingly. The fostering in economies of scale results in downward pressure on the

[38] Parameter values are as follows: $\omega = 2.5, z = 0.1, k_l = 4,\ k_s = 2,\ \bar{c} = 0.1,\ \sigma = 0.3$.

transaction prices. Figure 3.8-a and 3.8-c show that in the range $\theta < 5$, the fixed fee and the market share of the large bank is greater in post-SEPA while the fixed fee and the market share of the small bank are smaller in post-SEPA. The reason is that transaction volumes of the large bank are greater than transaction volumes of the small bank in this range of θ. Moreover, it is observed that when $\theta \cong 2$, in post-SEPA, the large bank corners the market as it has market share around 1, and the small bank loses almost all its market share, but in the range of $\theta > 2$, the large bank loses market share in post-SEPA while the small bank gains some market share. Therefore, if economies of scale foster in post-SEPA, then SEPA is pro-competitive. Figure 3.8-b shows that the ratio of cross-border transactions to domestic ones is lower than 1 that is consistent with the results of Corollary 1. Figure 3.8-d presents the profit of banks that follow the same path as their market shares. Figures 3.8-e and 3.8-f show that consumer surplus and welfare are improved in post-SEPA and increase till economies of scale reach a sufficiently large value and remain constant afterwards. Consumers benefit due to lower transaction prices and fixed fees that result from greater economies of scale. The figures depict that for sufficiently large θ, the asymmetry between banks reduces and both banks make the same profit in the market.

Figure 3.8. Compare results in pre-SEPA and post-SEPA.



3.6. Conclusion.

The present chapter has examined the effect of SEPA on competition between two asymmetric banks in the presence of economies of scale. Based on available empirical evidence, the chapter has considered two phases: pre-SEPA where payment systems are nationally diversified and banks are allowed to discriminate between transaction price of domestic and cross-border payments and post-SEPA where the national payment systems are compatible and banks apply uniform pricing for making domestic and cross-border payments. In post-SEPA, all banks are obliged to make a cross-border payment as cheap and easy as a domestic one. In this sense, there is no difference between domestic and cross-border payments and all euro payments in the SEPA zone are treated as domestic ones.

The results have shown that both banks set their transaction prices at the marginal costs. I found that when marginal costs are zero, the pre-SEPA domestic transaction price and the post-SEPA transaction price equal zero, but the pre-SEPA cross-border transaction price is equal to connectively cost. In this case, banks compete on fixed fees and the large bank sets a lower fixed fee than the small bank resulting in greater market share and profit in pre- and post-SEPA. The comparison of market shares in pre- and post-SEPA has shown that SEPA intensifies competition between banks. In another case where the marginal costs are constant in terms of the transaction volumes ($\rho = 1$), the large bank with greater capital sets lower transaction prices than the small bank while the small bank sets a lower fixed fee than the large bank. It was observed that there is a trade-off between fixed fees and transaction prices. This means that where the transaction prices are low the fixed fee is high and vice versa. The lower transaction prices lead to increasing transaction volumes, and the higher fixed fee allows banks to extract more consumer surplus. Then, the comparison between pre- and post-SEPA has revealed the impact of SEPA on banks and customers. Given economies of scale, two banks would not make benefit equally from SEPA. The transaction pattern has a vital role in competition between banks in post-SEPA. Based on results, if the share of cross-border transaction is smaller than domestic one, then competition between banks is less intense in post-SEPA. This result is consistent with Leibbrandt (2010) and Schaefer (2008), and the implication is that the SEPA project favours the large bank. Consumer surplus improves because customers receive better services in post-SEPA. Further analysis has focused on economies of scale that would have been affected by SEPA. In this regard, the cost saving through relatively large economies of scale leads to vanishing asymmetries between banks. In this case, SEPA helped the small bank to catch up and obtain the same profit as the large bank. This result was expected by the EC about the outcome of the SEPA project.

Further research will examine the enhancing cross-border competition due to lower entry barriers for payment systems. Moreover, the chapter can be extended to consider ρ different from 1.

3.7. Appendix.

Proof of Proposition 3.1. Given transaction prices equal marginal costs, fixed fee at equilibrium is obtained by:

$$\max_{w_i} \Pi_i = \max_{w_i} \alpha_i[(c_i q_i - C_i + \hat{c}_i \hat{q}_i - \hat{C}_i + V_i + \hat{V}_i - w_i - \bar{c}]$$

with $i \neq j \epsilon \{l, s\}$, $\alpha_i = \frac{1}{2} + \sigma[w_i - w_j]$. Using that $f_i = V_i + \hat{V}_i - w_i$, The first order condition can be written as:

$$\frac{\partial \Pi_i}{\partial w_i} = \sigma\left(n_i\left(q_i^\rho + \hat{q}_i^\rho\right) + f_i - \bar{c}\right) - \alpha_i = 0$$

with $n_i = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_i^{\frac{\beta}{(1-\beta)}}}$ and $\rho = \left(\frac{1}{(1-\beta)\theta}\right)$. Since α_i can be written as $\alpha_i = \frac{1}{2} + \sigma\left[\Delta_{ij} - f_i + f_j\right]$ with $\Delta_{ij} = V_i + \hat{V}_i - V_j - \hat{V}_j$, then $\frac{\partial \Pi_i}{\partial w_i}$ is given by:

$$\frac{\partial \Pi_i}{\partial w_i} = \sigma\left(n_i\left(q_i^\rho + \hat{q}_i^\rho\right) + f_i - \bar{c}\right) - \frac{1}{2} - \sigma[\Delta_{ij} - f_i + f_j] = 0$$

By solving for f_i, I get

$$f_i = \frac{1}{4\sigma} + \frac{1}{2}\left[\Delta_{ij} + f_j - n_i(q_i^\rho + \hat{q}_i^\rho) + \bar{c}\right] \qquad (3.a\text{-}1)$$

By following the similar steps, f_j is given by:

$$f_j = \frac{1}{4\sigma} + \frac{1}{2}\left[\Delta_{ji} + f_i - n_j(q_j^\rho + \hat{q}_j^\rho) + \bar{c}\right] \qquad (3.a\text{-}2)$$

where $\Delta_{ji} = V_j + \hat{V}_j - V_i - \hat{V}_i$. Solving the above system of equations (3.a-1 and 3.a-2) for f_i and f_j, after simplifying, I get:

$$f_i^* = \frac{1}{2\sigma} + \frac{1}{3}[\Delta_{ij} - \left(2n_i(q_i^\rho + \hat{q}_i^\rho) + n_j(q_j^\rho + \hat{q}_j^\rho)\right)] + \bar{c}$$

By replacing $\Delta_{ij}$and $V = \frac{q^2}{2}$ in f_i^*, I obtain:

$$f_i^* = \frac{1}{2\sigma} + \frac{1}{6}[(q_i^2 + \hat{q}_i^2) - (q_j^2 + \hat{q}_j^2)] - \frac{1}{3}[2n_i\left(q_i^\rho + \hat{q}_i^\rho\right) + n_j\left(q_j^\rho + \hat{q}_j^\rho\right)] + \bar{c}$$

with $i \neq j \in \{l, s\}$, $n_i = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_i^{\frac{\beta}{(1-\beta)}}}$, $n_j = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_j^{\frac{\beta}{(1-\beta)}}}$ and $\rho = \left(\frac{1}{(1-\beta)\theta}\right)$.

To determine whether $(p_i^*, \hat{p}_i^*, f_i^*)$ with $i \epsilon \{l, s\}$ are optimal solution for the profit function

$$\Pi_i = \alpha_i[(p_i q_i - C_i + \hat{p}_i \hat{q}_i - \hat{C}_i + V_i + \hat{V}_i - w_i - \bar{c}]$$

with $\alpha_i = \frac{1}{2} + \sigma\left[w_i - w_j\right]$, I study the signs of leading principle minors of Hessian matrix. The Hessian of profit is given by:

$$H = \begin{bmatrix} -\alpha_i(1+n_i\rho q_i^{\rho-2}) & 0 & \sigma(-p_i+c_i) \\ 0 & -\alpha_i(1+n_i\rho \hat{q}_i^{\rho-2}) & \sigma(-\hat{p}_i+\hat{c}_i) \\ \sigma(-p_i+c_i) & \sigma(-\hat{p}_i+\hat{c}_i) & -2\sigma \end{bmatrix}$$

By evaluating at the equilibrium $(p_i^*, \hat{p}_i^*, f_i^*)$, I get:

$$H = \begin{bmatrix} -\alpha_i(1+n_i\rho q_i^{\rho-2}) & 0 & 0 \\ 0 & -\alpha_i(1+n_i\rho \hat{q}_i^{\rho-2}) & 0 \\ 0 & 0 & -2\sigma \end{bmatrix}$$

The leading principle minors show that the Hessian matrix is negative definite, and as a result there is not any incentives for bank i to deviate from $(p_i^*, \hat{p}_i^*, f_i^*)$.

$$\left|\frac{\partial^2 \Pi_i}{\partial p_i^2}\right| < 0, \begin{vmatrix} \frac{\partial^2 \Pi_i}{\partial p_i^2} & \frac{\partial^2 \Pi_i}{\partial p_i \partial \hat{p}_i} \\ \frac{\partial^2 \Pi_i}{\partial \hat{p}_i \partial p_i} & \frac{\partial^2 \Pi_i}{\partial \hat{p}_i^2} \end{vmatrix} > 0, \begin{vmatrix} \frac{\partial^2 \Pi_i}{\partial p_i^2} & \frac{\partial^2 \Pi_i}{\partial p_i \partial \hat{p}_i} & \frac{\partial^2 \Pi_i}{\partial p_i \partial w_i} \\ \frac{\partial^2 \Pi_i}{\partial \hat{p}_i \partial p_i} & \frac{\partial^2 \Pi_i}{\partial \hat{p}_i^2} & \frac{\partial^2 \Pi_i}{\partial \hat{p}_i \partial w_i} \\ \frac{\partial^2 \Pi_i}{\partial w_i \partial p_i} & \frac{\partial^2 \Pi_i}{\partial w_i \partial \hat{p}_i} & \frac{\partial^2 \Pi_i}{\partial w_i^2} \end{vmatrix} < 0$$

To check unique solutions, I study whether:

$$c_i\big(q(0)\big) > 0 \text{ and } c_i'\big(q(p_i)\big) < 0$$
$$\hat{c}_i\big(\hat{q}(0)\big) > 0 \text{ and } \hat{c}_i'\big(\hat{q}(\hat{p}_i)\big) < 0$$

where $p_i^* = c_i(q(p_i))$, $\hat{p}_i^* = \hat{c}_i(\hat{q}(\hat{p}_i))$, and $q(p_i) = w - p_i$, $\hat{q}(\hat{p}_i) = w - \hat{p}_i$. Equations 3.3 and 3.4 satisfy the conditions $c_i\big(q(0)\big) > 0$ and $\hat{c}_i\big(\hat{q}(0)\big) > 0$. Moreover, the first derivative of marginal costs with respect to transaction prices satisfy the conditions $\frac{\partial c_i}{\partial p_i} < 0$ and $\frac{\partial \hat{c}_i}{\partial \hat{p}_i} < 0$. Thus, the equation $p_i = c_i(q(p_i)$ has a unique solution.

At equilibrium, the market share is given by

$$\alpha_i^* = \frac{1}{2} + \sigma[\Delta_{ij} - f_i^* + f_j^*]$$

with $\Delta_{ij} - f_i^* + f_j^* = \frac{1}{6}[(q_i^2 + \hat{q}_i^2) - (q_j^2 + \hat{q}_j^2)] + \frac{1}{3}[n_i\big(q_i^\rho + \hat{q}_i^\rho\big) - n_j\left(q_j^\rho + \hat{q}_j^\rho\right)]$. The profit of bank i at the equilibrium is straightforward.

■

Proof of Proposition 3.2. Given transaction price equals marginal cost, the fixed fee in the post-SEPA is acquired by:

$$\max_{\widetilde{w}_i} \widetilde{\Pi}_i = \max_{\widetilde{w}_i} \tilde{\alpha}_i \, [\tilde{c}_i \tilde{q}_i - \tilde{C}_i + \tilde{V}_i - \widetilde{w}_i - \bar{c}] - F$$

with $\tilde{\alpha}_i = \frac{1}{2} + \sigma[\widetilde{w}_i - \widetilde{w}_j]$, $\widetilde{w}_i = \tilde{V}_i - \tilde{f}_i$, and $i \neq j \epsilon \{l, s\}$. The first order condition for bank i is:

$$\frac{\partial \widetilde{\Pi}_i}{\partial \widetilde{w}_i} = \sigma[n_i \tilde{q}_i^\rho + \tilde{f}_i - \bar{c}] - \tilde{\alpha}_i = 0.$$

with $n_i = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_i^{\frac{\beta}{(1-\beta)}}}$ and $\rho = \left(\frac{1}{(1-\beta)\theta}\right)$. By substituting the market share as $\tilde{\alpha}_i = \frac{1}{2} + \sigma[\tilde{\Delta}_{ij} - \tilde{f}_i + \tilde{f}_j]$ with $\tilde{\Delta}_{ij} = \tilde{V}_i - \tilde{V}_j$ into the above expressions, I get:

$$\frac{\partial \breve{\Pi}_i}{\partial \widetilde{w}_i} = \sigma\left[n_i \tilde{q}_i^{\rho} + \tilde{f}_i - \bar{c}\right] - \frac{1}{2} - \sigma[\tilde{\Delta}_{ij} - \tilde{f}_i + \tilde{f}_j] = 0$$

By solving for $\tilde{f}_i$, I get:

$$\tilde{f}_i = \frac{1}{4\sigma} + \frac{1}{2}\left[\tilde{\Delta}_{ij} + \tilde{f}_j - n_i \tilde{q}_i^{\rho} + \bar{c}\right] \qquad (3.a\text{-}3)$$

By following the similar steps, I get

$$\tilde{f}_j = \frac{1}{4\sigma} + \frac{1}{2}\left[\tilde{\Delta}_{ji} + \tilde{f}_i - n_j \tilde{q}_j^{\rho} + \bar{c}\right] \qquad (3.a\text{-}4)$$

where $\tilde{\Delta}_{ji} = \tilde{V}_j - \tilde{V}_i$. Solving the above system of equations (3.a-3 and 3.a-4) for $\tilde{f}_i$and $\tilde{f}_j$, I get:

$$\tilde{f}_i^* = \frac{1}{2\sigma} + \frac{1}{3}[\tilde{\Delta}_{ij} - \left(2n_i \tilde{q}_i^{\rho} + n_j \tilde{q}_j^{\rho}\right)] + \bar{c}$$

Equivalently:

$$\tilde{f}_i^* = \frac{1}{2\sigma} + \frac{1}{3}[\frac{(\tilde{q}_i^2 - \tilde{q}_j^2)}{4} - \left(2n_i \tilde{q}_i^{\rho} + n_j \tilde{q}_j^{\rho}\right)] + \bar{c}$$

with $n_i = \frac{1-(1-\beta)\theta}{(1-\beta)\theta k_i^{\frac{\beta}{(1-\beta)}}}$ and $\rho = \left(\frac{1}{(1-\beta)\theta}\right)$. To check the concavity of profit function

$$\widetilde{\Pi}_i = \tilde{\alpha}_i[\tilde{p}_i \tilde{q}_i - \tilde{C}_i + \tilde{V}_i - \widetilde{w}_i - \bar{c}] - F$$

with $\tilde{\alpha}_i = \frac{1}{2} + \sigma[\widetilde{w}_i - \widetilde{w}_j]$, I get the Hessian of profit as

$$H = \begin{bmatrix} -\tilde{\alpha}_i(1 + n_i \rho \tilde{q}_i{}^{-2}) & \sigma(-\tilde{p}_i + \tilde{c}_i) \\ \sigma(-\tilde{p}_i + \tilde{c}_i) & -2\sigma \end{bmatrix}$$

By evaluating the Hessian in $(\tilde{p}_i^*, \tilde{f}_i^*)$, I get:

$$H = \begin{bmatrix} -\tilde{\alpha}_i(1 + n_i \rho \tilde{q}_i{}^{\rho-2}) & 0 \\ 0 & -2\sigma \end{bmatrix}$$

The leading principle minors show that the Hessian matrix is negative definite as

$$\left|\frac{\partial^2 \widetilde{\Pi}_i}{\partial \tilde{p}_i^2}\right| < 0, \quad \begin{vmatrix} \frac{\partial^2 \widetilde{\Pi}_i}{\partial \tilde{p}_i^2} & \frac{\partial^2 \widetilde{\Pi}_i}{\partial \tilde{p}_i \partial \omega_i} \\ \frac{\partial^2 \widetilde{\Pi}_i}{\partial \omega_i \partial \tilde{p}_i} & \frac{\partial^2 \widetilde{\Pi}_i}{\partial \omega_i^2} \end{vmatrix} > 0$$

So, $(\tilde{p}_i^*, \tilde{f}_i^*)$ characterised as optimal two-part tariff in the post-SEPA phase.

The equilibrium market share is then

$$\tilde{\alpha}_i^* = \frac{1}{2} + \sigma[\tilde{\Delta}_{ij} - \tilde{f}_i^* + \tilde{f}_j^*]$$

with $\tilde{\Delta}_{ij} - \tilde{f}_i^* + \tilde{f}_j^* = \frac{1}{3}[\frac{(\tilde{q}_i^2 - \tilde{q}_j^2)}{4} + n_i\tilde{q}_i{}^\rho - n_j\tilde{q}_j{}^\rho]$. The profit of bank i at the equilibrium is straightforward.

■

Proof of Proposition 3.3. In pre-SEPA with $\rho = 1$, $k_l > k_s$, and given $\theta > 1$, I get:

$$p_l^* = k_l^{1-\theta} < p_s^* = k_s^{1-\theta}.$$

The domestic transaction price charged by the large bank is less than the domestic transaction price charged by the small bank. It is straightforward to conclude that the cross-border transaction price charged by the large bank is less than the cross-border transaction price charged by the small bank since $\hat{p}_l^* = p_l^* + z < \hat{p}_s^* = p_s^* + z$. The large bank sets greater fixed fee than the small bank since

$$f_i^* = \frac{1}{2\sigma} + \frac{(q_i^2 + \hat{q}_i^2) - (q_j^2 + \hat{q}_j^2)}{6} + \bar{c} \qquad i \neq j \in \{l, s\}$$

and

$$f_l^* - f_s^* = \frac{(q_l^2 + \hat{q}_l^2) - (q_s^2 + \hat{q}_s^2)}{3} > 0$$

The expression of the fixed fee is simplified because of $n_i = 0$. The fixed fee charged by the large bank is greater than the fixed fee charged by the small bank since it has larger transaction volumes. Moreover, the fixed fee of bank i increases with k_i but decreases with k_j with $i \neq j \in \{l, s\}$ as long as

$$\frac{\partial f_i^*}{\partial k_i} = \frac{(\theta - 1)(q_i + \hat{q}_i)}{3k_i^\theta} > 0$$

$$\frac{\partial f_i^*}{\partial k_j} = -\frac{(\theta - 1)(q_j + \hat{q}_j)}{3k_j^\theta} < 0$$

In post-SEPA with $\rho = 1$, $k_l > k_s$, and $\theta > 1$, I get:

$$\tilde{p}_l^* = k_l^{1-\theta} < \tilde{p}_s^* = k_s^{1-\theta}.$$

The fixed fee of bank i equals:

$$\tilde{f}_i^* = \frac{1}{2\sigma} + \frac{\left(q_i^2 - q_j^2\right)}{3} + \bar{c}$$

with $i \neq j \epsilon \{l, s\}$. The large bank with greater transaction volumes sets its fixed fee above the small bank since

$$\tilde{f}_l^* - \tilde{f}_s^* = \frac{2}{3}\left(q_l^2 - q_s^2\right) > 0$$

As pre-SEPA, the fixed fee of bank i increases with k_i but decreases with k_j as long as

$$\frac{\partial \tilde{f}_i^*}{\partial k_i} = \frac{2(\theta - 1)q_i}{3k_i^\theta} > 0$$

$$\frac{\partial \tilde{f}_i^*}{\partial k_j} = -\frac{2(\theta - 1)q_j}{3k_j^\theta} < 0.$$

▪

Proof of Proposition 3.4. At equilibrium, from equation 3.14, the profit of bank i in pre-SEPA is given by:

$$\Pi_i^* = \alpha_i^*[f_i^* - \bar{c}] \quad \text{with } i \neq j \in \{l, s\}$$

Since $\alpha_i^* = \sigma[f_i^* - \bar{c}]$, I get the other expression for profit of bank i as follows:

$$\Pi_i^* = \frac{1}{\sigma}\alpha_i^{*2} \quad \text{with } i \neq j \in \{l, s\}$$

The difference between profit of the large bank and small bank is equal to:

$$\Pi_l^* - \Pi_s^* = \frac{1}{\sigma}(\alpha_l^{*2} - \alpha_s^{*2})$$

The large bank has more profit than the small bank since it has greater market share.

In post-SEPA, from equation 3.18, the profit of bank i is given by

$$\tilde{\Pi}_i^* = \frac{1}{\sigma}\tilde{\alpha}_i^{*2} - F \text{ with } i \neq j \in \{l, s\}$$

Similar to pre-SEPA, in post-SEPA, the large bank has more profit than the small bank since it has greater market share.

▪

Proof of Corollary 3.1. In order to study the relation between fixed fees of the large bank in the pre- and post-SEPA, I compute:

$$\tilde{f}_l^* - f_l^* = \frac{1}{3}\left(q_l^2 - q_s^2 - \frac{(q_l^2 + \hat{q}_l^2) - (q_s^2 + \hat{q}_s^2)}{2}\right)$$

After simplifying I get:

$$\tilde{f}_l^* - f_l^* = \frac{(q_l^2 - q_s^2) - (\hat{q}_l^2 - \hat{q}_s^2)}{6}$$

The large bank sets higher fixed fee in the post-SEPA than pre-SEPA when $\frac{(\hat{q}_l + \hat{q}_s)}{(q_l + q_s)} < 1$. This ratio always holds since the cross-border transaction is more expensive than the domestic one. Similar analysis for the small bank gives:

$$\tilde{f}_s^* - f_s^* = \frac{(q_s^2 - q_l^2) - (\hat{q}_s^2 - \hat{q}_l^2)}{6}$$

The small bank sets higher fixed fee in the post-SEPA than pre-SEPA when $\frac{\hat{q}_l + \hat{q}_s}{q_l + q_s} > 1$, but this ratio never establishes.

By considering $\alpha_i^* = \sigma[f_i^* - \bar{c}]$, $\tilde{\alpha}_i^* = \sigma[\tilde{f}_i^* - \bar{c}]$, it follows that the large bank has greater market share in post-SEPA than pre-SEPA but the small bank loses market share in post-SEPA than pre-SEPA. For sufficiently small fixed adjustment cost, the large bank makes more profit in post-SEPA than pre-SEPA.

■

Proof of Corollary 3.2.

1- The differences between domestic transaction prices charged by the large bank and the small bank in pre-SEPA is:

$$p_l^* - p_s^* = \frac{1}{k_l^{\theta-1}} - \frac{1}{k_s^{\theta-1}}$$

For sufficiently high economies of scale, I get:

$$\lim_{\theta\to\infty}(p_l^* - p_s^*) = \lim_{\theta\to\infty}(\frac{1}{k_l^{\theta-1}} - \frac{1}{k_s^{\theta-1}}) = 0$$

It shows that the difference between transaction prices deminishes when $\theta \to \infty$. It is also satisfied for cross-border transaction prices as:

$$\hat{p}_l^* - \hat{p}_s^* = p_l^* - p_s^* + z - z$$

$$\lim_{\theta\to\infty}(\hat{p}_l^* - \hat{p}_s^*) = \lim_{\theta\to\infty}(p_l^* - p_s^*) = 0.$$

Since $\tilde{p} = p$, the result of post-SEPA is the same as for pre-SEPA:

$$\lim_{\theta\to\infty}(\tilde{p}_l^* - \tilde{p}_s^*) = 0$$

The differences between fixed fees of the large bank and the small bank in pre-SEPA diminish when $\theta \to \infty$:

$\lim_{\theta\to\infty}\left(f_i^* - f_j^*\right) = \lim_{\theta\to\infty}\frac{1}{3}\left((\omega - p_i)^2 + (\omega - \hat{p}_i)^2 - \left(\left(\omega - p_j\right)^2 + \left(\omega - \hat{p}_j\right)^2\right)\right) = 0$ with $i \neq j \in \{l, s\}$.

Similarly in post-SEPA:

$\lim_{\theta\to\infty}(\tilde{f}_i^* - \tilde{f}_j^*) = \frac{2}{3}\left(q_i^2 - q_j^2\right) = 0$ with $i \neq j \in \{l, s\}$.

The market share of the large bank when $\theta \to \infty$ equals market share of the small bank in pre- and post-SEPA:

$$\alpha_l^* = \alpha_s^* = \frac{1}{2}$$

$$\tilde{\alpha}_l^* = \tilde{\alpha}_s^* = \frac{1}{2}$$

So, they earn the same profit as

$$\Pi_l^* = \Pi_s^* = \frac{1}{4\sigma}$$

$$\widetilde{\Pi}_l^* = \widetilde{\Pi}_s^* = \frac{1}{4\sigma} - F$$

2- The effect of greater economies of scale on consumer surplus is obtained by compting:

$$\lim_{\theta \to \infty} (CS) = \frac{\omega^2 + (\omega - z)^2}{2} - \frac{5}{8\sigma}$$

$$\lim_{\tilde{\theta} \to \infty} \left(\widetilde{CS}\right) = \omega^2 - \frac{5}{8\sigma}$$

For sufficiently large economies of scale, consumer surplus converge to a certain amount.

∎

Chapter 4

Card Payment Market and Retail Prices: An Empirical Analysis of The Effects of The Interchange Fee on Price Levels in Spain

4.1. Introduction.

In the euro area, 55% of the total amount of non-cash payments[39] belonged to card payments in 2017. On the global level, this share was 69% (Capgemini, 2019). The widespread use of card payment has drawn the attention of antitrust authorities to investigate the behaviuor of card payment networks (as for example Visa and MasterCard). Their main concern was the level of the interchange fee (henceforth IF). This fee is generally set by card networks and is an important component of the cost of accepting cards by merchants. Antitrust authorities have argued that the level of the IF has gone against competition principles. They have claimed that card networks set arbitrarily high IF that harms cardholders and merchants. In this regard, they have intervened in the card payment market by capping the IF. For example, the antitrust cases in Australia, the United States, the European Union, and also regulatory changes in countries like Spain, have limited the power of card networks to set arbitrarily high IF.

The present chapter aims to address a specific policy question regarding how changing in the IF affects retail prices. In this respect, I consider the two sides of the card payment network and investigate the effect of IF changes from the merchant side and the cardholder side. On the merchant side, I study the extent to which IF changes affect the cost of accepting cards. Then, I analyse the effect of the change in this cost on retail prices. On the cardholder side, I study the extent to which IF changes affect card payment usage, and then, I analyse the relationship between card payment usage and retail prices. In the last step, I compute the total effect of IF changes on retail prices by aggregating the effects of two sides from the two former steps.

The econometric method used in this chapter is the dynamic heterogeneous panel data technique proposed by Pesaran, Shin, and Smith (1999), which is based on the autoregressive distributed lag (ARDL) model. This technique allows me to study the short- and long-run effects of IF changes on retail prices. The importance of studying the short- and long-run relationships is due to the price stickiness in the short-run. An extensive literature argues that it is plausible that merchants do not rapidly adjust their prices in response to a change in their cost in the short-run.

---

[39] Non-cash payments include card payment, credit transfer, direct debit, and check.

I consider the Spanish card payment market as a case study. The data is obtained from two main sources: the Bank of Spain and the National Statistics Institute of Spain and mainly consists of the card payment market information aggregated at quarterly level and the consumer price index (CPI) at sector level. This is complemented with other data such as the total household expenditure among different merchant sectors from 2008:1 to 2019:4.

The main results are as follows. In the long-run, results of the merchant side indicate that a decrease in the IF leads to a reduction in the cost of accepting card as had been predicted by the antitrust authorities. I find strong evidence suggesting that merchants pass a reduction in the cost of accepting cards to cardholders by decreasing retail prices. On the cardholder's side, I find that the IF reduction results in a decrease in card payment usage, which leads to a reduction in retail prices. Therefore, the total effect is a reduction in retail prices in the long-run which I am able to quantify. This result is in line with what had been expected by regulatory authorities. In the short-run, a decline in the IF has a significant effect on retail prices neither on the merchant side nor on the cardholder side.

The remainder of the chapter is organised as follows. In section 4.2, I provide the general view of the card payment market from two perspectives: closed payment card network and open payment card network. In section 4.3, I provide an overview of the two-sided market. In particular, it is discussed how the open payment card network is consistent with this market. I also provide some explanations of why IF exists and why it has a fundamental role in determining the fee structure in the card payment market. In section 4.4, I review the antitrust policy regarding the IF level. Then, I present the main regulations regarding the IF in Europe and especially in Spain. Both policies have had the ultimate aim of avoiding high retail prices for customers as a result of high IF levels. Section 4.5 reviews the main empirical studies related to the effects of capping the IF. Description of data and definition of variables are outlined in section 4.6. The empirical strategy and the ARDL model are explained in section 4.7. Section 4.8 discusses the results of the IF changes on retail prices from the cardholder side and the merchant side. Finally, section 4.9 offers some concluding remarks. The appendix reports the Schwarz Bayesian Criterion test.

4.2. Card Payment Networks.

The focus of this section is to define the two card network types, namely closed payment card network and open payment card network. In this regard, it is first necessary to describe the key players in a card network and their roles in an economic transaction whose payment is carried out by means of card (or 'card transaction') as follows.

The cardholder is a customer who uses a card to make a purchase at a merchant or withdraw money from an automated teller machine (ATM). The cardholder is often an individual, but it can also be a business.

The merchant is a business that accepts a card payment at the checkout counter or allows the cardholder to pay with a card via the Internet. The merchant can be a store, a supermarket, a pharmacy, or any business that sells what a cardholder buys. It is equipped with payment processing terminals such as Point-Of-Sale (henceforth POS) or software (in the case of online shopping) by its bank. All merchants have a unique identification number to identify them when communicating with payment processors.

Acquirers are banks that provide transaction processing to merchants. They hold merchant accounts and provide devices (such as POS terminal or software) to the merchants. Thus, merchants are enabled to accept card payment and acquire the payment amount. Acquirers compete with each other to attract more merchants.

Issuers are banks that issue cards to cardholders on behalf of a card network. They act as a go-between for the cardholder and the card network by holding the cardholder accounts and checking whether he has sufficient funds in order to execute a payment. Issuers compete with each other to attract more cardholders.

Card networks supply the electronic networks and connect all the players described above in order to execute payments. In general, the card networks are in charge of transferring information between an issuer and an acquirer, verifying card details, and monitoring the settlement of transactions. They also brand the cards, which provide them with recognition. The specific brand denotes that the card payment transaction is executed under that card network. Both issuer and acquirer need to be members of the card network.

Generally, the process of a card transaction is as follows. First, the cardholder provides his card information to a merchant, whether by swiping the card or dipping it on the merchant's POS terminal, or inserting the card information to the merchant's website through online payment solutions in the case of online shopping. Then, the merchant's payment processing terminal sends the card number, transaction amount, and merchant ID number to the acquirer. The acquirer passes the authorization request to the card network, which forwards it to the issuer. The issuer checks whether the cardholder has sufficient funds or credit in his account. If adequate amounts are presented and the transaction is not fraudulent, the issuer sends an authorization code to the network which is then sent to the acquirer. The acquirer informs the merchant and the merchant provides the goods or services to the cardholder.

4.2.1. Closed Payment Card Network[40].

The closed payment card network comprises the three parties as shown in figure 4.1. The main feature to note with this system is that the issuer and the acquirer are the network itself. A card payment transaction is executed within the network from a cardholder account to a merchant account. As a matter of fact, the network authorizes and handles all aspects of payment (Tirole (2011), Borestam and Schmiedel (2011)). In the closed payment card network, Economides (2009) considers two sequential markets per card transaction as follows:

Market 1 is formed between a cardholder and the card network, where the card network supplies a card as the payment instrument. The card network incurs a cost of c_B for providing services per cardholder. The cardholder pays a membership fee to the card network (f) that is typically a fixed monthly or annual fee, whereas the card network offers some benefits to the cardholder (henceforth b_B) such as cash-back, travel insurance, and loyalty rewards to encourage them to substitute card payment for cash.

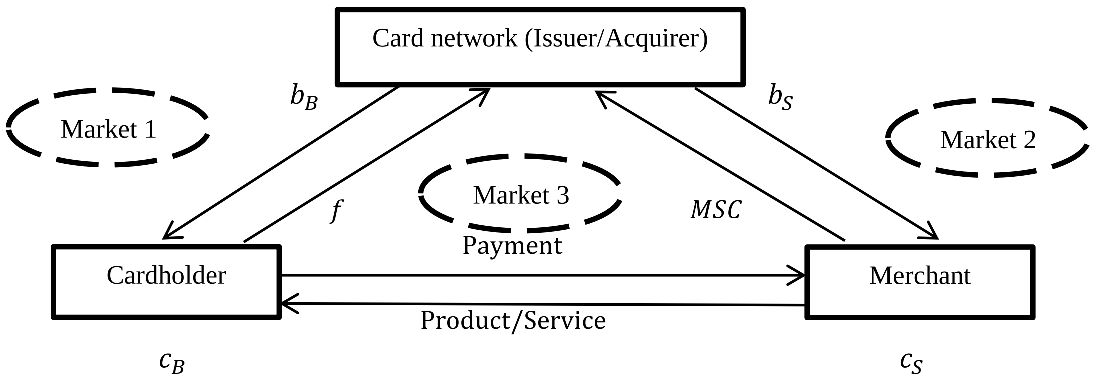
[40] The closed payment card network is also known as the three-party card network in part of the literature such as Rochet and Tirole (2002), Economides (2009), and Borestam and Schmiedel (2011).

Market 2 is formed between a merchant and the card network, where the card network supplies the merchant with payment services such as clearing electronic payments and settlement guarantees for POS[41]. The card network incurs a cost of c_S for providing those services per transaction. The merchant obtains some conveniences and transaction benefits from accepting a card payment (henceforth b_S) such as security, protection against fraud and theft, guarantees that the payment will be received quickly. The merchant must pay a fee to the card network for receiving payment services which is a percentage of the amount of each card transaction and is known as a merchant service charge (henceforth MSC)[42]. The MSC is set as a result of a negotiation between the card network and the merchant, so that its level can depend on the volume and value of the merchant's POS transactions.

In order to have a more comprehensive view, I also define the goods and services market as Market 3 where the transaction between cardholder and merchant takes place, i.e. the merchant supplies its products or services and the cardholder purchases them at POS or via the Internet.

Note that there is no fee between the issuer and the acquirer since they are the same entity in the closed payment card network.

Figure 4.1. Closed payment card network.



4.2.2.Open Payment Card Network[43].

If the role of the issuer and/or acquirer is played by an entity different than the card network, such as a bank, then the card network is an open payment one (such as Visa and MasterCard networks) (Rochet and Tirole (2002), Gans and King (2003), Borestam and Schmiedel (2011)). The openness is in the sense that any bank can join the card network and act as an issuer and/or an acquirer. The parties of such a network are shown in figure 4.2. The open card network provides payment services for a cardholder and a merchant through the intermediation of an issuer and an acquirer.

[41] Settlement guarantees for POS are related to the credit card payment. After a credit card payment is made, the issuer sends an authorization code to the merchant that may be stored in a data file on the POS terminal referred to as a 'batch'. At the end of the day, the merchant will send all the codes to the card network for sorting and forwarding to issuers. At settlement, the issuer releases the fund to the card network and the card network deposits the transaction amount in the merchant's bank account. The mechanism of the credit card payment is described at the end of this section.

[42] In Europe, this cost is known as the merchant service charge, while in America it is known as the discount fee.

[43] The open payment card network is also known as a four-party card network in the literature; see references in footnote 39.

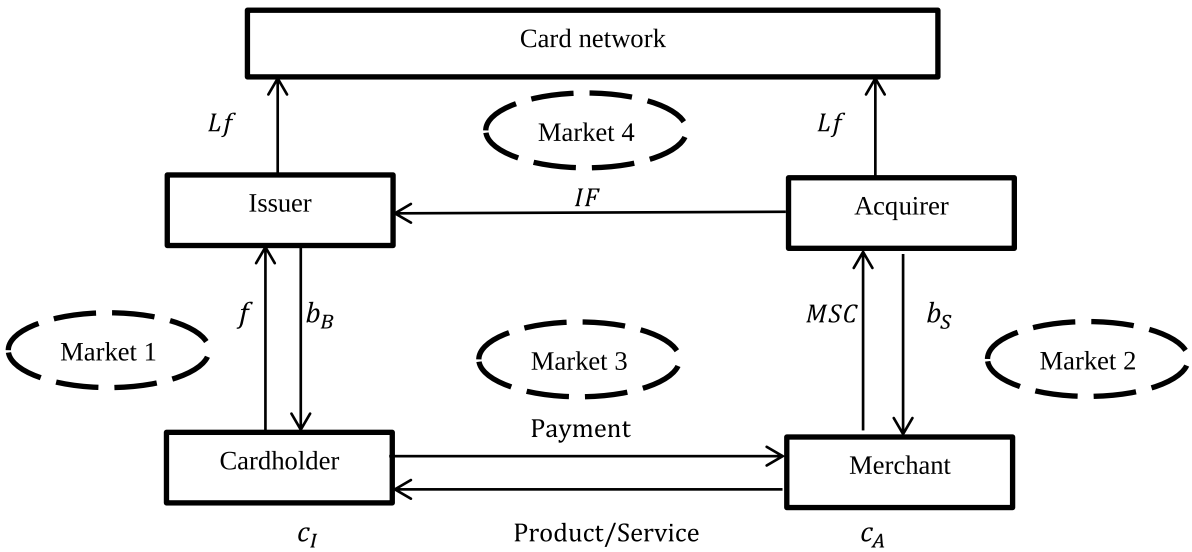
Similarly to the closed card network case, three markets are generated by any card transaction: Markets 1, 2 and, 3 with the issuer and/or the acquirer replacing the card network. Moreover, Economides (2009) defines a market between an issuer and an acquirer in the open card network (Market 4) which does not exist in the closed card one.

Market 4 is formed between an acquirer and an issuer as they deal through an open payment card network. The existence of this market is the main difference between the open and the closed card networks. In this market, the issuer transfers to the acquirer the amount of the purchase or transaction between the cardholder and the merchant which was carried out by means of a card. Besides, the issuer receives the IF from the acquirer per card transaction. Generally, the IF is a percentage of each card transaction amount but it could be a flat-rate per transaction. For example, in 2007, the maximum IF level for Visa debit card in Europe was €0.28 per payment.

The IF is the main and critical feature of the open payment card network. This fee may be reached by bilateral agreement between issuers and acquirers. In the absence of general agreements between parties, it is set by the open payment card network.

The amount of the IF tends to be highly variable depending on a combination of several factors such as the card's type and the merchant's sector[44]. It is worth emphasizing that in the open payment card network, the payment is guaranteed by the issuer against fraud and cardholder default. Therefore, the IF exists to compensate for the risk and cost associated with the card payment that the issuer entails. In other words, the IF covers some costs on the issuing side with the acquiring side. Generally, the IF is passed through to the merchants by the acquirer and comprises a large fraction of the MSC. The MSC follows the structure of the IF in terms of the card's type and merchant's sector. Issuers often use a portion of IF revenue to offer rewards to cardholders. These rewards are generally increased by card usage.

Figure 4.2. Open payment card network.



[44] The IF varies across merchant sectors. For instance, in 2018 in Spain, the interchange fee at gas-stations for debit cards was 0.146%, while the interchange fee at a restaurant for debit card was 0.126% (Bank of Spain, 2018).

Another feature of the open payment card network that distinguishes it from the closed card network is the presence of a licence fee (henceforth Lf). The Lf is a fee that the open card network charges the acquirer and the issuer banks in order to allow the transactions through its system. The Lf is generally set based on the number of cards issued or/and the number of transactions made.

Finally, it should be mentioned that when the issuer is the same as the acquirer, i.e. the same bank serves the cardholder and the merchant, the model simplifies as the IF does not exist.

The process of transfer of the funds to the merchant's account depends on whether the card being used is a debit or credit one. Next, I discuss this distinction.

In the debit card case.

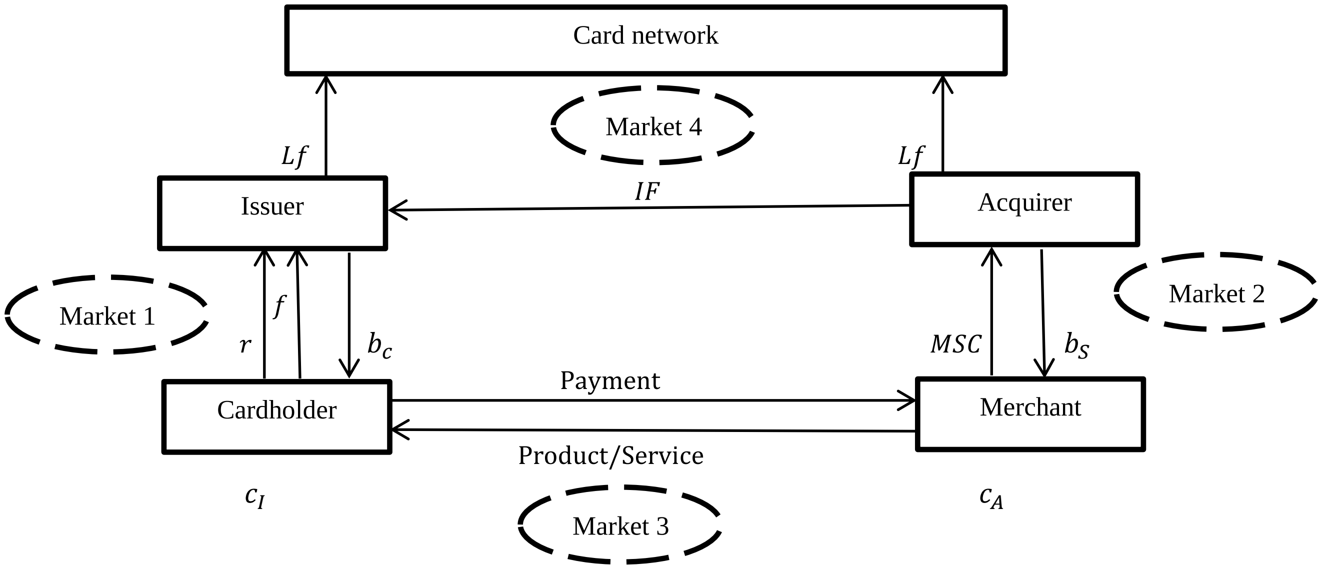
When a debit card is used, the purchased amount is debited from the cardholder's account in the issuer. The issuer then subtracts the IF from the total amount of the transaction and transfers the net amount through the network to the acquirer. Then, the acquirer deducts the MSC from the transaction amount and transfers the rest to the merchant's account.

In the credit card case.

In the case of a credit card, the issuer pays for the transaction on behalf of the cardholder; the amount is debited from the issuer and is transferred to the merchant's account after deducting the IF and the MSC. In such case, the issuer grants a line of credit within the determined credit limits allocated to the cardholder in order to pay the merchant for the purchased goods or services. For each credit transaction, the available credit goes down by the amount of the purchase. The issuer gives a certain amount of time to the cardholder to repay the borrowed funds. As the cardholder pays back his debt to the issuer, the credit line is available again. In general, the cardholder pays to the issuer once every month for all the purchases made in the previous month. Since the credit card transaction has a higher risk than the debit one, the issuer has to assume a borrowing cost when it provides credit to its depositors as well as for the loans that it may have taken from other financial institutions which is called *credit funding cost.* This cost makes a credit card more expensive than a debit card for the issuer. Therefore, the issuer receives a larger IF for the credit card transaction than for the debit one. For example, in 2018 in Spain, the interchange fee at gas-stations was 0.146% for debit cards and 0.287% for credit ones (Bank of Spain, 2018). Figure 4.3 shows the structure of a credit payment in an open payment card network. The difference between the fee structure in the credit card and the debit one is the interest rate (r) that a credit cardholder pays for borrowing money from the issuer. It affects the cost of using a credit card for cardholders. If the credit cardholder pays for his purchases when billed, he may receive some benefits (b_c) such as exemption from paying the interest. But if the cardholder prefers to pay in instalments, he has to pay a fee based on the interest rate (r).

It is noteworthy that the closed payment card network is one special case of the credit card in an open payment card network. The credit cards issued by Amex, Diner's Club, and Discover are the most common examples of credit card networks. The network issues a credit card, then grants and extends lines of credit to the cardholder and processes the transaction. Since the focus of this chapter is on the IF, from now on I only consider the open payment card network.

Figure 4.3. Credit payment in an open card network



4.3.Card Payment as a Two-Sided Market.

4.3.1.General View.

Many different authors have used the concept of the two-sided market to study the card payment networks[45]. Before explaining their details, I provide an overview of the two-sided market theory and then I explain how the card payment network is consistent with this theory. For this purpose, I refer to the work of Rochet and Tirole in (2002, 2003, 2006) since it is one of the main reference of the two-sided market model.

A two-sided market has some characteristics that differentiate it from the one-sided market that has dominated neoclassical economic theory since Alfred Marshall. In such a market, there are two distinct parties (or two distinct sides) that interact or transact through a common platform (or a common network). A platform is a third-party that allows or facilitates interaction (or transaction) between two parties. To clarify this point, consider some examples. A newspaper or magazine is a platform that provides interaction between readers and advertisers. The interaction occurs when readers read the adverts. A search engine such as Google allows interaction between users and advertisers and it occurs when advertisers capture the users' eyeballs (for example, users click on adverts). A caller and a receiver interact via a telecom-network. The interaction between them occurs through a phone conversation. In a nightclub, men and women interact when they meet (or talk to) each other at the club. A shopping mall facilitates interaction between customers and merchants. In order to have a precise definition of a two-sided market, I cite the definition of Rochet and Tirole (2003), who define the two-sided market as follows.

[45] See Rochet and Tirole (2002, 2003, 2006), Wright (2004), Armstrong (2006), Chang et al. (2005), Economides (2009), Bedre-Defolie and Calvano (2013), Evans et al. (2015), Carbo-Valverde et al. (2016), Manuszak and Wozniak (2017), among others.

A market with network externality is two-sided when ‘it is characterised by the presence of two distinct sides whose ultimate benefit stems from interacting through a common platform’[46].

A network externality means that the utility and participation of one party depends on the participation of the other party on the platform. The externality may be positive or negative. For instance, in the case of a search engine or a newspaper, advertisers are affected positively by the number of users or readers while users or readers are affected negatively by the activity of the other party (given that publicity is usually considered a nuisance). In further work, Rochet and Tirole (2006) explain that the externality can comprise two parts, namely ‘usage externality’ and ‘membership externality’. The existence of these two externalities depends on two types of decisions that would be made by members of each party: ‘usage decision’ and ‘membership decision’. According to these two decisions, Rochet and Tirole (2006) define usage and membership externalities as follows[47].

‘Usage externality’ arises where one party benefits from interacting over the platform. Then, the other party exerts usage externality by interacting with the former party. For instance, if a caller benefits from being able to make a phone call with a friend, then his friend exerts usage externality on the caller by receiving the call.

‘Membership externality’ arises when members of one party derive positive (or negative) benefits from the possibility of interacting with one additional member of the other party. For instance, a caller gets a positive membership externality from one additional friend who appears on the same telecom-network.

Building on the definition of usage and membership externalities, Rochet and Tirole (2006) characterise the two-sided market from two different angles. Before embarking on these definitions, a discussion is needed on the two types of fees that appear in two-sided markets: membership fee (f), and usage fee (a)[48].

The membership fee is a fee that the member of each party pays to the platform in order to become a member of the platform. The usage fee is a fee paid by the members of each party to the platform in order to transact or interact with the members of the other party. The usage fee is paid per transaction so that it affects the willingness of parties to transact with each other. Rochet and Tirole (2006) refer to the two distinct parties as to the buyer (B) and the seller (S) who interact, or transact, through a platform. Then, based on the usage externality, they define the two-sided market in the following way[49]:

[46] Rochet and Tirole quotations (2003, page 990).

[47] The usage externality is also known as direct externality and the membership externality as indirect externality in the literature.

[48] The usage fee is sometimes referred to as transaction or interaction fee between parties.

[49] Based on my terminology, price in this definition refers to the fee.

'Consider a platform charging per-interaction charges a^B and a^S to the buyer and the seller sides. The market for interactions between the two sides is one-sided if the volume V of transaction realized on the platform depends only on the aggregate price level

$$a = a^B + a^S$$

i.e. it is insensitive to reallocations of this total price a between the buyer and the seller. If by contrast V varies with a^B while a is kept constant, the market is said to be two-sided'[50].

The above definition shows that a market characterises as one-sided if the fee structure does not have any effect on the volume of transactions. In other words, the fee structure is neutral in the one-sided market. This is the case, for instance, for the electricity market that was presented by Rochet and Tirole (2006). Suppose there is an electricity market that is governed by bilateral agreements between generators and customers. On the one hand, generators pay a usage fee to inject their power into the transmission system. On the other hand, customers pay a usage fee to remove electricity from the system. If any fee paid by the generators is completely passed through to the customers, then the fee structure does not matter and only the aggregate fee paid to the transmission system is important. Therefore, the market should be treated as the one-sided market. In contrast, the market is characterised as two-sided if, for a given total fee, reallocation of fees between the two parties that keeps the sum constant affects the volume of transactions on the platform. According to this definition, the volume of transactions is sensitive to the fee structure.

From another angle, Rochet and Tirole (2006) define the two-sided market as a market with

'The existence of cross-group externalities: the net utility on side i increases with the number of members N^j on side j'[51].

The property of 'cross-group externality' seems to refer to the 'membership externality'. For instance, consider a shopping mall. On the one hand, customers are interested in visiting malls with more merchants, and on the other hand, merchants tend to pay more for a place located in a mall with more customers. It means that the benefit of customers (or merchants) to be present at a mall depends on the number of merchants (or customers).

One critical issue is that the 'size of cross-group externality' may differ between two parties. One party may get a large (positive) externality through interaction with the opposite party on a platform, while the other party may get a low (even negative) externality from interacting with the former party (Armstrong, 2006). Take a few examples. An advertiser exerts a low (even negative) externality on each reader or user of a newspaper or a search engine, while the reader or the user exerts a positive externality on each advertiser. In the shopping mall, merchants exert a positive externality on each customer and vice versa, but the size of this externality may differ between customers and merchants.

The 'cross-group externality' creates a 'chicken and egg' problem. This means that to attract one party, a platform should have large members of the opposite party, but the latter party will be interested to join only if they expect many members of the former party to appear (Caillaud and Jullien, 2003). Thus, the platform should set fees in such a way as to attract both parties. The platform may give subsidies to one party and recover the loss by over-charging the other one (Caillaud and Jullien, 2003). For instance, the search engine charges no usage fee to users in order to attract them to the platform. Or a shopping mall can offer free parking to customers in order for them to visit the mall and therefore, attract more merchants. Accordingly, the benefit that each party derives from being on

[50] Rochet and Tirole quotations (2006, page 648).

[51] Rochet and Tirole quotations (2006, page 657).

the platform depends on how well the platform performs attracting members of the other party. Therefore, summarizing the above definitions, the two-sided market can be defined from three perspectives:

1. Based on the network externality without differentiation between usage and membership externalities (definition of Rochet and Tirole (2003)).
2- Based on the transaction volume and fee structure (definition of Rochet and Tirole (2006)).
3- Based on the 'cross-group externality' (definition of Rochet and Tirole (2006)).

4.3.2. Open Payment Card Network as a Two-Sided Market.

The open payment card network is an example of a two-sided market. The two distinct parties are the cardholder and the merchant that transact through the card network to which their banks belong: the issuer and the acquirer. It is worth recalling that the cardholder and the merchant do not transact with the open payment card network directly, but instead, it is their banks who deal with the card network. Figure 4.3 in section (4.2) shows this mechanism in detail.

A card transaction occurs when the cardholder uses his card to pay to the merchant. The cardholder and the merchant benefit from the transaction on the card network. The cardholder benefits from the convenience and lower risk of not having to withdraw and carry cash and may also receive some rewards for paying by card. The merchant benefits from the lower transactional cost compared to that of accepting cash and obtains security and theft protection. It is noteworthy that the customer tends to join a card network if many merchants accept it and the merchant is willing to join the card network if many cardholders use the network's card. In other words, the participation of the cardholder depends on the participation of the merchant on the network and vice versa. Based on the definition of Rochet and Tirole (2003), such a market is characterised as a two-sided market.

Different authors (see, for example, Rochet and Tirole (2002), Wright (2004), Bedre-Defolie and Calvano (2013), Borestam and Schmiedel (2011) among others) have shown that the allocation of fees on the open payment card network is in favour of the cardholder and against the merchant. As previously explained, the merchant pays the MSC, while the cardholder pays the membership fee and may receive a reward. The reward may be large enough to result in a zero or even negative membership fee. This incentivises the cardholder to use the card payment instead of other payment forms such as cash or check. Thus, by accepting the card a merchant exerts a usage externality on the cardholder. This mechanism affects the volume of transactions and leads to an increase in card usage. Based on Rochet and Tirole (2006)'s second definition, such a market is characterised as the two-sided market.

The value of card holding to the cardholder depends on the number of merchants who accept the card, and the merchant values the card acceptance according to the extent that cardholders use it. To attract cardholders, the card network should have merchants, but merchants will be willing to join the card network if many cardholders also do. This is the 'chicken and egg problem' in the card payment market. The card networks solve it by offering rewards to cardholders through issuers. The cardholder has more incentives to use a card rather than the other forms of payment when the benefit from the card usage is greater than the membership fee. By offering rewards to cardholders, issuers affect the participation of cardholders on the market. Therefore, the card network becomes more attractive for the merchant and results in getting both sides on board. This shows that there is 'cross-group externality' in the open payment card network that is consistent with the third definition of the two-sided market by Rochet and Tirole (2006).

4.3.3. Fee Structure in Open Payment Card Network.

As mentioned in section (4.3.1), a platform may charge a membership fee (f) and a usage fee (a) to its members. Unlike the other platforms, the open card payment network does not directly set these two fees to their final users. Instead, as shown in section (4.2), the issuer sets a membership fee to the cardholder (f), the acquirer sets a usage fee to the merchant (MSC), and the card network sets the licence fee (Lf) to the issuer and the acquirer. A number of works (see, e.g. Rochet and Tirole (2002, 2006) Rysman (2009), Evans et al. (2015), Adachi and Tremblay (2020)) explain that in the open payment card network, the fees (or rewards) that the cardholders and the merchants pay to (or receive from) their banks depend on the IF, which is paid by the acquirer to the issuer per card transaction. I follow the simple model of Rochet and Tirole (2002) to explain this relationship. Assume that there is a single payment card network in which acquirers compete with each other while issuers have a certain degree of market power. The card network sets the same IF to all acquirers. After the IF has been set, the issuer sets a membership fee (f) to its cardholders as follows.

$$f = F(c_I - \text{IF}) \tag{4.1}$$

where f is defined as a function of issuer's cost (c_I) and the IF for one card transaction. Rochet and Tirole (2002) therefore assume that the membership fee decreases with the IF. The inverse relationship between the membership fee and the IF indicates that the higher IF lowers the membership fee. If the benefit from using the card (b_B) is greater than the membership fee, then the cardholder has more incentives to use it rather than other forms of payments. Rochet and Tirole (2002) define the demand for cards as follows.

$$D(f(c_I - \text{IF})) = 1 - H(f(c_I - \text{IF})) \tag{4.2}$$

where $H(f)$ is the cumulative distribution function that captures the fraction of customers with $b_B < f$ that do not have incentive to hold and use the card: card demand is a decreasing function of the membership fee.

On the other side of the market, the acquirer sets the MSC in a way that it covers its cost (c_A) and the IF.

$$\text{MSC} = c_A + \text{IF} \tag{4.3}$$

The IF adds to the acquirer's cost of providing payment card services to merchants. The acquirer generally passes the IF to the merchant and it comprises the main fraction of the MSC[52]. Rochet and Tirole (2002) assume that acquirers are competitive and fully pass the IF to merchants. Economic theory specifies that the full pass-through is only possible if there is perfect competition with constant returns to scale. If these conditions are not met, then pass-through relies on the market structure, extent of product differentiation, and competitive interactions between firms as well as curvature of demand. In such case, it is expected that the pass-through rate will be less than 100% (Weyl and Fabinger (2013), Williams et al. (2014)).

[52] For instance, in the United States, the IF comprises 75% of the MSC (Hayashi, 2006).

The asymmetric fee allocation between the cardholder and the merchant depends on the elasticity of their demands for card payments. Borestam and Schmiedel (2011) argue that the merchant's demand for accepting cards is less elastic than the cardholder's demand for using cards. This implies that the merchant's willingness to accept cards is affected relatively little by changing the MSC but the cardholder's decision to use or hold the card is affected aggressively by changing the membership fee and/or the reward. Their explanation is based on the evidence that card payment has become a necessity payment instrument in many businesses such as restaurants, hotels, gas stations, online selling, and so on. Also, widespread acceptance of cards within the merchant sectors, as well as the cardholder's expectations with respect to using his card rather than cash or check, lead to merchants having a more rigid demand for card payments. The other reason for asymmetric fee allocation may relate to the participation of parties in several card networks. In practice, merchants have to a great extent join several platforms (in other words, they are multi-homing) since they accept cards of various networks. Consequently, cardholders may have less incentive to hold several cards of the same type. Armstrong (2006) explains that this feature leads to a card network having monopoly power over providing access to its cardholders for merchants. It means that if a cardholder joins one card network, then the merchant can access the cardholder only by joining the same network. This feature causes the merchant to pay a larger share of the fee level than the cardholder. In the following, I explain why merchants accept card payments although it is costly for them.

Merchant acceptance.

Rochet and Tirole (2002) and later Wright (2004) and Bedre-Defoli and Calvano (2013) explain that the competitive merchants have a strategic reason to accept the card, which is to steal rival's customers and to retain their current customers. So, if they do not accept the card, they will lose part of their sales. Monopoly merchants also have the incentive to accept card payment since it shifts customer's demand upward and consequently accrues additional revenue.

One of the purposes of this chapter is to test the degree of the 'Merchant internalisation, which is the concept to which Rochet and Tirole (2002) attribute card acceptance. As the cardholder benefits from paying by the card, the merchant by accepting the card exerts usage externality on the cardholder. By increasing card acceptance, merchants offer additional surplus to cardholders and can extract part of the consumer's surplus by setting higher retail prices. Given 'Merchant internalisation', merchants are also less resistant to the level of the MSC, as they can pass it through to retail prices. Chang, Evans, and Garcia Swartz (2005) and later Evans and Mateus (2011) among others study the extent to which merchants pass the MSC into retail prices.

The MSC as a variable cost of accepting card payment has an impact on retail prices charged by merchants to cardholders. Rochet and Tirole (2002) analyse the impact of the IF on retail prices of goods and services. They assume that there are two merchants that sell the same products and accept card payment. They normalise the number of card transactions to 1 and use the Hotelling model where customers are uniformly distributed on the segment [0, 1] and the two merchants are located at either extreme. Each merchant maximises its profits in terms of retail prices as follows:

$$\max_{p_i}\{[p_i - \left(\tau + D\big(f(c_I - \text{IF})\big).MSC(IF)\right)]x_i\} \tag{4.4}$$

where the term $(\tau + D\big(f(c_I - \text{IF})\big).MSC(IF))$ is the merchant's marginal cost in which τ captures the transaction cost associated with other form of payments, D is the card demand that is given by equation 4.2, and the MSC is the merchant service charge that is given by equation 4.3. The term x_i is the market share of merchant i with $i \in \{1, 2\}$. Given retail prices of both merchants (p_i, p_j) with

$i \neq j \in \{1, 2\}$, merchant i's market share is given by $x_i = \frac{1}{2} + \frac{p_j - p_i}{2\sigma}$ where σ reflects the level of transportation costs. Solving equation (4) yields

$$P = [\tau + D(f(c_I - \text{IF})).MSC(IF)] + \sigma \tag{4.5}$$

Equation 4.5 indicates that the IF affects retail prices through two sides: from the cardholder side by affecting card demand and from the merchant side by affecting the MSC. The main analysis of the present chapter relies on equation 4.5 since this is a way to test if 'Merchant internalisation' has an effect on prices.

The model of Rochet and Tirole (2002) is built based on an important assumption that merchants do not make price discrimination against customers who pay by a card or cash. This assumption is in line with the 'no- surcharge' rule that is imposed by open payment card networks. This rule does not allow merchants to charge an extra fee on a cardholder rather than on customers who pay with cash or check. Thus, there is only one retail price in terms of payment method and the choice of payment instrument does not impact on the retail prices. The no-surcharge rule leads to 'Merchant internalisation' in the form of higher prices for all customers. Moreover, this rule promotes card payment that is more efficient than cash payment, but it allows the open card network to set the high IF that ultimately passes to all customers. Under this rule, customers who pay with cash grant subsidy to cardholders since both cardholders and cash customers are charged the same price but cardholders receive rewards from the issuer (Carlton and Frankel (1995)). In contrast, if merchants are allowed to charge an extra fee on the cardholder rather than on a customer who pays with cash or to offer some discounts for cash payments (known as the surcharge), then there are different retail prices for cash and card payments. In this case, the merchant is enabled to steer customers towards the payment method that is cheaper by using price signals, but that method may be inefficient as cardholders may switch to paying by cash, leadings to a decrease in card usage and, in turn, to a decrease in merchant's card acceptance. In this case, the IF has a neutral effect on the market and open card networks cannot operate at their optimal level (Gans and King (2003)). Since the main aim of this chapter is to test 'merchant internalisation', I make my analysis under the 'no-surcharge' rule assumption.

Now I move to explain the two additional roles of the IF: internalisation of externality and balancing card usage and card acceptance.

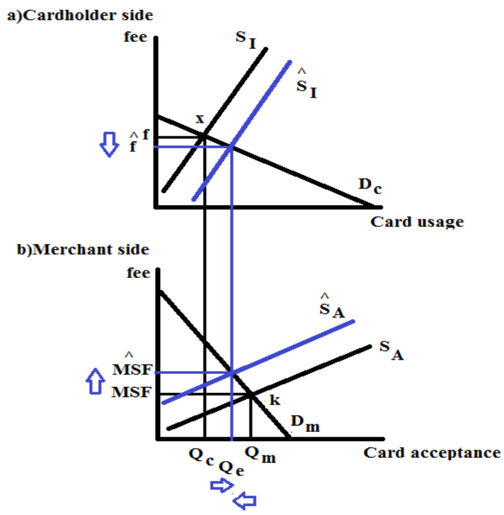
Internalisation of externality.

One important role of the IF is to internalise the membership externality that exists in card payment markets. To clarify this feature, I start from the closed card payment network. As explained in section (2), the closed card network sets the membership fee and the MSC without using the IF. Suppose that the closed card network splits into two separate departments, issuing and acquiring, and there is no fee between them. In such case, issuers and acquirers set their own fees in order to maximise their own profit irrespective of the existence of the membership externality. Therefore, the issuer sets a high membership fee to cardholders and/or eliminates rewards, and the acquirer sets a high MSC. Consequently, card usage by cardholders and card acceptance by merchants are reduced. In fact, the issuer does not consider that one additional card acceptance by the merchant accrues additional revenue for it. Likewise, the acquirer does not evaluate that one additional cardholder leads to additional revenue by increasing the number of card transactions. In other words, they do not consider that their fee-setting affects the profitability of the other side of the market. The membership externality can be internalised through the IF. The existence of the IF leads to the issuer setting a lower membership fee or the higher rewards that encourage card usage. Through the membership externality, card acceptance is more valuable for merchants, resulting in more card acceptance. Overall, when the membership externality is internalised by the effect of the IF, card payment volumes increase and that leads to both the issuer and the acquirer making more profits (Rysman and Wright (2014)).

Balancing card usage and card acceptance.

The other main role of the IF is to balance the card usage against the card acceptance. It is important to highlight that the open card payment network has a specific feature that requires equal participation of the two sides: a cardholder must match with a merchant in order to make a card payment. Figure 4.4 shows how the IF balances the participation of both sides of the market. First, consider figure 4.4-a that illustrates the market between the cardholder and the issuer (Market 1 in section (2)). The horizontal axis shows the number of cards and the vertical axis shows the membership fee. The curve S_I shows the supply of cards by the issuer and the curve D_c shows the demand for cards by customers. Equilibrium is reached at point x, with Q_c showing the number of issued cards and reflects the cardholder's participation in the market. As the IF increases from its zero level, the curve S_I shifts rightwards since the issuer has more incentives to issue more cards. Figure 4.4-b shows the market between the merchant and the acquirer (Market 2 in section (2)). The horizontal axis shows the number of cards accepted and the vertical axis shows the MSC. The curve S_A shows the supply of payment services offered by the acquirer to the merchant and the curve D_m shows the demand for card acceptance by merchants. The equilibrium is reached at point k, with Q_m showing the card acceptance in the merchant's side, which reflects the merchant participation in the market. As the IF increases above zero, curve S_A shifts leftwards, and providing payment services become more expensive. Now, consider figure 4.4 as a whole that presents the two-sided card payment market. It is observed that the card usage is less than the card acceptance ($Q_c < Q_m$). So, there is no one-to-one relationship between card usage and card acceptance. Thus, a new equilibrium is required. The positive IF causes supply curves to move in a way that both sides reach equal participation at Q_e. If the IF equals zero, then the number of transactions is constrained by the cardholders' participation, as it shows lower card usage. There is plenty of literature (see, e.g. Schmalensee and Evans (2007), Klein et al. (2006), among others) on the economics of card payment that argues that the IF is set at the level that maximises the total volume of card transactions.

Figure 4.4. Mechanism of allocation of fees between two sides in an open payment card market.



Source: Europe Economics (2016).

4.4. Antitrust Policy on Open Payment Card Networks.

The payment card network originally is the result of an association of banks, which can take different forms, including a Joint Venture among banks as when they are not able to provide payment services on their own and therefore they delegate them to a new card network built jointly by them. The association of banks creates specific payment card services that its members cannot produce it singly (Carlton and Frankel (1995), Evans and Schmalensee (1995)). Payment card networks have set some rules, such as the IF, in order to control the relationship between their members. Rochet and Tirole (2002) and Sykes (2014) among others argue that setting of the IF as the outcome of an agreement among banks is beneficial as it economises the high transaction costs of individual negotiations between multiple issuers and acquirers. It reduces the per card transaction cost of all bilateral negotiations between banks. On the contrary, Prager et al. (2009) argue that the setting of a common IF for all banks could be interpreted as collective price determination by the member banks. Therefore, it is possible that this approach could be considered as illegal collusion under antitrust principles.

Antitrust authorities on a routine basis assess anticompetitive aspects of the IF. They argue that card networks set an arbitrarily high IF compared to any costs incurred by issuers or acquirers. The high IF limits the acquirer's power to set the lower MSC when negotiating with merchants. In fact, the IF determines a floor under the MSC and restricts competition between acquirers; therefore it is unlikely that an acquirer would be willing to reduce the level of its MSC below the IF. The restriction on competition between acquirers results in inflating the cost of accepting cards. Despite the high MSC, merchants are compelled to accept card payment since refusing the card may result in losing part of their customers. In turn, merchants pass the MSC to cardholders by inflating their retail prices. In such case, cardholders pay twice for the card usage: once through the membership fee and the second time through higher retail prices. On the other hand, higher retail prices may lead to lower sales that harm merchants. So, the high IF results in limited competition between acquirers, which ultimately harms cardholders and merchants. Competition in the card payment market takes place at two interrelated levels: upstream competition, as different card networks such as Visa and MasterCard try that banks join them, and downstream competition, as on the one side, acquirers compete to attract more merchants and on the other side, issuers compete to attract more cardholders to hold and use their cards.

Open payment card networks compete with each other when they try to expand, which they do by attracting more banks to join them. The IF is a key strategic variable in this competition (Pindyck (2007)). They compete by offering higher IF to issuers so that they issue the network's card brands instead of cards of a rival. Therefore, competition between payment card networks increases the IF level that generates more profits for issuers per card transaction. Issuers have the incentive to return some part of the IF to cardholders to encourage them to increase card usage. Due to the existence of the membership externality, this causes card acceptance to be more attractive to merchants.

Downstream competition takes place at the two sides of the market: competition between issuers and competition between acquirers. Issuers compete for cardholders. The higher IF generates a higher profit margin per card transaction for issuers. In the competition for more cardholders, issuers have an incentive to offer zero or low membership fees and more rewards on card usage in order to encourage cardholders to retain and use their cards. Under imperfect competition, issuers may pass less than 100% of the increasing IF to cardholders resulting in supra-competitive profits (Prager et al. (2009)). At the other side of the market, acquirers compete for merchants to accept more cards. A high IF (resulting from the upstream competition) leads to a high MSC and accepting cards becomes then more expensive for merchants, which is to their detriment. Merchants will make less profit unless they increase their retail prices. This process of 'merchant internalisation' harms cardholders since they lose some part of the surplus that they obtain from card usage by facing higher retail prices.

With reference to the negative effects of the high IF on cardholders and merchants, the European Commission (henceforth EC) and some public authorities have intervened in the card payment market. In the following, I explain in more detail the main policy interventions regarding the IF in Europe and particularly in Spain.

4.4.1.Interchange Fee Regulation in Europe.

The EC has investigated the behaviour of the two major open card networks (MasterCard by 45% market share and Visa by 44% market share in Europe in 2016[53]) on different occasions regarding their IF. According to antitrust rules in the EU, the collective determination of the IF is legal if it promotes the efficiency of the open payment card networks in terms of technical progress or improved services that outweigh the limited of competition between acquirers. Moreover, all customers and merchants have to get a significant share of these benefits. The share of benefits must compensate for any actual or potential losses from the restriction of competition (EC (2007), MEMO/07/590).

The EC has investigated MasterCard's IF level. The EC accused MasterCard of setting an arbitrarily high IF for cross-border transactions with credit and debit cards in the EEA[54]. MasterCard failed to provide proper evidence to convince the EC that its IF level promoted progress and innovations that could pass significant benefits to customers. In 2007, the EC prohibited MasterCard's IF. This decision was reached after 15 years of investigation regarding MasterCard's IF (EC (2007), Memo/07/590). Although MasterCard was granted 6 months from December 2007 to come forward with new method of setting the IF level for debit and credit cards transaction in the EEA, it failed to provide it and decided to temporarily repeal the cross-border IF to avoid paying any penalties. MasterCard announced that it continued to look for the IF level which could meet antitrust rules. In 2009, MasterCard undertook a significant reduction in maximum weighted average IF level for cross-border transactions: A reduction from the range from 0.8% to 1.9% per transaction in 2007 to 0.3% in 2009 for credit card and a reduction from the range from 0.4% to 0.75% per transaction in 2007 to 0.2% in 2009 for debit card in the EEA. The new IF levels were calculated based on the 'tourist test' methodology (EC (2009), MEMO/09/143). This method compares the cost of accepting the card to the cost of accepting cash payment by merchants to find the optimal IF level, defined as the one at which the merchant would be indifferent between the payment methods used by his customers. This means that at that level the merchant would not pay a higher MSC than the transaction benefits obtained through accepting cards. In 2013, the EC launched some new investigations regarding MasterCard's IF level related to the payment made in the EEA by a cardholder from non-EEA countries (inter-regional IF), i.e. the issuer is located in another region of the world. Also, this investigation affected the IF related to an acquirer that provided services to a merchant in another EEA country. In 2015, the EC accused MasterCard of breaching EU antitrust rules.

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[53] According to the RBR's study in 2017.

[54] Cross-border transaction means a payment transaction where issuer and acquirer are located in two different countries.

The first objection was that the 'inter-regional IF' was too high. The second one was related to one of MasterCard's rules that forbad acquirers to propose a lower IF to a merchant located in another country in the EEA, where the MSC might be higher. Based on this rule, the acquirer was obliged to apply the IF of the country where the merchant was located. This rule harmed merchants since it limited the possibility that merchants could take advantage of the lower MSC by acquirers in another EEA country (EC (2015), IP/15/5323). In 2019, the EC fined €570 million to MasterCard because of breach of antitrust rules regarding restricting cross-border competition between acquirers (EC (2019), IP/19/582).

The first investigation regarding Visa's IF level took place in 2001 as the EC suspected that Visa's European cross-border IF went against competition defence principles. The EC claimed that Visa set arbitrarily high IF in the cross-border card payments in the European Economic Area (EEA). The main concern was that such high IF restricted cross-border competition between acquirers that consequently harmed merchants and customers. By that time, Visa had set the IF on a level that balanced costs associated with issuers and acquirers and incomes received from cardholders and merchants. In 2002, Visa was forced to reduce the level of IF for cross-border transactions operated with debit and credit cards in the EEA. In this regard, Visa set the IF based on the issuer's costs. Visa had proposed a flat-rate IF for the debit cards and a progressive reduction in the IF for the credit cards over the following five years, between 2002 and 2007[55]. Visa's proposal was accepted by the EC. The regulated IF level for the debit card was such that the yearly weighted average rate of the different IF levels of Visa's European cross countries would not exceed €0.28 per payment. This reduction for Visa credit card's IF was such that the weighted average rate of the IF for cross-border payments had to fall from 1.1% to 0.7% in 2007 (EC (2002), Case No. COMP/29.373)[56]. After the expiry of those caps, in 2008, once again the EC investigated Visa's IF policy. In this occasion, it focused on domestic and cross-border payment card transactions in the EEA. The EC asserted that Visa's IF level restricted competition between acquirers on the MSC, increased the cost of accepting cards, and ultimately inflated customer prices.

As a result of such investigation, in 2010, Visa agreed to cut the IF over a period of four years to a level of 0.2% of the transaction amount for all domestic and cross-border payments carried out only with debit cards. The level of 0.2% was in line with the reduction of MasterCard's IF in 2009. The 0.2% level was reached as an application of the 'tourist test' methodology (EC (2009), MEMO/09/143). In a further investigation in 2012 regarding Visa's credit card IF, the EC forced Visa to reduce the IF for credit card. In 2013, Visa agreed to reduce the IF for Visa credit card to a level of 0.3% of the transaction amount for four years. The level of 0.3% was in accordance with the reduction of MasterCard credit card's IF in 2009.

As a result of these investigations regarding the practices of Visa and MasterCard in setting the IF, the EC realised that the IF level varied significantly across the EEA. The evidence provided by Borestam and Schmiedel (2011) shows that there were significant differences in the IF levels across European countries (Table 4.1). The dispersion of IF levels applied to a €100 payment was

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[55] MasterCard and Visa claimed that the EC discriminated between them. Visa argued that MasterCard enjoyed the high IF during the time that Visa has accepted to reduce its IF since 2002, while MasterCard argued that Visa benefited since the EC recognised that Visa's IF can contribute to technical progress.

[56] The IF was set according to a certain amount for debit card and percentage of the transaction amount for the credit card.

considerable. From the EC's point of view, this diversity was problematic since it prevented further integration in Europe and made it difficult to create an internal market. In line with the SEPA project[57], capping the IF was essential to facilitate cross-border payments. In this regard, in 2013 the EC proposed the European Parliament and the Council to put a cap on the IF. In 2015, the European Parliament and the Council imposed a cap on the IF for all domestic and cross-border transactions with debit and credit cards among the EEA[58]. The aim of this regulation was to harmonise the IFs across the EEA and reduce their levels. Based on this regulation the maximum permissible IF for a transaction carried out with credit cards was 0.3% of the transaction amount and 0.2% for debit ones. This cap applies to all debit and credit card payments in the EEA.

Table 4.1. Overview of minimum debit card interchange fees for €10 and €100 transactions in 2010[59].

Interchange fees	**Amount debit card transaction**	
	€10	€100
Maximum (euro)	0.3	1.55
Minimum (euro)	0.01	0.01
Average (euro)	0.1	0.47
Standard deviation	0.07	0.47
Number of reporting countries	20	20

Source: Borestam and Schmiedel (2011).

4.4.1.1.Interchange Fee Regulation in Spain.

Until 2018, there were three national financial associations of banks in the form of card payment networks in Spain, namely *Servired*, *Euro 6000*, and *Sistema 4B*[60]. All banks belonged to each one of them. They were licenced as principal members of Visa and MasterCard and allowed to issue cards, set the operating rules, and the level of the IF. Their behaviour has consistently drawn the attention of regulators in Spain. To some extent, the evolution of the capping of the IF in Spain has followed the EC's basic principles.

The first investigation regarding the card payment market in Spain took place in 1999. The Spanish competition authority (at that time, the Tribunal de Defensa de la Competencia, henceforth TDC) forced the national card networks to cut their IF levels from 3.5% in July 1999 to at a maximum of 2.75% in July 2002, by reducing 0.25 points per year. Before the expiry of this regulation, in April 2002, the TDC asked the Spanish card networks to detail their methods of setting the IF. In April 2003, the TDC argued that their methods were contrary to the principle of competition. The reason was that the methods of setting the IF were not sufficiently justified in terms of costs; they did not

[57] SEPA project is discussed in Chapter 3.

[58] Regulation no 2015/751 on interchange fees entered into force in June 2015 and became binding on 9 December 2015. Following the SEPA project in 2012 and 2014, the capping IF seeks to step towards closer European financial integration.

[59] Due to the lack of appropriate information, authors were unable to provide an overview of credit card IF.

[60] In 2018, the National Commission of Markets and Competition (CNMC) authorized the merger of the three domestic card payment systems in Spain. The intention was to form a single domestic card payment system in Spain that could compete on equal terms with Visa and MasterCard. The CNMC declared that financial institution members, merchants, and end-users were free to decide whether to use the new domestic card payment system or the old ones. For more information on this topic see https://www.cnmc.es/2018-02-01-la-cnmc-autoriza-con-compromisos-la-fusion-de-los-tres-sistemas-de-pago-con-tarjeta-que.

distinguish between credit and debit cards, while the cost of a credit transaction was different from the cost of a debit one. Consequently, the TDC ruled that the IF levels were set arbitrarily without any cost justification. Therefore, the TDC requested the Spanish card networks to set the IF based on the issuer's cost method which was proposed by Visa in 2002. The Spanish national card networks appealed against the TDC's decision to the Supreme Court and maintained their position until the agreement of 2005.

There are two important events that significantly affected the setting of IF in Spain. The first one took place in December 2005, when the Ministry of Industry, Tourism, and Trade and the Ministry of Economy reached an agreement with merchant associations and card networks on the reduction of the IF levels, with different schedules for debit and credit cards. The objective of this agreement was to reduce the MSC through lowering the IF and ultimately obtain a reduction in retail prices. At that year the inflation rate was 3.3% in Spain and this agreement was considered to be a way to reduce it. The agreement established that the IF must be set based on the cost of providing services by distinguishing between debit and credit cards. So, the level of the IF was to be progressively reduced during a transitional period of three years from 2006 to December 2008, as shown by table (4.2). The table shows that the IF for the credit card is stated in percentage terms while the debit card one is in monetary terms. In the case of merchants with an annual revenue from POS card payment of less than €100 million, the reduction in credit card IF was 21% between 2006 and 2008, 40% for revenue between €100 and €500 million, and 18% for revenue above €500 million. In the case of debit cards, the reduction was 24% for merchants with revenue from POS card payment of less than €100 million, 30% for those with revenue between €100 and €500 million, and 22% for those with revenue above €500 million. Besides, the Ministry of Industry, Tourism, and Trade and the Ministry of Economy provided a guarantee clause for the IF related to debit and credit cards for the following two years, 2009-2010. The aim was to protect merchants, and eventually customers, from the high IF. The aforementioned regulation expired in December 2010. After that, the Spanish card networks were free to set the IF based on the issuer's cost, but any agreement between card networks had to be reported to the National Commission of Markets and Competition (CNMC) in order to prove compatibility with antitrust legislation.

Table 4.2.Projected evolution of the maximum IF during 2006-2010

	2006		2007		2008		2009-2010	
Merchant's annual POS revenue (€)	**Debit (€)**	**Credit (%)**	**Debit (€)**	**Credit (%)**	**Debit (€)**	**Credit (%)**	**Debit (€)**	**Credit (%)**
0-100 mill	0.53	1.40	0.47	1.30	0.40	1.10	0.35	0.79
100-500 mill	0.36	1.05	0.29	0.84	0.25	0.63	0.21	0.53
>500 mill	0.27	0.66	0.25	0.66	0.21	0.54	0.18	0.45

Source: Ministry of Industry, Tourism and Trade of Spain[61].

The second important event took place in July 2014 and was in line with the EC's proposal regarding capping the IF in 2015. The objective of this regulation was the same as the Agreement in 2005. The Royal Decree-Law (RDL) 8/2014 approved the cap on IF with different schedules for debit and credit cards. In compliance with this regulation, the IF for the debit card must be set as a percentage of the transaction amount. The maximum permissible IF for an operation carried out with

[61] http://www.comercio.gob.es/en/comercio-interior/distribucion-comercial-estadisticas-y-estudios/tarjetas-de pago/ pages/ tarjetas-de-pago.aspx.

debit cards was 0.2% of the transaction amount, with a maximum of 7 euro cents. In an operation carried out with credit cards, the maximum permissible IF was 0.3% of the transaction amount. In addition, the RDL 8/2014 restricted the maximum permissible IF for transactions of less than 20 euros so that the maximum fee for debit cards was 0.1% of the transaction amount and for the credit card was 0.2% of the transaction amount. The RDL 8/2014 anticipated what EC's regulations were about to impose.

4.5. Literature Review.

Evaluating the effects generated by capping the IF on issuers, merchants and cardholders are the main concern of the existing empirical studies in the card payment market. Carbo-Valverde et al. (2016) is the closest work to this chapter. They apply the two-sided markets theory to study the effects of the IF reduction on markets 1, 2, and 4 described in section (4.2). They use quarterly payment card data from 45 Spanish banks from 1997 to 2007. The data includes bank-level information on payment cards such as transaction volume by issuer and acquirer, the IF and MSC for debit and credit cards, annual credit fee, merchant acceptance, number of cardholders, and number of ATM and POS terminals. In market 1, they find that card usage increases as a result of capping the IF. In market 2, their results show that card acceptance and transaction volumes increase when the IF is decreased. In market 4, they find that issuers benefit from capping the IF since the increase in card transactions can offset the loss of the IF's revenue. However, contrary to the aim of this work, they do not investigate the effect that IF may have on prices paid by customers.

Regarding the effects of the EC regulation 2015, Ardizzi and Zangrandi (2018) study the effects of this cap on MSC and merchant acceptance in the card payment market in Italy. They only focus on market 2 and do not study the effects of capping the IF on the cardholder side. They use the half-yearly institution-level data (banks and non-banks in the acquiring market) of 400 financial institutions that reported to the Bank of Italy from 2009 to 2017. Their results show that the MSC is reduced and the merchant acceptance is increased as a consequence of this policy in Italy. Recently, two consultancy groups (Ernst & Young and Copenhagen Economics (2020)), in a report for the EC, show that acquirers pass 50% of the IF reduction to merchants and hold 50% as savings as a consequence of the regulation 2015. In order to find to what extent the merchants pass the lower MSC to customers, they use a meta study approach[62]. They find that, on average, the merchants pass 66% of the reduction in their costs to customers in the form of lower retail prices.

Some of the existing relevant papers analyse policy changes on IF in the United States and Australia. In 2011, the US Federal Reserve Board implemented the Durbin Amendment (also known as Regulation II), which was part of the Dodd-Frank financial reform legislation and enforced a reduction on the debit card IF from 44 cents to 21 cents per transaction plus 0.05% of the transaction amount for debit card issuers with assets above USD 10 bn. This means that smaller debit card issuers were exempt from this regulation. The objective of this regulation was to reduce the IF, which ultimately benefited merchants and customers. Wang (2012) studies the effect of this cap on the revenues of issuers, relying on descriptive comparative statistics. He finds that the revenue of treated issuers (issuers with assets above USD 10 bn) decreased while the revenue of untreated issuers

[62] The meta-study approach is a simulation of the effects taking the values from other papers that have studied pass-through. This method considers that the pass-through rate is consistent with the historical average cost pass-through rate from other empirical studies, such as studies that focus on the effect of cost change on retail prices due to imposing a tax or a change in the foreign exchange rate.

(issuers with assets below USD 10 bn) increased. Merchants benefited from this regulation by paying lower MSC. The impact of this regulation on customers was less clear since, on the one hand, the issuers argued that they would increase membership fees, and on the other hand merchants argued that they would decrease retail prices due to the lower IF. Evans, Litan, and Schmalensee (2011) study the effects of the IF cap on membership fees by focusing on households and small businesses in the short-run. They find that the cap harmed lower-income households and small businesses since issuers immediately offset a reduction in revenue due to the lower IF by increasing membership fees. They argue that these harms are unlikely to be compensated by price reductions in the short-run since retail prices are sticky and merchants do not change quickly the prices in response to the cost reduction.

In 2003, the Reserve Bank of Australia (RBA) enforced a cap on the credit card IF, by which the IF was reduced from 0.95% to 0.55% of the transaction amount. The RBA argued that the credit card IF was set too high, resulting in too low charges of credit card usage (even negative) by cardholders from a social perspective. This leads the overuse of the credit card compared to other cheaper payment forms. Chang, Evans, and Garcia Swartz (2005) use the data provided by Visa card network in Australia between 1992:3 and 2005:1 to study the effects of capping the credit card IF from the cardholder's side and the merchant's side. On the cardholder's side, they study the effect of this cap on the issuer's revenue and the cardholder's fee. On the merchant's side, they study how much of the IF reduction passes to the merchant through the lower MSC and how much of the MSC reduction passes to buyers through lower retail prices. Most of their work relies on descriptive comparative statistics. They find that issuers lost around 42% of their IF's revenues but they were able to offset their losses by charging higher fees to cardholders. Merchants benefited from this regulation with a 0.21% reduction in the MSC. Chang, Evans, and Garcia Swartz (2005) argue that merchants passed their cost saving to retail prices at a lower rate than the reduction in the MSC. By considering 50% pass-through rate, they state that the reduction in retail prices would be 0.105%.

Evaluating the effects of the IF reduction on retail prices is an important policy question that previous work has not examined by taking into account the two-sided nature of card payment markets. The main contribution of this chapter is to fill this gap. In particular, applying the ARDL model allows me to study the short- and long-run impacts of the IF reduction on retail prices. An important reason to study the short- and long-run relationships is that many prices are sticky in the short-run and merchants are reluctant to change prices quickly, as argued by Evans, Litan, and Schmalensee (2011), Carlton (1986), Alvarez et al. (2010), Dhyne et al. (2006), Anderson et al. (2015). As mentioned before, the stickiness of prices is the argument used by Evans, Litan and Schmalensee (2011) to discuss that the harms of lower IF levels are unlikely to be compensated by price changes in the short run. However, as will be discussed below, there will be long run effects worth taking into account.

4.6. Data Description.

The data used in this study have been obtained from two main sources: the Bank of Spain and the National Statistics Institute of Spain (henceforth INE).

The payment systems department of the Bank of Spain provided quarterly data related to national card payment networks from 2008:1 to 2019:4. The data contains information on the number of devices accepting card payment located in Spain owned by Spanish banks (POS and ATM), volume and value of card transactions at POS and ATM, and volume of cards in circulation. The data also provides rich information on the MSC for domestic payment transactions across 21 different merchant sectors in Spain. The definition of each merchant sector is based on the aggregation of up to 100 different business categories. The data shows that the MSC differs among merchant sectors. Moreover, the data contains the IF levels, on which two time periods can be identified: the first period includes the data from 2008:1 to 2014:2 and the second period includes the data from 2014:3 to 2019:4. In the first period, the data comprises two different measurements of the IF. One measurement is carried out according to the details of the 2005 Agreement, so that the IF is reported in terms of turnover value (table 4.2). The second measurement in 2008:1 to 2014:2 period reports the IF in terms of intra-and inter-network transactions, and details the figures for the same merchant sectors as the MSC. In the second period, the IF is reported in accordance with the RDL 8/2014 and the Regulation No. 2015/751 on IF, which requires distinguishing between credit card and debit card payments. In this case, data is provided across 9 different merchant sectors (Bank of Spain (2014)).

The above information indicates that there are no uniform data series on the IF. To overcome this problem, I use the following procedure to build a homogeneous series. In the first period, I pick the levels of IF for intra- and inter-network transactions, since this allows me to study the IF across the same merchant sectors as the MSC. This data indicates that the inter-network IF is greater than the intra-network one, as it includes the interconnection cost that is a fixed amount per transaction (Bank of Spain (2014)). Then, to obtain a single value for IF in this period, I compute the average of inter- and intra-network IFs for each merchant sector. In the second period, I compute the average of debit and credit IFs for each merchant sector. Figure 4.5 illustrates the resulting evolution of IFs in some selected merchant sectors across my sample period. The higher IFs belong to the restaurant and the drugstore sectors and the lower ones belong to the transportation and the large supermarket sectors. The figure shows that the IFs sharply drop in 2014:3 in line with the RDL 8/2014 and then smoothly fluctuate up to 0.2% and become almost identical in all sectors.

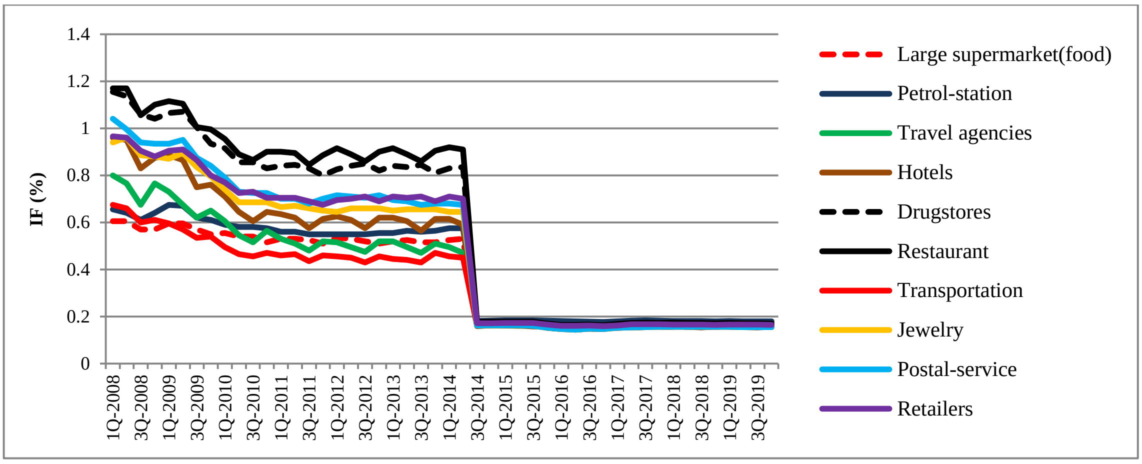
As mentioned earlier, one of the objectives of capping the IF was to decrease the MSC. From the data, it is observed that the IF reduction correlates with lower MSC. Figure 4.6 shows that, in general, the MSCs have downward trends. The higher MSCs are those of postal services and restaurants and the lower ones those of petrol stations and large supermarkets. The MSCs dropped in 2014:4, after the cap imposed on the IF in 2014:3. This may indicate that the MSC in the current period depends on the IF level in the previous period. While the IF appeared to have stabilised after the third quarter of 2014, the MSCs of some merchant sectors continued to fall during the sample period. However, a visual inspection can barely be used as adequate evidence of policy impact. Therefore, it is essential to analyse empirically whether decreasing the IF causes a reduction in the MSC.

The data also shows that after regulation 2014, the number of cards in circulation (comprising debit and credit cards) grew significantly. Table (4.3) shows the annual average increase in the number of payment cards.

Besides, the number of POS terminals significantly grew after regulation 2014. The number of ATM decreased over sample period except in 2016 and 2018 (table (4.4)).

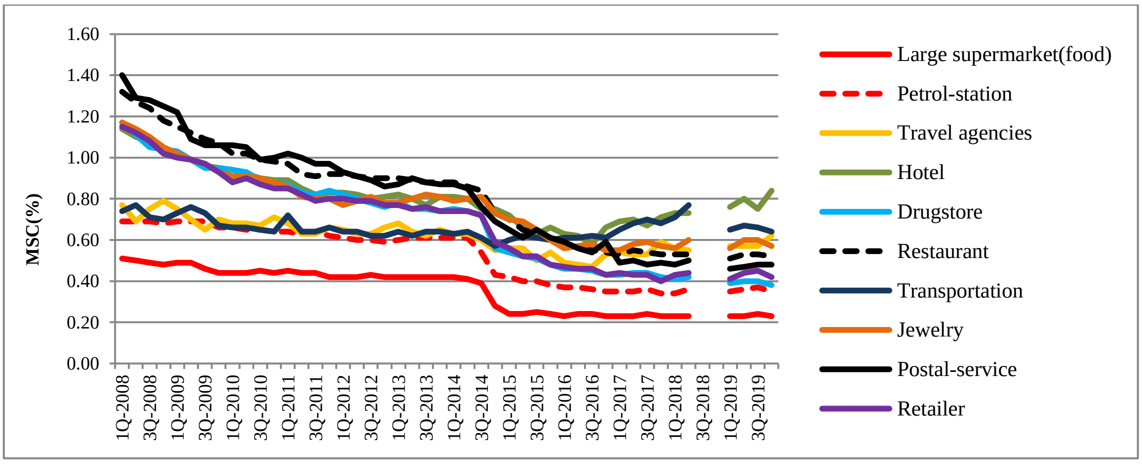
Tables (4.5) and (4.6) show the annual average growth rate of volume and value of card transactions at POS and ATM, respectively. It is observed that the card usage grew at POS. This evidence could show that card payments replace cash payments in Spain during the sample period, in line with the report on the assessment of the effects of the EC's IF cap in 2015 provided by Ernst & Young and Copenhagen Economics (2020).

Figure 4.5. Aggregate average IF paid by an acquirer to issuer per card transaction among some selected merchant sectors (%).



Source: Bank of Spain and own calculation.

Figure 4.6. Aggregate average MSC for some selected merchant sectors (%).



Source: Bank of Spain and own calculation.

Table 4.3. Annual average growth rate of number of cards in circulation in Spain (%).

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
-1.6	-3.01	-5.6	0.02	0.26	-0.94	0.81	5.51	7.12	4.35	5.25

Source: Bank of Spain and own calculation.

Table 4.4. Annual average growth rate of number of accepting devices in Spain (%).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
POS	2.49	-0.96	-0.26	-0.68	-4.50	-5.24	12.64	5.80	6.35	5.16	4.63
ATM	-0.02	-0.27	-0.34	-0.21	-0.47	-0.48	-0.20	0.08	-0.02	0.31	-0.15

Source: Bank of Spain and own calculation.

Table 4.5. Annual average growth rate of volume of card transaction at POS and ATM Spain (%).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
POS	2.25	5.84	3.90	0.92	2.38	8.51	7.21	13.43	12.61	13.13	15.76
ATM	-2.95	-0.16	-1.72	-4.22	-2.95	0.44	1.49	0.6	1.01	-0.28	-0.78

Source: Bank of Spain and own calculation.

Table 4.6. Annual average growth rate of value of card transaction at POS and ATM Spain (%).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
POS	-3.58	4.57	3.25	-0.79	1.1	7.42	6.09	10.72	8.73	8.49	9.74
ATM	-2.87	0.81	-0.43	-2.61	-1.26	1.97	3.11	2.96	3.54	1.90	1.97

Source: Bank of Spain and own calculation.

The second category of data, including the consumer price index (CPI) and the household total expenditure, is obtained from the INE. The CPI is a measure of prices of a basket of goods and services in an economy. The CPI is calculated based on the base year 2016 in Spain, using approximately 220,000 monthly prices. The INE provides the total household expenditure in the Household Budget Survey (Encuesta de Prespuestos Familiares) that contains detailed breakdown of consumption expenses by approximately 24,000 households. The total household expenditure contains all domestic costs incurred by households to satisfy their everyday needs. The CPI is reported monthly and the household total expenditure is reported annually. Since the data related to the card payment is reported quarterly, in order to have the same frequency among data, the monthly and annual data are converted into quarterly ones. Another issue is that the INE uses ECOICOP classification for products, but the data from the Bank of Spain is descriptive, not classified in the same way. To overcome this heterogeneity between two sources of the data, I take the merchant sectors reported by the Bank of Spain as the baseline and attempt to find the most similar sectors from the INE. In this regard, 10 different merchant sectors are selected that are perfectly suitable for the two sources. Thus, the investigation is restricted to large supermarket-food, petrol stations, travel agencies, hotels, drugstores, restaurants, transportation services, jewelry stores, postal services, and retailers. Table (4.7) provides the identification of each merchant sector. The number before each sector is ECOICOP digits reported by the INE. I exclude from the analysis the following sectors included in the original data from the Bank of Spain: supermarkets categorised as 'other', chemists, toll-highways, car rental, entertainment, casinos, massage-saunas, night clubs, low-value category items, payments to charity and solidarity organisations, and others.

Table 4.7. Identification of equivalent sectors in card payment fee data (Bank of Spain) and CPI (INE).

Bank of Spain	INE
Large supermarket(food)	01 Food and non-alcoholic beverages
Petrol station	0722 Fuels and lubricants for personal transport equipment
Travel agency	0960 Package holidays
Hotel	112 Accommodation services
Drugstore	0630 Hospital services
Restaurant	1111 Restaurants, cafes and the like
Transportation	0735 Combined passenger transport
Jewelry	1231 Jewelry, clocks and watches
Postal service	081 Postal services
Retailer	031 Clothing

Table (4.8) shows the definition of the variables that I use for the empirical models to be estimated. The CPI level (indexed at 100 in 2016) is used to measure the retail prices variable (P). The data does not contain the data related to the card payment usage at POS. Instead, it contains data related to the transaction volumes at POS and ATM. By using this information, I define the card payment usage at POS (VolPOS) as the portion of transaction volumes at POS to total transaction volumes at POS and ATM. This is a choice variable that indicates whether a cardholder chooses the card payment method or not. I assume that the card payment usage is the same for all the sectors. The corresponding data exist for the rest of the variables.

Table 4.8.Definition of the variables.

Variable	Unit	Definition
P	Number	Consumer price index (CPI)
MSC	Percent	Merchant service charge
IF	Percent	Interchange fee
Totexp	Billion Euros	Total household expenditure
VolPOS (card payment usage)	Percent	$\frac{\text{Volume of transaction at pos}}{(\text{Volume of transaction at pos} + \text{Volume of transaction at ATM})}$
NC	Number	Number of cards in circulation (Million)
POS	Number	Number of POS device (Million)

Table (4.9) shows the descriptive statistics of the variables. The table reports overall, between and within variations of the empirical variables. Within shows the variation over time (time variant), between shows the variation across sectors (time-invariant) and overall shows the variation over time and sectors. As can be observed, there is a strong variation in retail prices over time. The total expenditure varies strongly across merchant sectors. It is worth to remind that some variables such as VolPOS, NC, and POS are only time-variant.

Table (4.10) shows the descriptive statistics of the IF and the MSC at the sector level. The highest (lowest) MSC is that of postal services (large supermarket-food) and the highest (lowest) IF is that of restaurants (transportation services, jewelry stores, and postal services). The comparison of the average of the MSC and the IF at different merchant sectors shows that acquirers get lower margins in some sectors such as large-supermarket (food) and petrol stations. The intuition could be that these sectors have large transaction volumes, so their merchants have a better bargaining position vis-à-vis acquirers than merchants in sectors with lower volumes and thus they receive volume discounts and formally pay a lower MSC.

Table 4.9. Descriptive statistics of the variables.

Variable		Mean	Std.Dev.	Min	Max	Observations
P	Overal	98.4878	10.73706	60.711	128.963	N=480
	Between		5.700557	91.73571	110.5829	n=10
	Within		9.272359	67.24094	123.3459	T=48
MSC	Overal	0.678413	0.2262286	0.23	1.4	N=460
	Between		0.1479519	0.3582609	0.8213043	n=10
	Within		0.1773011	0.320587	1.260587	T=46
IF	Overal	0.4547613	0.2987823	0.14415	1.17	N=480
	Between		0.0834745	0.341299	0.5957115	n=10
	Within		0.2880739	0.0220749	1.047726	T=48
Totexp	Overal	4.434095	5.837232	0.02	19.67	N=420
	Between		6.133532	0.0278571	18.85119	n=10
	Within		0.3664421	2.825286	5.734334	T=42
VolPOS	Overal	0.7311549	0.0510493	0.6547304	0.8432481	N=460
NC	Overal	73.31152	5.24214	67.48	85.61	N=460
POS	Overal	1.586978	0.1503086	1.322	1.942	N=460

Table 4.10. Descriptive statistics of the IF and the MSC.

Merchant sector	Mean		Std.Dev.		Min		Max		Observations	
	IF	MSC	IF	MSC	IF	MSC	IF	MSC	IF	MSC
Large supermarket(food)	0.3684	0.3582	0.1935	0.1054	0.1528	0.23	0.605	0.51	48	46
Petrol station	0.4008	0.5263	0.2062	0.1377	0.1763	0.34	0.675	0.69	48	46
Travel agency	0.3828	0.6189	0.222	0.0781	0.1489	0.47	0.8	0.79	48	46
Hotel	0.4458	0.8136	0.2842	0.1336	0.1482	0.58	0.96	1.14	48	46
Drugstore	0.5620	0.7004	0.3868	0.2335	0.1442	0.38	1.155	1.17	48	46
Restaurant	0.5957	0.8213	0.4008	0.2395	0.1630	0.51	1.17	1.32	48	46
Transportation	0.3412	0.6582	0.1813	0.0480	0.1441	0.57	0.675	0.77	48	46
Jewelry	0.4675	0.7697	0.3009	0.1730	0.1441	0.55	0.96	1.17	48	46
Postal service	0.4919	0.8178	0.3245	0.2663	0.1441	0.46	1.04	1.4	48	46
Retailer	0.4910	0.6993	0.3100	0.2248	0.1585	0.4	0.965	1.15	48	46

Source: Bank of Spain and own calculation.

The partial correlations between variables are shown in table (4.11). All variables are expressed in natural logarithm terms. The table shows that the IF and the MSC are positively correlated. The card payment usage is highly correlated with the IF and the MSC. The correlation between card payment usage and the number of cards is also positive.

Table 4.11. Partial correlations between variables.

	Log (P)	Log (MSC)	Log (IF)	Log (Totexp)	Log (VolPOS)	Log (NC)	Log (POS)
Log(P)	1.00						
Log(MSC)	-0.39	1.00					
Log(IF)	-0.38	0.79	1.00				
Log(Totexp)	0.21	-0.36	-0.06	1.00			
Log(VolPOS)	0.46	-0.61	-0.81	-0.03	1.00		
Log(NC)	0.13	-0.22	-0.33	0.005	0.48	1.00	
Log(POS)	0.45	-0.58	-0.82	-0.01	0.96	0.64	1.00

4.7.Model Specification.

In order to examine the impact of the IF on retail prices, I take into account the two-sidedness nature of the card payment market. This means that the impact is examined from the merchant's and the cardholder's sides. In this respect, this section recalls the three markets involved in a card transaction with an open payment card network, as explained in section (4.2): Market 1 between issuers and cardholders, Market 2 between acquirers and merchants, and Market 3 between merchants and cardholders. Market 4 between acquirers and issuers is not studied since it is beyond the main purpose of this chapter.

In order to evaluate the effect of changes in the IF from the merchant side, Market 2 is considered. In this market, I focus on the sign and magnitude of the relationship between the MSC and the IF to find how changing the IF affects the merchant ($\frac{\partial MSC}{\partial IF}$). I specify the empirical version of equation 4.3 as follows.

$$\text{Log}\, MSC_{it} = \mu_i + \delta_{1i} \log IF_{it} + \delta_{2i} \log POS_{it} + \delta_{3i} \log NC_{it} + \gamma t + \epsilon_{it} \quad (4.6)$$

The dependent variable is the logarithm of MSC that is paid by merchant i (for $i = 1, \ldots, 10$) at time t (for $t = 2008{:}1, \ldots, 2019{:}3$). The most important explanatory variable is the logarithm of IF that is paid by an acquirer in merchant sector i at time t. To capture the effect of number of transactions on the MSC, I add the POS variable. As explained, there is the membership externality in the card payment market, i.e. more cardholders affect merchants' card acceptance and vice versa. To control this effect, I add the variable number of cards. The trend variable is shown by t and takes the value 1 at the starting point and grows by 1 each quarter. It can capture impacts such as the progress of digitalisation over time and may have an influence on MSC_{it}.

To study the impact of IF changes on the cardholder side, Market 1 is considered. As previously explained, issuers encourage cardholders to increase card usage by decreasing the membership fee (or offering rewards). In this regard, the empirical version of equation 4.2 is specified as follows.

$$\text{Log}\, VolPOS_{it} = \mu_i' + \beta_{1i} \log f_{it} + \delta_{3i}' \log POS_{it} + \delta_{4i}' \log TotExp_{it} + \gamma' t + \epsilon_{it}' \quad (4.7)$$

The dependent variable is the logarithm of card payment usage at POS. As I explained in section (4.6), it is defined as the portion of the transaction volume at POS to total transaction volume at POS and ATM. The variable POS is added to capture the attractiveness of using a card by cardholders that depend on the number of merchants that accept the payment card (membership externality). Moreover, the decision to use a card as a payment method instead of alternative payment instruments can be controlled by the total expenditure of the household. As in equation 4.6, t is the trend variable.

Equation 4.1 in section (4.3) has shown that an issuer sets the membership fee according to the difference between the marginal cost it bears from every transaction and the interchange fee. We can assume that such issuer's costs are constant, so that

$$\text{Log}\,(f_{it}) = c_I - \text{Log}\,(IF_{it}) \quad (4.8)$$

However, we can assume that the issuer experiences some kind of economies or diseconomies of scale, whereby the marginal cost of each transaction varies with the number of cards issued. So, equation 4.8 can be written as

$$\text{Log}\,(f_{it}) = c_I + \text{Log}\,(NC_{it}) - \text{Log}\,(IF_{it}) \quad (4.9)$$

where the number of cards (NC) is a proxy variable that captures the effect of economies or diseconomies of scale in the membership fee. In order to study how changing the IF affects card payment usage by cardholders ($\frac{\partial VolPOS}{\partial IF}$), I insert equation 4.9 in 4.7. Therefore, the econometric specification is defined as follows.

$$\text{Log}\, VolPOS_{it} = \omega_i' + \delta_{1i}' \log IF_{it} + \delta_{2i}' \log NC_{it} + \delta_{3i}' \log POS_{it} + \delta_{4i}' \log TotExp_{it} + \gamma' t + \epsilon_{it}' \quad (4.10)$$

with $\omega_i' = \mu_i' + c_I$.

In Market 3, the price equation 4.5 showed the effect of a change in the MSC and card payment usage on retail prices. This makes it possible to identify two effects: i) the relationship between retail prices and the MSC to find how much of a reduction in the cost of accepting card passes into cardholders ($\frac{\partial P}{\partial MSC}$), and ii) the relationship between retail prices and the card payment usage to find how a change in the card payment usage affects retail prices ($\frac{\partial P}{\partial VolPOS}$). The econometric specification of such equation follows the structure outlined below:

$$\text{Log}\, P_{it} = \mu_i'' + \delta_{1i}'' \log VolPOS_{it} + \delta_{2i}'' \log MSC_{it} + \delta_{3i}'' \log Totexp_{it} + \gamma'' t + \epsilon_{it}'' \tag{4.11}$$

The dependent variable is the logarithm of retail prices in the merchant sector i at time t. The key explanatory variables are the logarithm of the card payment usage and the MSC. It is essential to distinguish between a change in prices due to the changing demand of products and what is associated with a decline in the MSC. I do this by including the household total expenditure in each sector as a control variable. Moreover, this variable can also capture the effect of the economic cycle on consumption.

In order to examine the effect of the IF on retail prices from the merchant side, I make use of the following expression.

$$\frac{\partial P}{\partial IF} = \frac{\partial P}{\partial MSC} \frac{\partial MSC}{\partial IF} \tag{4.12}$$

Equation 4.12 shows how the IF reduction affects the MSC and how a change in the MSC affects retail prices. From the cardholder's side, the expression would be

$$\frac{\partial P}{\partial IF} = \frac{\partial P}{\partial VolPOS} \frac{\partial VolPOS}{\partial IF} \tag{4.13}$$

Equation 4.13 shows how the IF reduction affects the card payment usage and how a change in card payment usage affects retail prices. Combining both expressions, I will assess the total effect of a change in IF on retail prices, taking into account the relative magnitude of the effects of the two sides in the card payment market.

In order to estimate equations 4.6, 4.10 and 4.11 I follow the econometric method proposed by Pesaran, Shin, and Smith (1999) and study the short- and long-run relationships between variables. The reason is that in the available data, the time period (T=48) is relatively large. In this case, applying the traditional dynamic panel data estimators[63] such as GMM estimators can be problematic since the large time period requires a large number of instruments. The result of the Sargan test on the exogeneity of instruments is not valid. Therefore, the results obtained using GMM are likely inconsistent and unreliable (Pesaran and Smith (1995)). A further issue is that the traditional dynamic panel data estimators are typically limited to short time periods when the stationarity of the variables is ignored. Therefore, when the time period is large, it is necessary to examine whether variables are stationary and then study the relationship between them by applying the appropriate method.

Pesaran and Smith (1995) and Pesaran, Shin, and Smith (1999) argue that when the variables of interest are characterised by I (1) or I (0) and the time period is large, the short- and long-run relationships between variables should be examined by the autoregressive distributed lag (ARDL) approach. The typical process in this case is to first determine the order of integration, and then having determined that the variables have the same order use the ARDL approach. Therefore, the lag length must first be specified. In order to do this, I apply the Schwarz Bayesian Criterion (SBC) for each variable in each sector. Then I compare the orders offered by this test for each variable between 10 merchant sectors to determine the order of the ARDL model. The results of the SBC tests are shown in the appendix. Based on these results, in more than half of the merchant sectors the lag length is as follows: ARDL (1, 1) for equation 4.6, ARDL (1, 1, 1) for equation 4.10, and ARDL (1, 1, 1, 1) for equation 4.11. Given the lag lengths, I am able to apply the ARDL methods to estimate the

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[63] The traditional dynamic panel data estimators are GMM estimators (the GMM-difference estimator proposed by Arellano and Bond (1991) and the GMM-system estimator by Arellano and Bover (1995) and Blundell and Bond (1998)).

parameters of equations 4.6, 4.10, and 4.11.

4.7.1. ARDL Model.

Pesaran, Shin, and Smith (1999) define an ARDL model with lag length 1 for a panel with relatively large time period as follows:

$$y_{it} = \lambda_i y_{i,t-1} + \sum_{j=0}^{1} \delta'_{ij}\, x_{i,t-j} + \mu_i + \epsilon_{it} \tag{4.14}$$

where $i = 1, \dots, N$ and $t = 1, \dots, T$ represent the number of groups (or sectors) and the time period, respectively. The dependent variable is y_{it} and the vector of explanatory variables is x_{it}. The parameter μ_i shows the constant term. Pesaran, Shin, and Smith (1999) show that the model (4.14) can be re-parameterized and rewritten as an error correction model as follows:

$$\Delta y_{it} = \varphi_i \left(y_{i,t-1} - \theta_{0i} - \theta_i x_{i,t-1} \right) + \delta_i^* \Delta x_{it} + \varepsilon_{it} \tag{4.15}$$

where $\Delta\, y_{it} = y_{it} - y_{it-1}$, and $\Delta x_{it} = x_{it} - x_{it-1}$.The parameter $\varphi_i = -(1 - \lambda_i)$ is the error correction parameter, and $\left(y_{i,t-1} - \theta_{0i} - \theta_i x_{i,t-1}\right)$ is the error correction component. The Error correction term has to lie between 0 and -1, otherwise, the short-run relationships would not converge towards their long-run equilibrium at rate φ_i. The parameter φ_i shows the speed of adjustment to the long-run equilibrium. The parameters θ_{0i} and θ_i are the long-run relationships and they are equal to $\theta_{0i} = \frac{\mu_i}{1-\lambda_i}, \theta_i = \frac{\sum_{j=0}^{1} \delta'_{ij}}{1-\lambda_i}$. The parameter δ_i^* indicates the short-run relationship. If the panel is co-integrated, then the long-run relationship exists. In this case, the parameter φ_i significantly differs from zero.

There are three different estimators for estimating equation 4.15: the mean group (MG) estimator proposed by Pesaran and Smith (1995), the pooled mean group (PMG) estimator proposed by Pesaran, Shin, and Smith (1999), and the dynamic fixed effect estimator (DFE). For each sector, the MG estimates separate regressions and then calculates a simple arithmetic average of their coefficients. This estimator does not set any limits and allows all coefficients to differ across merchant sectors (Pesaran and Smith, 1995). The results of this estimator are consistent. The DFE allows only intercepts to differ across merchant sectors. This estimator imposes the restriction on the speed of adjustment, slope coefficients, and error variances to be equal across all merchant sectors in the short- and long-run. The PMG estimator is an intermediate estimator between MG and DFE, i.e. a combination of pooling and averaging of coefficients. The key feature of the PMG estimator is that it lets the intercepts, short-run coefficients, the speed of adjustment to the long-run equilibrium, and error variances to be heterogeneous across merchant sectors, but the long-run coefficients are constrained to be identical across merchant sectors. In other words, the parameters θ_{0i} and θ_i are the same across sectors. In fact, the PMG estimator allows examining the long-run homogeneity without imposing homogeneity in the short run. The long-run coefficients are consistent and efficient when the variables of interest are characterised by I (1) or I (0) (Pesaran, Shin, and Smith, 1999). All three estimators use maximum likelihood (ML) methods to estimate the short- and long-run relationships.

To choose among the MG, PMG, and DFE estimators, the Hausman (1978)-type test can be used. The null hypothesis is that there are no systematic differences between PMG and MG or PMG and DFE. If the null hypothesis is not rejected, then the PMG estimator is suggested because it is consistent and efficient. Under the PMG, the coefficients are homogeneous in the long-run. In other words, the Hausman test tests the existence of the long-run homogeneity of coefficients. If the null hypothesis is rejected, then the coefficients are not the same across the merchant sectors in the long-run and the PMG estimator is inconsistent. In such case, it is recommended to use the MG or DFE estimators (Blackburne III and Frank, 2007).

4.7.1.1.Implementing the ARDL Model in the Card Payment Market.

Herein, I follow Pesaran, Shin, and Smith (1999) and implement the ARDL model and error correction model for equations 4.6, 4.10, and 4.11. The ARDL model of equation 4.6 can be specified as follows:

$$\text{Log}\, MSC_{it} = \mu_i + \lambda_i \log MSC_{i,t-1} + \sum_{j=0}^{1} \delta_{1ij} \log IF_{i,t-j} + \sum_{j=0}^{1} \delta_{2ij} \log POS_{i,t-j} + \sum_{j=0}^{1} \delta_{3ij} \log NC_{i,t-j} + \gamma T + \epsilon_{it} \quad (4.16)$$

where $i = 1, \dots, 10$ represents the merchant sectors, t represents the time periods from 2008:1 to 2019:4, T is the trend variable, and μ_i represents the constant term. The error correction of equation 4.16 is given by:

$$\Delta\, \text{Log}\, MSC_{it} = \varphi_i(\log MSC_{i,t-1} - \theta_{0i} - \theta_{1i} \log IF_{it} - \theta_{2i} \log POS_{it} - \theta_i \log NC_{it}) - \delta_{1i}\, \Delta\log IF_{it} - \delta_{2i}\, \Delta\log POS_{it} - \delta_{3i}\, \Delta\log NC_{it} + \varepsilon_{it} \quad (4.17)$$

where $\theta_{0i} = \frac{\mu_i}{1-\lambda_i}, \theta_{1i} = \frac{\delta_{10i}+\delta_{11i}}{1-\lambda_i}$, $\theta_{2i} = \frac{\delta_{20i}+\delta_{21i}}{1-\lambda_i}$, $\theta_{3i} = \frac{\delta_{30i}+\delta_{31i}}{1-\lambda_i}$, and $\varphi_i = -(1-\lambda_i)$. The parameter θ are the long-run relationship between dependent and independent variables, and δ are the short-run relationship between them. The ARDL model of equation 4.10 can be defined as follows:

$$\text{Log}\, VolPOS_{it} = \omega_i' + \lambda_i' \log VolPOS_{i,t-1} + \sum_{j=0}^{1} \delta_{1ij}' \log IF_{i,t-j} + \sum_{j=0}^{1} \delta_{2ij}' \log NC_{i,t-j} + \sum_{j=0}^{1} \delta_{2ij}' \log POS_{i,t-j} + \sum_{j=0}^{1} \delta_{2ij}' \log TotExp_{i,t-j} + \gamma' T + \epsilon_{it}' \quad (4.18)$$

The error correction of equation 4.18 is given by:

$$\Delta\, \text{Log}\, VolPOS_{it} = \varphi_i' (\log VolPOS_{i,t-1} - \theta_{0i}' - \theta_{1i}' \log IF_{it} - \theta_{2i}' \log NC_{it} - \theta_{3i}' \log POS_{it} - \theta_{4i}' \log TotExp_{it}) - \delta_{11i}' \Delta\log IF_{it} - \delta_{21i}' \Delta\log NC_{it} - \delta_{21i}' \Delta\log POS_{it} - \delta_{21i}' \Delta\log TotExp_{it} + \varepsilon_{it}' \quad (4.19)$$

where $\theta_{0i}' = \frac{\omega_i'}{1-\lambda_i'}$, $\theta_{1i}' = \frac{\delta_{10i}'+\delta_{11i}'}{1-\lambda_i'}$, $\theta_{2i}' = \frac{\delta_{20i}'+\delta_{21i}'}{1-\lambda_i'}$, $\theta_{3i}' = \frac{\delta_{30i}'+\delta_{31i}'}{1-\lambda_i'}$, $\theta_{4i}' = \frac{\delta_{40i}'+\delta_{41i}'}{1-\lambda_i'}$, and $\varphi_i' = -(1-\lambda_i')$. The parameters θ' are the long-run coefficients and δ' are the short-run coefficients. The ARDL model of equation 4.11 follows the structure laid out below:

$$\text{Log}\, P_{it} = \mu_i'' + \lambda_i'' \log P_{i,t-1} + \sum_{j=0}^{1} \delta_{1ij}'' \log VolPOS_{i,t-j} + \sum_{j=0}^{1} \delta_{2ij}'' \log MSC_{i,t-j} + \sum_{j=0}^{1} \delta_{3ij}'' \log Totexp_{i,t-j} + \gamma'' T + \epsilon_{it}'' \quad (4.20)$$

The error correction of equation 4.20 is given by:

$\Delta \text{ Log } P_{it} =$
$\varphi_i''(\log P_{i,t-1} - \theta_{0i}'' - \theta_{1i}'' \log VolPOS_{it} - \theta_{2i}'' \log MSC_{it} - \theta_{3i}'' \log Totexp_{it}) - \delta_{11i}^{''} \Delta\log VolPOS_{it} - \delta_{21i}^{''} \Delta\log MSC_{it} - \delta_{31i}^{''} \Delta\log TotExp_{it} + \varepsilon_{it}''$ (4.21)

where $\theta_{0i}'' = \frac{\mu_i''}{1-\lambda_i''}$, $\theta_{1i}'' = \frac{\delta_{10i}^{''}+\delta_{11i}^{''}}{1-\lambda_i''}$, $\theta_{2i}'' = \frac{\delta_{20i}^{''}+\delta_{21i}^{''}}{1-\lambda_i''}$, $\theta_{3i}'' = \frac{\delta_{30i}^{''}+\delta_{31i}^{''}}{1-\lambda_i''}$, and $\varphi_i'' = -(1 - \lambda_i'')$. The parameter θ'' are the long-run coefficients, while δ'' are the short-run coefficients.

4.8. Estimation.

In this section, I first investigate the stationary level of variables to establish whether they are I(0) or I(1). Then, I check whether the panel data are co-integrated in order to ensure that the long-run relationship between variables exists. Finally, I present the estimation results of the error correction models

4.8.1. Unit Root Tests.

To investigate the stationary level of variables, I apply Maddala and Wu (1999) (henceforth MW test) and Im-Pesaran-Shin (2003) (henceforth IPS test) tests. The null hypothesis is that all panels contain unit roots. The alternative hypothesis is based on the heterogeneity specification that some panels (or at least one panel) are stationary. These tests differ from unit root tests in the time series since the MW and the IPS tests take into account the heterogeneity between different merchant sectors. Table (4.12) reports the results of the MW and the IPS tests. The table shows that Log (P) and Log (Totexp) are stationary, while Log (MSC), Log (IF), Log (NC), Log (VolPOS), and Log (POS) are integrated of order one. Nevertheless, all variables are stationary after taking first differences.

Table 4.12. Panel unit root test.

Variables	**Levels**				**First differences**			
	IPS With trend		**MW With trend**		**IPS With trend**		**MW With trend**	
	Test value (w-t-bar)	P-value	Test value (Chi2)	P-value	Test value (w-t-bar)	P-value	Test value (Chi2)	P-value
Log(P)	-3.987	0.00	108.12	0.00	-13.39	0.00	235.098	0.00
Log(MSC)	1.81	0.965	8.4	9.88	-6.09	0.00	150.88	0.00
Log(IF)	0.668	0.748	10.35	0.961	-6.75	0.00	219.28	0.00
Log(NC)	6.98	1.00	0.248	1.00	-5.32	0.00	114.2	0.00
Log(Totexp)	-1.83	0.03	31.24	0.052	-3.54	0.08	30.24	0.00
Log(VolPOS)	2.912	0.998	3.181	1.00	-18.91	0.00	370.64	0.00
Log(POS)	5.414	1.00	0.664	1.00	-22.47	0.00	468.45	0.00

4.8.2. Co-integration Test.

The relationship of co-integration is examined by Westerlund's ECM test (Westerlund (2007)). The null hypothesis is that co-integration does not exist. The logic is to test the null hypothesis by establishing whether an error correction exists for at least one sector or for the panel as a whole. This test contains four panel cointegration tests. Pa and Pt tests are designed to test the hypothesis that the panel is co-integrated as a whole, while Ga and Gt tests are designed to test that at least one merchant sector is co-integrated. The results of the four tests reveal that series are co-integrated (table 4.13).

Table 4.13. Panel co-integration test.

Statistic	Westerlund ECM panel co-integration tests		
	Value	z-value	p-value
Gt	-6.7	-13.26	0.00
Ga	-25.66	-4.47	0.00
Pt	-42.088	-29.63	0.00
Pa	-55.11	-16.29	0.00

Note: Results are obtained by applying 'xtwest' command in Stata.

4.8.3. The MG, PMG, and DFE Results.

The results of the unit root tests and co-integration test ensure that the available data are stationary after taking first differences and characterised by a co-integration process. Therefore, Pesaran, Shin, and Smith's (1999) approach is appropriate to examine the effect of IF changes on MSC, card payment usage and the retail prices. Here, I show the results of the PMG, the MG, and the DFE estimators for error correction models (4.17), (4.19), and (4.21).

The results of the estimation of equation 4.17 are reported in table (4.14). The table contains the results of the three estimators along with the Hausman test to compare the efficiency and consistency among the estimates. The results of the Hausman tests show that the PMG is preferred to the MG and DFE. Therefore, the analyses of parameters rely only on the results obtained with this estimator. The error correction coefficient is significantly negative, proving the reliability, consistency and efficiency of the long-run relationship between the variables. The results indicate that all variables' coefficients are significant in the long-run, while they are not significant in the short-run. The IF has a positive impact on the MSC in the long-run. In the results of the PMG estimator, the long-run coefficients are the same across merchant sectors and show that a 1% change in the IF will result in a change in the MSC of 0.41% in the long-run in all merchant sectors. The IF reduction is passed into the merchant through the lower MSC. This result is consistent with Ardizzi and Zangrandi (2018). In contrast, in the short run, the IF has no significant effect on the MSC which can be explained by the existence of agreements between acquirers and merchants on the MSC level that are unlikely to be re-negotiated immediately (Ardizzi and Zangrandi (2018), Evans et al. (2011)). The number of POS has a negative impact on the MSC in the long-run, since increasing the transaction volumes results in lowering costs per transaction. The number of cards has a positive effect on the MSC, since an increase in the number of cards leads to merchants having more incentives to accept cards and that causes an increase in the MSC in the long-run. However, its effect is not significant in the short-run.

Table (4.15) reports the estimation results of the effect of IF changes on card payment usage in the short- and long-run. The Hausman test confirms that the PMG is a more efficient estimator than the MG and the DFE. Therefore, the focus is on interpreting the results of the PMG estimator. The error correction coefficient is significantly negative, proving the efficiency of the long-run relationship between the variables. As shown in the table, the IF has a positive significant effect on card payment usage in the long-run. This result implies that an IF reduction leads to losing revenue for the issuer who, in turn, may compensate this loss by increasing the membership fees paid by cardholders and/or decreasing their card rewards. Facing higher membership fees or lower rewards, some cardholders will stop using cards, which would lead to a decrease in the card payment usage. Based on the PMG estimates, the long-run equilibrium relationships between the IF and card payment usage are the same across merchant sectors. The intuition is that the common reduction of the IF influences all sectors in a similar way. It can be concluded that in the long-run, irrespectively of the merchant sector, a lower

IF results in decreasing card payment usage by cardholders. The NC has a negative significant effect on card usage, showing that there are dis-economies of scale in the issuing market: marginal costs increase as the number of processed cards rises. Therefore, it results in increasing the membership fee and decreasing card usage. The variable POS has a positive effect on card usage in the long-run. Through the membership externality effect, more card acceptance results in more card payment usage by the cardholder which leads to expanding card transactions. This result is in line with the one obtained by Carbo-Valverde et al. (2016). They found that the impact of a 1% increase in merchant's acceptance on debit card usage is 0.44% and on credit card usage is 0.28%. My result, for both types of cards, lies exactly in the middle of the two values estimated by Carbo-Valverde et al. (2016). Finally, the negative impact of total expenditure on card usage could be explained by cardholders choosing alternative methods of payment when their costs increase. In the short-run, the IF and the NC have significant effect on card usage, while the POS has no significant effect.

I now turn to the analysis of the effect of the IF on retail prices, taking into account the impacts that arise from the two sides of the market. The results of the estimation of equation 4.21 are reported in table (4.16). The Hausman test favours the PMG over MG and DFE. Therefore, once again, the focus is on the results of this estimator. The table shows that the PMG estimates of all variables are significant in the long-run, but they are not so in the short-run. The error-correction term proves the existence of the long-run relationship across merchant sectors. Total expenditure has a positive impact on retail prices both in the short- and long-run, as it captures changes in retail prices due to the changing demand of products and services. Also, it shows the effect of the economic cycle on retail prices.

Impact of IF changes from the merchant side.

In the long-run, there is a direct relationship between the MSC and retail prices. The results show that a 1% decrease in the MSC results in a 0.065% reduction in retail prices in the long-run. Taking into consideration the results provided in table (4.14) in the long-run, it can be computed that a 1% reduction in IF will induce a 0.027% reduction in retail prices in the long-run since $\frac{\partial P}{\partial IF} = \frac{\partial P}{\partial MSC}\frac{\partial MSC}{\partial IF} = 0.065 * 0.41 = 0.0266$. It should be noted that merchants benefit from the IF reduction with a 41% reduction in the MSC. In contrast, in the short run, the PMG estimator produces the inverse relationship between the MSC and retail prices but this relationship is not significant. Recalling the results provided in table (4.14), I can conclude that the IF reduction has no significant effect on retail prices in the short-run.

Impact of IF changes from the cardholder side.

Table (4.16) shows that card payment usage has a positive impact on retail prices in the long-run. Recalling the results provided in table (4.15), where it was found that a lower IF leads to a reduction in card usage in the long-run, and taking into account the effect of a change in card payment usage on the retail prices, I can observe that reducing the IF leads to a decrease in retail prices from the cardholder side in the log-run. A 1% reduction in IF will decrease retail prices by around 0.004% in the long-run since $\frac{\partial P}{\partial IF} = \frac{\partial P}{\partial VolPOS}\frac{\partial VolPOS}{\partial IF} = 0.55 * 0.008 = 0.004$. As regards the short-run relationship, card payment usage has no significant effect on retail prices. Considering the results reported in table (4.15) in the short-run, I can conclude that the IF reduction has no significant effect on retail prices.

The total effect of IF changes on retail prices.

The total effect of the IF on retail prices depends on the magnitude of these two effects. In the long-run, I find that a 1% reduction in IF leads to a 0.0266% reduction on retail prices from the merchant side and additional 0.004% from the cardholder side, which gives the total effect around 0.03%. The data obtained from the Bank of Spain has shown that there is a sharp decline in the IF from 0.63 to 0.16 (74% drop) on average among all merchant sectors after the regulation 2014 in Spain. Therefore, based on the results of this chapter, a 74% reduction in the IF leads to a decrease in retail prices by 2.256% in the long-run. The annual inflation rate and annual cumulative inflation rate among 10 different merchant sectors are reported in table (17). By comparison of these results with the annual cumulative inflation rate, I find that the overall impact of a 74% reduction in IF was almost the same as the annual cumulative inflation rate over the period 2008-2019.

In short, the IF changes affect retail prices. According to the availability of data, this chapter provides strong evidence that the RDL 8/2014 and the EC regulation 2015, which led to IF reductions, has significant effect on reduction of the MSC and retail prices in the long-run.

Table 4.14. The merchant service charge model.

PMG, MG, and DFE estimates and Hausman tests

Estimator		**Pooled Mean-Group estimator (PMG)**		**Mean-Group estimator (MG)**		**Dynamic Fixed Effect (DFE)**	
Variable		Coef.	Std.Error	Coef.	Std.Error	Coef.	Std.Error
Long-run effect							
	Log(IF)	0.41*	0.015	0.24*	0.043	0.52*	0.08
	Log(POS)	-0.25**	0.044	-0.308*	0.079	0.58**	0.27
	LOG(NC)	0.42*	0.087	0.76*	0.115	0.75***	0.42
Short-run effect							
	Error correction	-0.205*	0.075	-0.46*	0.055	-0.102*	0.017
	Δ(Log(IF))	-0.038	0.031	-0.077*	0.026	-0.01	0.011
	Δ(Log(POS))	0.027	0.048	-0.072	0.047	-0.073	0.051
	Δ(Log(NC))	0.011	0.159	-0.48*	0.132	0.201*	0.19
	Constant	0.24*	0.081	0.115	0.533	-1.12	0.21
Number of observations		440					
Log Likelihood		888.7466					
Hausman test[1] (PMG or MG)		7.61 (p-value: 0.054)					
Hausman test[2] (PMG or DFE)		0.84 (p-value: 0.839)					

Note:*, **, and *** indicate significance at 1%, 5%, and 10%, respectively. Estimations are obtained by applying the 'xtpmg' command in Stata. For the DFE approach, intra-sector correlation in the computing standard errors is performed with the cluster (id) option.1PMG is efficient than MG under the null hypothesis at the conventional levels of significance.2PMG is efficient than DFE under the null hypothesis at the conventional levels of significance.

Table 4.15. The Card payment usage model.

PMG, MG, and DFE estimates and Hausman tests

Estimator		**Pooled mean-group estimator (PMG)**		**Mean-group estimator (MG)**		**Dynamic Fixed Effect (DFE)**	
Variable		Coef.	Std.Error	Coef.	Std.Error	Coef.	Std.Error
Long-run effect							
	Log(IF)	0.008*	0.001	0.007**	0.003	0.006*	0.001
	Log(NC)	-0.21*	0.011	-0.12*	0.034	-0.22*	0.012
	Log(POS)	0.36*	0.007	0.33*	0.017	0.35*	0.007
	Log(Totexp)	-0.02*	0.004	-0.09*	0.019	-0.012*	0.004
Short-run effect							
	Error correction	-0.43*	0.003	-0.48*	0.018	-0.42*	0.021
	Δ(Log(IF))	-0.006*	0.0004	-0.006*	0.001	-0.005	0.001
	Δ(Log(NC))	0.068*	0.012	0.046*	0.016	0.07*	0.024
	Δ(Log(POS))	-0.16	0.0013	-0.16*	0.003	-0.16*	0.006
	Δ(Log(Totexp))	0.0003	0.041	0.015	0.057	0.01	0.007
	Constant	-1.76*	0.012	-1.65*	0.103	-1.7*	0.084
Number of observations		410					
Log Likelihood		1641.034					
Hausman test[1] (PMG or MG)		0.07 (p-value: 0.999)					
Hausman test[2] (PMG or DFE)		0.00 (p-value: 1.00)					

Note:*, and ** indicate significance at 1%, 5%, respectively. Estimations are obtained by applying the 'xtpmg' command in Stata. For the DFE approach, intra-sector correlation in the computing standard errors is performed with the cluster (id) option. [1]PMG is efficient than MG under the null hypothesis at the conventional levels of significance.[2]PMG is efficient than DFE under the null hypothesis at the conventional levels of significance.

Table 4.16. The retail price model.

PMG, MG, and DFE estimates and Hausman tests

Estimator		**Pooled mean-group estimator (PMG)**		**Mean-group estimator (MG)**		**Dynamic Fixed Effect (DFE)**	
Variable		Coef.	Std.Error	Coef.	Std.Error	Coef.	Std.Error
Long-run effect							
	Log(VolPOS)	0.55*	0.102	-0.70	1.08	1.44*	0.316
	Log(MSC)	0.065*	0.018	-0.37	0.29	0.153**	0.074
	Log(Totexp)	0.13*	0.017	0.34**	0.162	-0.042	0.066
Short-run effect							
	Error correction	-0.35***	0.198	-0.58*	0.193	-0.36*	0.039
	Δ(Log(VolPOS))	-0.18	0.221	-0.201	0.24	-1.69*	0.38
	ΔLog(MSC)	-0.16	0.11	-0.107	0.09	-0.28*	0.070
	ΔLog(Totexp)	0.18	0.149	0.026	0.112	0.067	0.091
	Constant	1.29***	0.72	1.84***	0.99	1.96*	0.309
Number of observations		410					
Log Likelihood		1127.962					
Hausman test[1] (MG or PMG)		5.07 (p-value: 0.166)					
Hausman test[2] (PMG or DFE)		0.09 (p-value: 0.992)					

Note:*, **, and *** indicate significance at 1%, 5%, and 10%, respectively. Estimations are obtained by applying the 'xtpmg' command in Stata. For the DFE approach, intra-sector correlation in the computing standard errors is performed with the cluster (id) option. 1PMG is efficient than MG under the null hypothesis at the conventional levels of significance.2PMG is efficient than DFE under the null hypothesis at the conventional levels of significance.

Table 4.17. Inflation and annual cumulative inflation rate among 10 merchant sectors in Spain.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Annual cumulative inflation rate
Inflation	5.7	0.1	3.4	4.6	4	1.5	-0.6	0.6	-0.3	2.8	2.4	1.5	2.12%

Source: INE and own calculation.

4.9. Conclusion.

The present chapter has evaluated the effects of the IF reduction on retail prices in Spain in a context of policy changes its level for credit and debit card payments. The objective of these regulations was to achieve a decrease in the MSC and, ultimately, a decrease in retail prices. This chapter has studied the extent to which the IF reduction passes into cardholders through retail prices. Taking into account the two sidedness of the card payment market, the chapter has analysed the effect of the IF reduction on the MSC and card payment usage, and finally the joint impact of changes in the MSC and card payment usage on retail prices. The specification of the econometric model has relied on the error correction based autoregressive distributed lag (ARDL) model. The results show that the main channel by which changes in IF affect retail prices is through the merchant side. However, the impact of IF reduction on card usage has also contributed to reducing prices.

According to my knowledge, this is the first attempt to assess the effect of the IF reduction on retail prices in Spain by focusing on the two-sided market theory in the short- and long-run. The results obtained from the ARDL model provided robust evidence of decreasing the MSC as a result of the IF reduction in the long-run. Merchants have passed some part of their cost reduction to cardholders by deflating retail prices. Furthermore, the results show that the IF reduction leads to decreasing card payment usage, which also results in lower retail prices. The total effect of a 1% reduction in the IF is a 0.03% deflation of retail prices. In the long-run, this finding indicates that the capping IF has been successful in reducing retail prices in Spain. Although there are some limitations which can be due to its reliance on aggregate data this chapter sheds new light on examining the comprehensive effects of capping the IF.

4.10.Appendix.

The following tables show the Schwarz Bayesian Criterion (SBC) test for all variables in each sector.

LnP	Large supermarket (food)		Petrol station		Travel agency		Hotel		Drugstore	
Lag	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	-3.45	-3.45	-1.38	-1.34	-1.93	-1.89	-1.78	-1.74	-3.76	-3.72
1	-7.41*	-7.41*	-2.76*	-2.68*	-2.38*	-2.22*	-1.86	-1.78	-7.93	-7.85
2	-7.38	-7.38	-2.74	-2.61	-2.28	-2.16	-1.94	-1.82	-7.99*	-7.87*
3	-7.40	-7.40	-2.71	-2.55	-2.29	-2.21	-2.55*	-2.39*	-7.97	-7.81
Lag	Restaurant		Transport		Jewelry		Postal-service		Retailers	
	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	-3.93	-3.89	-2.01	-1.97	-1.06	-1.02	-1.27	-1.23	-2.24	-2.2
1	-9.94	-9.86	-5.50*	-5.42*	-5.50	-5.42	-4.81*	-4.73*	-4.7*	-4.53*
2	-10.4*	-10.28*	-5.47	-5.35	-5.99	-5.87*	-4.79	-4.66	-4.62	-4.5
3	-10.37	-10.21	-5.43	-5.27	-6.01*	-5.85	-4.77	-4.61	-4.40	-4.31

Lnmsc	Large supermarket (food)		Petrol station		Travel agency		Hotel		Drugstore	
Lag	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	0.46	0.51	0.23	0.27	-1.27	-1.23	-0.96	-0.91	0.54	0.58
1	-2.64	-2.56	-3.29	-3.20	-2.96*	-2.88*	-3.64*	-3.56*	-3.36*	-3.27*
2	-2.73*	-2.61*	-3.34*	-3.22*	-2.92	-2.79	-3.59	-3.46	-3.31	-3.18
3	-2.72	-2.55	-3.29	-3.12	-2.94	-2.77	-3.55	-3.38	-3.26	-3.09
Lag	Restaurant		Transport		Jewelry		Postal-service		Retailers	
	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	0.21	0.25	-2.49	-2.44	-0.4	-0.36	0.42	0.46	2.30	2.34
1	-4.23	-4.14*	-3.37*	-3.28*	-3.85*	-3.72*	-3.105*	-3.01*	-0.21*	-0.12*
2	-4.25	-4.12	-3.32	-3.19	-3.80	-3.68	-3.102	-2.97	-0.16	-0.04
3	-4.29*	-4.12	-3.33	-3.16	-3.81*	-3.686	-3.055	-2.88	-0.12	0.04

lnIF	Large supermarket (food)		Petrol station		Travel agency		Hotel		Drugstore	
Lag	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	1.81	1.90	1.80	1.84	1.95	1.99	2.23	2.27	2.59	2.63
1	-0.60*	-0.52*	-0.6*	-0.51*	-0.65*	-0.56*	-0.32*	-0.24*	0.08*	0.17*
2	-0.56	-0.43	0.55	-0.43	-0.60	-0.48	-0.27	-0.15	0.13	0.25
3	-0.51	-0.35	-0.51	-0.34	-0.55	-0.39	-0.23	-0.07	0.17	0.34
Lag	Restaurant		Transport		Jewelry		Postal-service		Retailers	
	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	2.54	2.58	1.74	1.78	2.33	2.37	2.4	2.44	-2.25	-2.21
1	0.08*	0.16*	-0.83*	-0.75*	-0.25*	-0.17*	-0.19*	-0.10*	-6.25	-6.16
2	0.13	0.25	-0.78	-0.66	-0.21	-0.08	-0.14	-0.02	-7.58*	-7.45*
3	0.17	0.34	-0.74	-0.58	-0.16	-0.002	-0.1	0.062	-7.53	-7.36

Lntotexp	Large supermarket (food)		Petrol station		Travel agency		Hotel		Drugstore	
Lag	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	-5.50	-5.46	-2.52	-2.48	-1.41	-1.37	-0.96	-0.92	-0.08	-0.05
1	-7.73	-7.64	-4.80	-4.71	-4.86*	-4.73*	-5.99*	-4.97*	-2.23*	-2.17*
2	-8.92*	-8.79*	-5.85*	-5.72*	-4.85	-4.70	-5.94	-5.86	-2.17	-2.096
3	-8.88	-8.71	-5.80	-5.63	-4.81	-4.64	-5.88	-5.77	-2.12	-2.015
Lag	Restaurant		Transport		Jewelry		Postal-service		Retailers	
	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC	AIC	SBIC
0	-2.17	-2.13	-1.78	-1.73	-0.27	-0.22	-0.57	-0.53	-2.25	-2.21
1	-5.37	-5.29	-4.68*	-4.60*	-3.65	-3.56	-1.51*	-1.42*	-6.25	-6.16
2	-6.9*	-6.77*	-4.62	-4.50	-4.20*	-4.07*	-1.47	-1.34	-7.58*	-7.45*
3	-6.85	-6.68	-4.58	-4.41	-4.18	-4.01	-1.42	-1.25	-7.53	-7.36

Lag	Lnnc	
	AIC	SBIC
0	-2.71	-2.67
1	-5.816*	-5.69*
2	-5.781	-5.61
3	-5.75	-5.51

Lag	LnPOS	
	AIC	SBIC
0	-0.20	-0.16
1	-3.37*	-3.21*
2	-3.14	-3.0612
3	-3.18	-3.0614

Lag	LnVolPOS	
	AIC	SBIC
0	-2.78	-2.74
1	-6.98*	-6.82*
2	-6.91	-6.78
3	-6.83	-6.74

Chapter 5

Conclusion

This doctoral dissertation had three main objectives. In chapter 2, I have studied whether the gap between search engines tends to increase or decrease over time. In chapter 3, I have investigated the effects of the SEPA project on competition between banks and welfare. In chapter 4, I have studied how the IF reduction affected retail prices in Spain.

In the second chapter, I have studied competition between two asymmetric search engines in a dynamic investment game. The main focus was to analyse under which conditions asymmetry between search engines tends to widen or narrow over time. I have considered a game where two search engines simultaneously invest in R&D to improve the quality of search services. I have applied the open-loop strategy where both search engines made decisions on the amount of R&D investment at the initial date and they could not change their decisions once the game evolves. I have found there is symmetric steady-state where both search engines had the same quality and invest symmetrically on R&D. I have shown that when steady-state is characterised as a saddle point, under different conditions, there is the optimal path that converges to the steady-state. In this case, the asymmetry between search engines narrowed over time and the low quality search engine could catch up the high quality one. I have further shown that increasing dominance with monopolisation is possible. Then, I have studied a dynamic investment game for a monopoly. I have found some conditions that the paths of quality and R&D investment converge to the steady-state equilibrium. The results of this chapter showed that the monopolist or dominant search engine had an incentive to invest in R&D to improve the quality of search result. Therefore, any regulation that would affect the future profitability of search engines might have an impact on the incentive to invest in R&D. The comparison of two models indicated that monopolist invests less in R&D relative to the search engines in the competitive environment. However, a further research is needed to apply the closed-loop strategy where search engines do not commit themselves to a particular path at the initial and can response to different qualities they observed.

In the third chapter, I have analysed the effect of SEPA project on competition between two asymmetric banks. To find the effect of SEPA, I have compared the pre-SEPA phase where payment systems were nationally diversified and banks were allowed to discriminate between transaction prices of domestic and cross-border payments and post-SEPA phase where the national payment systems were homogeneous across countries and banks applied uniform pricing for making domestic and cross-border payments. The results have shown that the transaction prices were set at the marginal costs. The transaction pattern had a vital role in the competition between banks in post-SEPA. This means that if transaction pattern was domestically oriented, then competition between banks was less intense in post-SEPA. Further analyses have shown that the cost saving through relatively large economies of scale led to vanishing asymmetries between banks. In this case, SEPA was pro-competitive and helped the small bank to catch up and obtain the same profit as the large bank. In contrast, for sufficiently small economies of scale, the large bank cornered the market as it had market share around 1, and the small bank lost almost all its market share. However, further research would examine the enhancing cross-border competition due to a lower entry barrier (as a consequence of SEPA) in the payment market.

In the fourth chapter, I have empirically evaluated the effect of the IF reduction on retail prices in Spain. By applying the two-sided market theory, I have shown how the IF reduction affected retail prices from the merchant side and the cardholder side. I have applied the dynamic heterogeneous panel data technique proposed by Pesaran, Shin, and Smith (1999) that allowed me to study the short- and long-run effects of the IF changes on retail prices. In the long-run, the results have indicated that the IF reduction led to a lower cost of accepting cards through decreasing the MSC. Merchants passed some part of the MSC reduction to cardholders by decreasing retail prices. On the other side of the market, the lower IF led to cardholders had less incentive to choose card payment method resulting in lower card usage. Consequently, it led to lower retail prices. The accumulated effect of the two sides has shown that a 1% reduction in the IF led to a 0.03% reduction in retail prices. In the short-run, the IF reduction has not had a significant effect on retail prices. Although there are some limitations due to the lack of data related characteristics of acquirers and issuers, and the membership fees, I believe this chapter could shed new light on examining the comprehensive effects of the IF reduction.

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