The Effects of Switching Costs over the Pricing Strategies of Operators in Mobile Telecommunications Market

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Submitted to the Graduate School of Arts and Sciences
in partial fulfillment of
the requirements for the degree of
Master of Arts

Sabancı University
August 2008

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DATE OF APPROVAL: 01.08.2008

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Mustafa Koç - Economics, Master Of Arts Thesis, 2008

Abstract

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Supervisors: İzak Atiyas, Toker Doğanoğlu

Keywords: Mobile telecommunications market, switching costs, price discrimination, asymmetric networks, call externality, late entry

This thesis analyzes how the pricing decisions of mobile telecommunication operators are affected in a market where consumers' switching costs exist in favor of the incumbent firm which entered the market earlier. The market consists of two periods such that an incumbent firm owns all consumers in the first period and faces a new entry in the second period. As long as new consumers enter the market in the beginning of the second period, there will be both attached customers who suffer switching costs if they cancel their contract and subscribe to the new entrant and also unattached customers with no switching costs. In addition, the consumers attach value to receiving calls as well as making calls which will be introduced into their utilities by the concept of call externality.

In this context, the incumbent firm will exploit switching costs by increasing off-net prices higher than the new entrant's so that it decreases the attractiveness of the new entrant's network due to the fact that it lowers the amount of calls that a subscriber of the new entrant receives. Therefore, the incumbent firm will be able to manipulate the market dynamics through its tariffs by seizing the opportunity of switching costs. Moreover, this thesis shows that the incumbent's market share increases with the access charges so that the incumbent will prefer higher access charges. In terms of welfare analysis, it would be inferred that switching costs will decrease consumer surplus in both price-discrimination and non-discriminatory prices cases. Therefore, the best practice would be imposition of remedies which eliminate or reduce switching costs in the market.

Abstract

MOBİL TELEKOMÜNİKASYON PAZARINDA GEÇİŞ MALİYETLERİNİN İŞLETMECİLERİN FİYATLANDIRMA STRATEJİLERİ ÜZERİNE ETKİLERİ

Mustafa Koç, Yüksek Lisans Tezi, 2008

Tez Danışmanları: İzak Atiyas, Toker Doğanoğlu

Anahtar Sözcükler: Mobil Telekomünikasyon Pazarı, geçiş maliyetleri, fiyat farklılaştırması, asimetrik işletmeciler, çağrı dışsallığı, pazara sonradan giriş

Bu tez, pazara önceden girmiş olan yerleşik işletmecilerin lehine tüketicilerin geçiş maliyetlerinin bulunduğu bir pazarda, mobil teleko münikasyon işletmecilerinin fiyatlandırma stratejilerinin nasıl etkilendiğini incelemektedir. Söz konusu pazar iki safhadan oluşmaktadır. Birinci safhada yerleşik işletmeci pazardaki bütün tüketicilere sahip olup ikinci safhada pazara yeni giren bir işletmeciyle karşılaşmaktadır. İkinci safhanın başında pazara yeni katılan tüketiciler olacağından, pazarda hem işletmecilerini değiştirmeleri halinde geçiş maliyetlerine maruz kalacak bağlı müşteriler hem de geçiş maliyetleri olmayan bağımsız müşteriler bulunacaktır. Ayrca, müşteriler çağrı yapmanın yanı sıra çağrı almaktan da fayda edinmektedirler ve bu kavram çağrı dışsallığı olarak müşterilerin fayda fonksiyonlarında yer almaktadır.

Bu kapsamdaki çalışmalarımızın neticesinde, yerleşik işletmecinin pazara sonradan giren işletmeciye göre daha yüksek şebeke dışı fiyatlar belirleyerek geçiş maliyetlerinin avantajını kullanacağı görülmektedir. Böylelikle, şebeke dışı çağrı sayısı azalacağndan yeni işletmecinin aboneleri daha az çağrı almakta ve bu durum da aboneler açısından yeni işletmecinin çekiciliğini azaltmaktadır. Dolayısıyla, yerleşik işletmeci geçiş maliyetlerinin avantajını kullanarak pazar dinamiklerini kontrol edebilmektir. Ayrıca, bu tez göstermektedir ki; yerleşik işletmecinin pazar payı arabağlantı ücretlerinin artmasıyla orantılı olarak artış göstermektedir. Bu yüzden yerleşik işletmecinin yüksek arabağlantı ücretleri tercih edeceği söylenebilmektedir. Tüketicilerin refah seviyeleri üzerine yaplan analizin sonucunda ise hem fiyat farklılaştırmasına izin verildiği

hem de şebeke içi - şebeke dışı fiyat farklılıklarına izin verilmediği durumlarda geçiş maliyetlerinin tüketici refahını düşürdüğü görülmektedir. Bu nedenle, pazardaki geçiş maliyetlerini ortadan kaldırmaya veya azaltmaya yönelik düzenlemelerin uygulanmasının en iyi yöntem olacağı söylenebilir.

Bu tez, çalışmalarım sırasında sonsuz sevgisiyle her zaman yanımda olan ve bu zor dönemde hayatıma anlam katan Seray Akkor'a, desteklerini bütün eğitim hayatım boyunca esirgememiş olan annem Gülhanım Koç, babam Mehmet Emin Koç ve kardeşim Aysun Koç'a adanmıştır.

Hepinize sonsuz teşekkürler.

Desteğiniz, anlayışınız, sevginiz ve her şeyden önce varlığınız için...

Sevgilerimle

Mustafa Koç

Acknowledgements

First of all, I would like to thank to all faculty members and administrative staff of Faculty of Arts and Social Sciences of Sabancı University for their assistance throughout my master program. It was a great chance for me to work as a teaching assistant to İzak Atiyas who encouraged me to studying Regulatory Economics in telecommunications industry. Here, I also send my special thanks to my supervisors İzak Atiyas and Toker Doğanoğlu who made great contributions by providing valuable documents, suggestions and solutions during my studies regarding the preparation of this thesis. In addition, I would like to thank especially to TÜBİTAK which provided a significant opportunity to me for the preparation of this thesis by valuable funding during my thesis period. Moreover, Faculty of Arts and Social Sciences of Sabancı University provided a lot of opportunities including funding, accommodation, academic resources and academic assistance which deserve big thanks. Finally, I am very appreciated to all academicians who contributed to my thesis with previous studies and findings whose names are given in the reference page.

In conclusion, I would like to thank all people who either directly or indirectly made contributions to my thesis.

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1 Introduction

In this thesis, on-net and off-net pricing strategies of mobile telecommunication firms will be analyzed under the existence of one-sided consumers switching costs in a telecommunications market where firms are able to apply differentiated prices for on-net and off-net calls. In other words, subscribers of one network, which represents an incumbent firm, will face uniform switching costs if they would like to change their old network and subscribe to the new entrant firm in the telecommunications market presented in the model. Additionally, this paper includes the concept of call externality which is defined as extra utility gained by consumers when they receive calls.

Nowadays, on-net and off-net pricing decisions of telecommunication companies are highly debated in the telecommunications industry especially in the markets in which one of the companies retains competitive advantage compared to other companies as a result of factors such as market share, brand loyalty etc. The situation becomes much more dramatic in the case of existence of an incumbent firm which mostly dominates the market due to an early entry. On the other hand, on-net and off-net pricing strategies have also essential impact over the interconnection balances of companies due to the fact that the firms are able to affect the incoming and outgoing call balances between operators.

Furthermore, this paper will also try to reveal that the existence of switching costs in the telecommunications market affects the firms' pricing decisions to a high extent. It will be examined whether the firms would seize the opportunity of switching costs in order to lock the consumers in to the network and gain extra profit through prices discriminated with the assistance of switching costs.

In this context, regulators may look for an optimal remedy for the firms' pricing structures in order to ensure consumers' well-being. However, the firms who retain the competitive advantage in terms of switching costs would like to transform this advantage into monetary profits. On the other hand, firms without switching cost advantage would require the regulatory bodies to take their competitive disadvantage into consideration while maintaining effective competition. In this context, an important regulatory policy that may be used by the regulators would be to require the mobile operators not to discriminate between the on-net and off-net calls. Therefore, after showing the impact of switching costs on the pricing

strategies of firms in a market where price discrimination is allowed, then I will try to find out the equilibrium pricing strategies of the firms under the obligation of non-discrimination between on-net and off-net prices which would be imposed by regulators as an optimal remedy.

Hence, based on the issues mentioned above regarding the mobile telecommunications market in EU and Turkey, I would argue that retail mobile telecommunications markets with consumers' switching costs could lack effective competition and consequently require necessary regulations. Nice examples for switching costs in other kinds of markets from everyday life could be given as learning costs born when an accustomed brand of automobile is changed or similarly when an accustomed type of keyboard (F or Q basically) is changed, lack of bonus programs and campaigns of a highly used credit card for frequent users, commitment problems arising from penalty fees in the case of cancelation of a long-term contract or agreement, compatibility problems when a complementary product is purchased from another firm different than the current one.

Switching costs will arise in the case that a buyer purchases a particular product during a period of time and would like to switch to another substitute product in the future and finds it costly to switch from the accustomed product to the new one. Therefore, the market in which the effects of switching costs will be analyzed should contain consumers making decisions in different periods. In my model, the market will be constructed as a two-period market in which one of the firms will represent the incumbent which holds all consumers in the first period and the other firm will represent the new entrant which makes an entry to the mobile telecommunications market in the second period. However, only the choice of firms in the second period will be taken into consideration with the assumption that the incumbent firm in the first period owns the all subscribers in the market. In this setup, consumers of the incumbent firm will bear switching costs in the second period if they would like to change their network and subscribe to the new entrant. Moreover, there will be new consumers entering into the market in the second period who do not have any binding situation to the incumbent and will not have any switching costs as a result. On the other hand, there will be leaving subscribers with the same amount of entering consumers in the second period so that the total number of consumers is kept constant. The existence of both type of consumers with switching costs and without switching costs makes the situation more dramatic and decision process more complex.

Furthermore, network effect is one of the most important factor amplifying the power of a firm in price discrimination. Briefly, network effects are said to exist if a consumer gains extra utility as more people adopt the same good. Thus, network effect in mobile telecommunications would correspond simply to gaining utility from size of subscriber base of the mobile telecommunication firm that one subscribes to. Moreover, network effect becomes very important in price discrimination such that the operators would create price-mediated network externalities. The concept of tariff-mediated network externality is mentioned by Laffont, Rey, and Tirole (1998b) such that a network may discriminate against its rivals. This situation creates an opportunity of shaping the traffic balance between the rivals' network and the own network. Therefore, I argue that the decision of operators regarding price-discriminate or the level of discrimination would depend on the network size of the operators.

Another factor that would influence the decision of operators in price discrimination is the call externality which means that consumers will obtain utility from receiving calls. Since the pricing decisions of operators affect the incentives of consumers in making calls and consequently the level of off-net calls make a contribution to the utility levels of rival operators' consumers, then price discrimination decisions of operators are affected by the existence of call externality. Obviously, call externality is highly related to the size of networks due to the fact that large number of subscribers making more on-net calls would provide a competitive advantage for the operator with larger network. Thus, call externality is assumed to be correlated to the tariff-mediated network externality in short notice. As a result, my model will also include the concept of utility from receiving calls which takes a role in operators' price discrimination decisions.

Briefly, my model includes the concepts of switching costs and call externality in a mobile telecommunication market where firms are able to make price discrimination between on-net and off-net calls. The market is composed of two periods so that there will be both new consumers entering to the market and old ones exiting the market.

In this setting, one of the outcomes of my model is that the incumbent mobile operator has incentive to set higher off-net prices in order to attain its subscribers due to the switching costs. Moreover, it would be inferred that the incumbent operator's incentive to set higher access charges increases as the switching costs

increase. Results of price non-discrimination, which has been suggested as a regulatory remedy, indicates that the incumbent will prefer setting lower per-minute prices and then it takes the consumer surplus created by lower per-minute prices through higher fixed fee. However, this remedy would create traffic and payment surplus for the new entrant in terms of interconnection. In terms of welfare analysis, it turns out that it is difficult to reach general conclusions. However, it can be shown that, by eliminating some of the core market characteristics dealt in this paper such as call externality and asymmetry between the operators resulting from the switching costs, the price discrimination would be welfare-improving for the consumers.

This paper has been organized as follows. A comparative look into the European and Turkish mobile markets is provided in Section 2. Then, Section 3 provides a literature review on the concepts included in this paper. Section 4 presents the model. Section 5 discusses the results and provides findings. The case of non-discrimination is discussed in Section 6. Welfare effects of price discrimination and non-discrimination are analyzed in Section 7. Finally, Section 8 concludes with recommendations for regulatory policy.

2 The European and Turkish Mobile Markets in Comparison

Even though the retail mobile telecommunication markets are in keen interest by regulators, competition authorities, operators, consultants and academicians, those retail markets are not regulated in the member states of the European Union because of the belief that effective competition has been settled in European Union retail mobile telecommunication markets. The factors contributing to the competitiveness of the European Union mobile telecommunication markets could be listed as the implementation of number portability, less time between entry dates of successive operators in the case of sequential entry, necessary remedies from the early dates of the markets regarding the interconnection rates (or most widely-known as access charges), fair policies for the spectrum allocation. All of these factors have been main drivers of effective competition by eliminating endogenous differences between operators and enabling operators to compete on offers and quality. Furthermore, these factors performed significant roles in the elimination of switch-

ing costs by removing the grounds of consumer lock-in. Obviously, retail mobile telecommunication markets with longer incumbency periods, which provide higher degree of first-mover advantage to the incumbent firm, will have more consumers' switching costs as a result. With the purpose of analyzing the effects of factors contributing to the existence of switching costs, it will be beneficial to investigate European Mobile Telecommunications Markets and Turkish Mobile Telecommunications Markets in more detail. Thus, the following two sub-chapters will help understand the reasons of switching costs and lack of effective competition.

2.1 European Union Mobile Telecommunications Markets

Mobile telecommunications services in the European Union were initiated in 1980s with the introduction of first generation (1G) analogue mobile systems. However, the problems such as incompatibility, low quality and security, capacity constraints existed during the era of first mobile systems. In the late 1980s and early 1990s, second generation (2G) digital mobile technologies were invented and common standards named GSM-900 and DCS-1800 have been developed by European Union countries. In this context, licenses for 2G mobile telecommunications services were granted to several operators in each country in order to encourage competition and move away from monopolies. With reference to the penetration rates in EU countries in the early years of introduction of 2G mobile telecommunications services, it would be argued that the implementation was quite successful.

Due to the enhancement of European economic integration, European commission required the development of a competitive pan-European liberalized telecommunications sector. In this context, the Commission called for a common regulatory framework for telecommunications services in 1994. The body of regulations that have progressively emerged during the 1990s is often referred as the "1998 Regulatory Framework". With reference to 1998 Regulatory Framework, the European Commission has been responsible for developing a common regulatory framework and monitoring the implementation of the common framework in the member states. Therefore, all member states have been obliged to establish national regulatory authorities (NRAs) which would be responsible for the implementation of EU regulations within the member states. More precisely, NRAs are responsible for the establishment of a competitive telecommunications market while protecting consumers' rights and encouraging the innovation in the industry. The most important development in 1998 regulatory framework concerning the regulatory

tools was the designation of operators as having significant market power (SMP). Accordingly, SMP operators would be obliged to charge non-discriminatory, transparent and cost-oriented prices in the market where they are designated as having SMP. In addition, those operators are obliged to provide access for other operators which would like to end calls in their networks and prepare cost accounting reports for the sake of transparency. As a result of those regulatory measures, a more competitive market structure was achieved which resulted in lower prices, high variety and quality of mobile services according to Grzybowski(2005) which provides a seminal work on the effects of EC regulations over the competitiveness of the mobile telecommunications markets. In those years, independent of 1998 framework, the mobile number portability regulations were imposed by member states which would be argued to decrease the switching costs and consequently contributed to the emergence of lower prices. Concerning the further harmonization of the regulatory measures in member states, the European Commission renewed the regulatory framework in 2002 by publishing new directives. In this context, the new 2002 Framework Directive constituted the backbone for the other regulatory directives and the Commission's recommendations. First of all, after significant supervision, the Commission determined the markets which are susceptible to ex-ante regulation due to the fact that effective competition has not been established in those markets yet and the Commission published Relevant Markets Recommendation, in which 18 markets are determined in either wholesale and retail level for both fixed and mobile sectors. Within the relevant markets, two of them are related to mobile markets: Market 15 is Mobile Access and Call Origination Market and Market 16 is Mobile Call Termination Market. The relevant markets are defined as the markets which lacks effective competition and requires regulatory supervision so that NRAs should determine the SMP operators in those markets at national level and impose necessary obligations compliant with the Commission's directives. In this context, operators determined as having SMP in the relevant markets are obliged to provide non-discriminatory access and cost-oriented call termination or origination prices within the Interconnection and Access Directive. Additionally, the Commission published Universal Service and Users' Rights Directive which ensures the consumers' benefits such as receiving equal access conditions to mobile services and opportunity to change their operators while retaining their numbers. Thus, the Commission introduced the obligation that NRAs should make Number Portability available for all subscribers within new framework in 2002. On the other hand, no retail market has been determined as a relevant market so that

retail markets are not subject to regulatory supervision due to the fact that retail mobile telecommunications markets are competitive enough in Europe. However, significant competition infringements are expected to be solved through ex-post regulations which require taking necessary actions compliant to competition law after a competition infringement is observed.

In relation to the competitiveness of the mobile markets in the EU, I will provide the studies that examine the factors contributing to the competitiveness of the mobile markets. One of the most important factors strengthening the competitiveness of the mobile markets would be the implementation of Mobile Number Portability. Since the main focus of this paper is the effects of switching costs over the pricing strategies of the operators, then the effects of number portability over prices would constitute a representative figure for my study. Grzybowski (2008) examines the effects of regulatory measures over price levels where those measures are fixed-line telephony liberalization and the implementation of number portability by also taking the startup time of GSM services into consideration. He states that price levels depend on the market concentration and the number of competitors which vary between countries due to the differences in the implementation of regulations. In his paper, he uses a structural model for supply and demand to estimate country-specific price elasticities and conjectural variations which include number of operators, GDP levels, bond returns, labor and electricity costs. As a result of the model he finds out that the regulatory variables decrease conjectural variations. This result indicates the negative impact of number portability on price levels. Regarding that the EC and industry regulators often interpret cross-country price variation as differences in competitiveness, Grzybowski (2008) concludes that the competitiveness of the mobile industry varies over time due to the differences in the implementation of regulation by pointing out that the liberalization of fixed-line telephony market and the introduction of mobile number portability have significant negative impact on conjectural variations that lead to lower prices. Furthermore, Grzybowski (2005) measures the impact of regulatory variables on price levels and demand for mobile services where the regulatory variables could be listed as the introduction of number portability, regulation of interconnection charges and presence of airtime resellers (such as MVNOs). He constructs an econometric model which also includes inverse of the number of mobile operators as explanatory variable and time trend variable in order to take rapid technological change into consideration. Grzybowski (2005) finds out that competition is fiercer and prices are lower in coun-

tries that already enforce the portability of mobile numbers and MNP also raises consumer surplus. He concludes that the implementation of number portability in the mobile telephony has a negative impact on prices and on the other hand regulation of interconnection charges through the designation of mobile operators with SMP increases the demand for mobile telephony possibly because regulation decreases prices and costs however any significant direct impact of this regulatory variable on prices has not been found.

In conclusion, it would be argued that the retail mobile telecommunications market is not regulated through regulations of the EC due to the fact that effective competition has been established in retail markets through the implementation of mobile number portability and effective control on interconnection charges through SMP designations. These regulatory measures are proved to have negative impact on prices and increasing effect on consumer surplus through establishment of effective competition. Therefore, the European retail mobile telecommunications may not require regulatory supervision unless there are significant competition infringements.

2.2 The Turkish Mobile Telecommunications Market

In Turkey, Mobile Telecommunications Services started being provided in 1994 by two mobile network operators, Turkcell and Telsim, through revenue sharing agreements with Turk Telekom. Then, Turkish Mobile Telecommunications industry faced a duopoly period until the entry of Aria and Aycell in 2000. However, after the long incumbency period and due to the lack of effective regulatory policies such as national roaming which was promised to TIM, new entrants were not able to compete effectively with well-established incumbents. As a result of lack of effective competition in the market, Aria and Aycell decided to merge in 2004 in order to survive and compete with the incumbent operators in a more effective way.

First of all, regarding concentration indexes compared to those of EU-15 member states, it would be argued that effective competition in Turkish retail mobile market has not been established yet, by 2008. The reasons behind the poor performance of Turkish market would be mainly specified as structural problems related to the regulatory policies in the early years of the market. Seminal work in the literature, which examines the historical development of Turkish Mobile Telecommunications Market and the effects of regulatory policies in this market, is Atiyas and Doğan

(2007). In that paper, they argued that longer incumbency period often implies larger asymmetries between the incumbents and the late entrants in terms of (i) geographical coverage and (ii) subscriber base and both asymmetries feed the first-mover advantage of the incumbents. Briefly, their arguments centered around the idea that first-mover advantages are amplified by the existence of tariff mediated network externalities and switching costs and the degree of first-mover advantage increases with the length of the incumbency period. In this context, it would be beneficial to summarize the arguments stated by Atiyas and Doğan in order to examine the situation in Turkish Mobile Telecommunications Market since the structural problems mentioned in that paper constitutes the main motivation of my paper. Furthermore, it would be appropriate to state that the conjecture discussed in Atiyas and Doğan (2007) will be confirmed in this paper.

According to Atiyas and Doğan (2007), the Turkish mobile industry is one of the most concentrated markets in Europe; the penetration rate positioned as the second lowest among the OECD countries and the price comparisons for the mobile market indicate that Turkey had one of the highest mobile telecommunication prices among the OECD countries in 2004. In particular, the paper emphasizes the negative impact on competition of delaying new entry until after 7 years of incumbency. It would be beneficial to provide a historical background of Turkish Mobile Telecommunications Market which has been initiated through GSM licenses awarded to Turkcell and Telsim in 1994. At the beginning, those licenses were revenue sharing agreements with Turk Telekom until 1998 which is the start year of the concession agreements for both operators that have been signed in exchange for 500 million $. As a result of this change there has been a significant increase in customer base after 1998. Throughout the early years of the market, Turkcell gained a significant first-mover advantage over Telsim due to the fact that Turkcell entered the market a few months before Telsim and more importantly Telsim's activities were suspended for eight months by reason of violation of revenue agreement. Therefore, Turkcell dominated the market in the early years of the market both in terms of revenue and market share such that Turkcell's market share reached up to 80 % in those years (Please refer to Table 2 in Atiyas and Doğan (2007) for the evolution of market shares in Turkish Mobile Market.)

In 2000, the Government decided to award three additional GSM licenses. One of those licenses were to be awarded to Turk Telekom and two separate tenders were planned for the the remaining two licenses. However, Turkish GSM auction

design took a place for itself in the economics literature as a bad auction according to Binmore and Klemperer (2001). The GSM license award process was designed as follows: the winning bid of the first tender was going to be the minimum bid for the second tender and Turk Telekom had to pay the same price for the third license. Nonetheless, there had been no participant for the second tender since the first tender had been won by İş-TIM with a bid of 2.5 billion $ which was deemed to be very high. This situation caused the license fees of the new entrants - Aria (the brand of İş-TIM) and Aycell (the mobile subsidiary of Turk Telekom) - to be five times as high as those of the incumbents. As a result of the new entries, Atiyas and Doğan (2007) states that penetration rates in Turkish mobile market increased significantly following the entry as well as substantial decrease in per-subscriber revenues from 216 $ to 114 $ could be attributed to the entry.

In order to facilitate the entry, the Government allowed İş-TIM to sign national roaming agreements with other operators. However, both of the incumbent operators either did not provide national roaming or offered unacceptable conditions for the new entrants so that Aycell and Aria were not able to effectively compete in geographical coverage. As a result, Aria and Aycell decided to merge in 2004 and constituted the brand "Avea".

With the purpose of providing the reasons behind the structural problems in Turkish mobile market, I am going to summarize the arguments stated in Atiyas and Doğan (2007) and analyze the effects of those structural problems over competition. First, the concentration index computed as Herfindahl-Hirschman Index (HHI)would provide an idea about the competition level of Turkish mobile market. By the end of pre-merger period, Turkey had the second highest market concentration index, 0.51, among the OECD countries that had 4 MNOs and a higher index than other all other OECD countries that had 3 operators stated by Atiyas and Doğan (2007). In addition, I also conducted similar analysis using the current market shares of mobile operators in EU-15 countries so that Turkey had the second highest concentration index among those countries (Please refer to appendix for comparative concentration index table). Even though the entry had driven up the mobile penetration, Turkey stood as the second lowest among all OECD countries with respect to mobile penetration rates by the end of pre-merger period. Similarly, the same analysis has been performed for EU - 15 countries and Turkey with the current values and it has been showed that Turkey has the lowest penetration rate compared to EU - 15 countries. It would be beneficial to analyze factors that affect

consumers subscription choice, which in turn affects the degree of competition, as mentioned in Atiyas and Doğan (2007) . Since those factors are also structural problems in Turkish mobile market, a suitable background for the motivation of this thesis will be provided. Briefly, those structural problems observed in Turkish mobile market could be listed as lack of national roaming which created slower network roll-out and geographical coverage disadvantages for the new entrants, lack of regulations in the early years of the entry regarding interconnection rates that resulted payment imbalance in terms of interconnection payments, high switching costs of subscribers due to long incumbency period, lack of number portability regulation, price-discriminated tariffs offered by the dominant firm which caused traffic imbalances through network externalities.

In the early years of the entry, geographical coverage was one of the most important first-mover advantages for the incumbents. The setting of a market with sequential entry is described by Atiyas and Doğan (2007) such as: incumbents have already built their network and reputation, locked-in some customers, and face smaller new entrants for competition. They further argue that incumbents are likely to deny roaming if new entrants find it difficult to reach the critical subscriber base in the absence of roaming. In line with these arguments, the same situation was realized in Turkish mobile market. In Turkey, the new entrants license conditions required them to make necessary investments in order to reach a coverage ratio of 50% in 3 years and 90% in 5 years except the coverage gained by national roaming. Therefore, the national roaming right granted to new entrants would be considered as a temporary remedy to facilitate entry. Since concession agreements of the incumbents did not include any roaming obligations, the incumbents did not provide national roaming for the new entrants. Therefore, with their low coverage, Aria and Aycell had to compete against the incumbents which almost reached full coverage due to a long incumbency period.

In case that operators are allowed to discriminate prices between on-net and off-net calls, operators tend to set higher off-net prices than on-net prices in order to create a network externality effect which creates incentive for customers to join the same network with their close friends or relatives. In Turkish mobile market, the effect of network externality has arisen as a result of both interconnection rates and retail tariffs. In this context, entry in Turkish mobile market constitutes a good example for the literature of entry deterrence such that the incumbents both increased interconnection rates significantly whenever entry occurred and launched

new tariffs which included significantly discriminated on-net and off-net prices. Therefore, I will provide the historical evolution of interconnection rates in Turkish mobile market to point out the effects of interconnection regime over the competitiveness of market. In 1998, after the operators granted GSM licenses, they also signed interconnection agreements with each other and Trk Telekom so that mobile termination rates were set as 1.4 $-cents/min symmetrically. The incumbents mobile operators continued to charge interconnection rates at this level until March 2001 when the first new entrant Aria entered the market. Regarding the retail prices in those years, I would argue that operators gained excessive profits through very high retail tariffs compared to too low interconnection charges in the period of duopoly away from the effective competition. In the absence of any regulation regarding interconnection rates, just before the entry of Aria in March 2001, Telsim and Turkcell signed a new interconnection agreement with each other by sharply increasing the interconnection rates to 20 $-cents/min symmetrically. In those years, Telecommunications Authority had been established recently within 2000 and had not published any regulation on access and interconnection so that interconnection rates were set by commercial negotiations between operators. On the other hand, Peitz (2005) proved that asymmetries in favor of late entrants would increase the consumer surplus. Thus, in terms of consumer welfare,it would have been beneficial if TA had intervened the negotiation process and set asymmetric rates between operators regarding their differences in cost elements and competitive power in those years. Following the entry, Aria and Aycell signed interconnection agreements with other operators at symmetric level of 20 $-cents/min as interconnection rate. This significant increase in the interconnection charges would be regarded as a tool for entry deterrence such that Calzada and Valletti (2005) suggest that the incumbents would prefer to deter entry by setting interconnection charges above costs. In May 2003, Telecommunications Authority published Ordinance on Access and Interconnection while imposing asymmetry between operators in favor the late entrants, Aria and Aycell. Following Ordinance on Access and Interconnection, Telecommunications Authority started publishing standard reference interconnection rates for each telecommunication operators. This regulation has also been complemented with the obligation of operators to submit their reference interconnection offers (RIO) so that Telecommunications Authority would utilize these offers for determination of standard reference interconnection rates. As a result of these regulations, Telecommunications Authority has been able to determine interconnection rates of telecommunication operators in case of any dispute between the operators. In this

context, Telecommunications Authority has determined asymmetric interconnection rates in favor late entrants, Aria and Aycell - later merged to constitute Avea. However, throughout the years without any regulation regarding interconnection rates, the symmetric interconnection rates caused payment imbalances between the mobile operators in favor of the incumbents as a result of traffic imbalances created by new discounted tariffs of the dominant operator with significant on-net / off-net price discrimination. Therefore, it would be useful to mention the issue of retail price discrimination of the incumbents since price discrimination affected the revenues in the market to a high extent in the early years of new entries.

Turkish mobile market also contains a suitable example of tariff-mediated network externality. Following the new interconnection rate agreements and just before Aria's entry, Turkcell introduced its tariff packages with price discrimination. With this tariff, the price of on-net calls was reduced to 11 euro-cents/min from 22 euro-cents/min and the price of off-net calls was increased to 33 euro-cents/min from 29 euro-cents/min. The most significant result of significant price discrimination of Turkcell was the traffic imbalance between operators such that the large subscriber base of Turkcell preferred to make large number of on-net calls due to the high difference between on-net and off-net prices. The only suitable response to Turkcell tariffs was to introduce tariffs in which off-net calls are charged even below on-net prices of Turkcell and also below interconnection rates. This strategy was followed by Aria for only for a few months since Aria had to bear losses for off-net calls. In addition, this strategy caused large traffic from Aria subscribers to Turkcell subscribers due to very low off-net prices and very low traffic from Turkcell subscribers due to the significant price discrimination.

Number portability would be regarded as the other regulation that can contribute to the establishment of effective competition in Turkish mobile market. Concerning the long incumbency period in Turkish mobile telecommunications market, it would be argued that Turkish consumers are heavily dependent on their mobile numbers so that they are so much reluctant in switching their operators. The lack of mobile number portability regulation (later the implementation) was one of the most important reasons of switching costs in Turkish mobile market. Even though Telecommunications Authority had included the number portability regulation into its work plan for 2004, the regulation has only been published in February 2007 and the implementation studies were established within 2008. In conclusion, under the situation of late entry and lack of necessary regulations in the early years of

the entry such as national roaming, retail price control and interconnection rates regulation, mobile number portability would have been a good instrument in the establishment of effective competition in Turkish mobile market.

Regarding the effects of price discrimination on the competitiveness of the market, it is known that Avea, Vodafone, Borusan Telekom and SabancıTelekom placed their complaints to Telecommunications Authority stating that the on-net prices of the incumbent operator is lower than interconnection rates and there has been high on-net/off-net differentials in the tariffs of Turkcell. With reference to the complaints of these operators, Telecommunications Authority published a notification in September 2007 concerning on-net and off-net tariffs of mobile operators. The relevant articles of the notification would be summarized as follows:

- The on-net tariffs of Turkcell should not be lower than the lowest interconnection rate that Turkcell applies to other operators.
- Regarding the prices of GSM - GSM calls in general subscription packages for all operators, the upper limit has been determined as 0,66 YTL/min (inc. VAT).

Therefore, Telecommunications Authority intervened the retail mobile telecommunications market for the first time. Compared to the regulations in EU member states, the regulation of a retail market in mobile telecommunications industry would be regarded as a radical decision. However, the structural problems mentioned in this section would provide solid explanations for the differences between European mobile markets and Turkish mobile market that would justify this decision of Telecommunications Authority. On the other hand, the requirements of the decision regarding on-net calls were not applied by Turkcell and a court case was initiated against the decision. As a result, the Council of State has decided the stay of execution for the implementation of the decision due to the reason that Telecommunications Authority does not have the authority to determine lower limit for the retail prices according to the concession agreement.

As a result, the long incumbency period with late entries after 7 years, the lack of necessary regulations to create a more competitive environment in Turkish mobile market in the early years of the entry such as national roaming and facility sharing, the lack of regulations regarding interconnection rates and mobile number

portability would be argued to be the reasons of consumers' switching costs in Turkish mobile market. These switching costs are said to affect the pricing strategies of the firms significantly in Turkish mobile market. When compared to European mobile telecommunications markets, Turkish mobile market lacks the regulatory measures such as number portability so far and effective control on interconnection charges in the early years of the new entries until the las quarter of 2003. These regulations have been proved to have positive impacts on the establishment of effective competition and negative impacts on the prices through reducing switching costs of subscribers. Therefore, Turkish retail mobile telecommunications may be subject to regulatory supervision or at least requires necessary regulations to be implemented urgently such as mobile number portability and cost-oriented interconnection regime. In this context, the motivation of this paper is based on the switching costs, which have arisen as a result of lack of effective implementation of necessary regulations in Turkish mobile market and are considered to have significant impact on the pricing strategies of operators.

3 Literature Review

This chapter will provide a literature review about the previous works on the concepts discussed within the context of my model. With reference to factors contributing the competitiveness of the mobile markets and having significant impact on price levels, the concepts that will discussed could be listed as price discrimination between on-net and off-net calls, asymmetry between networks, call externalities in the market and existence of consumers' switching cots. Presentation of these works will not only provide a background on the literature but also will indicate the contributions of my study.

I will be using the widely-used competing interconnected network model which is mainly based on the competition on a Hotelling Line. In this setting, the operators are placed in the two ends of a unit line and consumers place themselves along the same line according to their tastes. Each consumer will prefer buying the product or the service from one of the firms by incurring transportation costs in order to go to the end of the line where their preferred firm is located from the point they placed themselves. On the other hand, they receive a utility from buying their preferred firm so that each consumer will subscribe to one of the firms according to their net surpluses. Consequently, there will be a consumer who is indifferent

between purchasing from either firms. Thus, the location of indifferent consumer will reveal the market share of the firms due to the fact that all consumers up to the point of indifferent consumer will buy from the first firm and the consumers ahead of the indifferent consumers' point will buy from the second firm. This model of competing firms under the existence of transportation costs is introduced by Hotelling (1929). As a result, in my model, the mobile operators are placed in the two ends of a Hotelling Line and subscriber will place themselves according to their preferences and make their subscription decisions by taking into consideration the utilities from making receiving calls.

The model of competing interconnected networks which provides the backbone of of my study was first initiated by Armstrong (1998) and LRT (1998a). Briefly, the main focus of these papers was the determination of the effects of collusive access charges over the retail prices. However, these works were developed under the assumption that consumers derive utility from only making calls but do not get utility from receiving calls. In the model presented in LRT (1998a), two-part tariff pricing strategy is proposed for the operators so that each operator charges their own subscribers a fixed fee and a single price for both on-net and off-net calls. In addition, rather than using a general form of utility and demand, LRT (1998a) introduce a utility function which yields a constant elasticity demand function. Within the context of the study, they examine whether established networks could not use their interconnection agreements to enforce collusive behavior. Thus, they suggest that under some conditions over the level of utility, there exists a certain value above which there would be no equilibrium access price. Moreover, they provide a Ramsey benchmark for the level of access charges and find out that the Ramsey access charge is smaller than the marginal cost of access, however the monopoly access charge exceeds the marginal cost of access. Therefore, these works are suitable for providing a backbone to my model due to the fact that these are the seminal works in the literature of competing interconnected networks.

In the model of interconnected networks in which operators pay each other access charges and network externality becomes important, operators would like to discriminate prices between on-net and off-net calls. For the reason that firms would be facing net outflow calls if their only strategy is lowering non-discriminated retail prices, then the firms choose price discrimination in order to manipulate amount of incoming and outgoing calls. As mentioned in the previous section, on-net/off-net price discrimination have been used in order to modify traffic balance

between operators in Turkish mobile telecommunications market and acquire more subscribers since they are concerned with the amount of calls they receive and the fact that they can make a greater amount of cheaper on-net calls when they subscribe to a network with a larger subscriber base. On the other hand, high off-net pricing would be purely based on the incentive to decrease the amount of outgoing calls so that off-net prices would be set excessively above cost which is expected to decrease consumer surplus.

Therefore, concerning the effects of price discrimination mentioned, the models with price discrimination are of keen interest from my view point. LRT(1998b) provide a valid starting point for price discrimination between on-net and off-net calls. In that paper, they showed that price discrimination would be favored by the incumbents in the case of absence of large scale entry and price discrimination of the incumbent would be opposed by the late entrants and consumers. LRT (1998b) also impose a sort of utility function which yields constant elasticity demand function similar to the non-discriminatory companion paper. LRT (1998b) mainly examine how the nature of competition is affected by the possibility of price discrimination and find out that network externalities exist if the access price embodies a positive markup over marginal cost such that a network discriminates against the rival network. They define this type of discrimination as neither cost-based nor demand-based discrimination but as a clear distortion so that this discrimination introduces a misallocation of resources on the demand side in order to modify traffic balances favorably. Under linear pricing, if the two networks are poor substitutes and if there is a markup on access, social welfare is higher under price discrimination than under uniform pricing. LRT (1998b) also provide a useful result such that if the access charge is small and close to marginal cost or the networks are poor substitutes, then there exists a unique symmetric and stable equilibrium.

Later then, Gans and King (2001) analyzed the access pricing strategies of firms under a model of price discrimination with two part tariff and showed that the firms would have incentive to set access charges below their marginal costs. An interesting outcome of Gans and King (2001) indicates that the price competition, even under price discrimination, would be softened in the case of using Bill-and-Keep method in interconnection pricing which means zero access charges between operators. On the other hand, also Peitz (2005) analyzed the level of access charges in a two-part tariff structure with termination-based price discrimination. In addition, Peitz (2005) introduced an asymmetric market into his model and reached the conclusion that providing an access markup for the new entrant operator, both the

profits of this operator and more importantly consumer surplus increase. In fact, Peitz(2005) follows the framework developed by LRT (1998b) for both the pricing and costing structure which is differentiated by the introduction of asymmetric access prices in favor of the late entrant operator. In this setting, he conducts the analysis for access prices around the cost concerning the impacts of asymmetric access prices over the profits of the late entrant, consumer surplus and subscription prices. Additionally, De Bijl and Peitz (2002) showed that equilibrium on-net and off-net call prices would be set at cost and the differential could be determined by nothing but access charges. Similar to Peitz (2005), they also showed that asymmetric access charges increase both the entrants profits and consumer welfare. De Bijl and Peitz (2002) construct their model with a lot of variations such as asymmetries in consumers' demand and already-established customer base for one of the networks. However, this paper differs from my work due to the fact that they examine the effects of asymmetric access charges over the profits and consumer welfare rather than examining retail pricing strategies. They finally conclude that regulator may use asymmetric access prices as a tool in order to facilitate the entry, so that in the long term competition intensifies. Jeon, Laffont and Tirole (2004) provided a seminal work for the literature of price discrimination in which they analyze the Receiving-Party-Pays (RPP) regimes which require subscriber to pay reception charges when they receive calls. In their model, they introduced a five-part tariff which includes on-net and off-net prices for both outgoing and incoming calls and fixed fee. They followed the same framework developed by LRT (1998b) in terms of utility and profit functions. Moreover, they introduced the concept of call externality by assuming that consumers obtain utility not only from making calls but also from receiving calls. In this context, they provide analyses regarding reception charges by concentrating on the symmetric equilibria. In the subsection where they analyzed the effects of absence of reception charges, they constructed a model without reception charges so that the mentioned model constitutes a suitable framework for the model I used in this paper. Hence, they provided that on-net calls are priced under cost due to the internalization of call externality and moreover they indicated that off-net prices would go to infinity depending on the level of call externality so that consumers do not make any demand for off-net calls. As a result, JLT (2004) provides that connectivity break-down would occur due to the fact that operators would set off-net prices going to infinity at some region of market shares under the absence of reception charges.

In telecommunications markets, the size of networks would be very important so that networks may use the advantage of their sizes by providing network externality. In this respect, asymmetry between the sizes of networks could serve as a competitive advantage for the larger networks. However, many works in the literature of interconnected networks study the symmetric equilibrium. In contrast, Carter and Wright (1999) introduced a pre-defined asymmetry such as brand loyalty to the consumers' utility functions for one of the networks so that market is shared asymmetrically between the operators. In that paper, they followed the competing interconnected networks model developed by LRT (1998b) by introducing an asymmetry to the utility functions of the operators and they ultimately showed that non-reciprocal access prices would be used by the incumbent as a barrier to entry. In addition, Carter and Wright (2003) kept using the asymmetry component in the utility functions of consumers and showed that incumbent operators would strictly prefer reciprocal access charge set at cost. Even though two-part tariff structure was used in these papers, termination-based price discrimination was not taken into consideration and main focus of these are concentrated around the determination of access prices. In this paper, I introduced the asymmetry by assuming that one firm, the incumbent, penetrates the whole market in the first period as the sole operator. Then the second period, which is the core interest of my work, starts with a mass of attached customers to the incumbent bearing switching costs in the case of subscribing the other network, the new entrant. Therefore, the switching costs introduced into the utility functions of consumers in this paper resemble the pre-defined asymmetry element included in the utility functions of consumers by Carter and Wright (1999, 2003).

The concept of call externality, which means consumers get utility from receiving calls, is an undeniable feature of telecommunications sector. In this respect, the concept of call externality becomes very important. The models, which take into consideration the utility of receiver consumers in addition to the utility of caller consumers, were introduced by Kim and Lim (2001), JLT (2004), Wright (2002a), DeGraba (2003), Berger (2004, 2005), Valletti and Houpis (2005), and Valetti and Cambini (2006). The inclusion of call externalities to the models was mainly necessitated by the examination of Receiving Party Pays principle. In the case that subscribers derive utility from receiving calls, Kim and Lim (2001) examine how Receiving Party Pays Principle (RPP) contributes to the internalization of the call externalities. They introduce two models where the first model stands for

a monopoly which is out of the scope of this paper and the second model consists of the introduction of call externalities to the model of LRT (1998a) with the networks competing in linear prices. In both models they assume that access charge is not regulated but determined cooperatively under the existence of the reception charges with linear pricing of calls. Briefly, their results indicate that the price of calls decreases with the existence of RPP principle however the access charge is higher. Furthermore, within the RPP concept, JLT (2004)find out that calling charges should be set below the marginal cost of a call due to the internalization of call externality and also come up with the result that connectivity break down would arise if networks discriminate prices between on-net and off-net calls as stated earlier in the previous paragraph. Moreover, Berger (2004) conducts an analysis regarding the impacts of reciprocal access charges in a model of network competition under linear pricing and termination-based price discrimination while introducing call externalities to the model and Berger (2005) makes the same analysis under non-linear pricing (two-part tariffs). Moreover, Cambini and Valetti (2006) also introduce call externalities to their model under the assumption of calls made and received are complements to each other. In that study, they showed that operators set positive reception charges only when access charges are sufficiently low.

Finally, it would be beneficial to mention the related literature regarding the concept of switching costs which constitutes the significant part of my study. The effects of switching costs over the competition were analyzed in several works by Klemperer. First, in the models for two-period markets Klemperer (1987a) showed that firms set lower prices in the first period to attract consumers so that they can exploit those attached customers later in the second period with the advantage of switching costs. It that paper, Klemperer (1987a) introduces a model where a fraction ν of second-period consumers is new comers in the market, and a fraction $1-\nu-\rho$ of first-period consumers remain in the market which have unchanged preferences across periods. In this setting, a fraction ρ of consumers have tastes for product characteristics in the second period that are independent of their first-period tastes. This situation means that the second period location of these consumers on the line segment is independent of their first-period location. Moreover, a fraction ν of first-period consumers leave the market after the first period and are replaced by new consumers with the same fraction, who are uniformly distributed along the line. The remaining consumers with a fraction of $1-\nu-\rho$ have unchanged tastes for the product characteristics. Similar to my model, that article examines

a two-period differentiated-products market in which a fraction of the consumers are locked-in through switching costs that they face in the second period in the case that they would like to change their product supplier. However, the switching costs exist for both firms in Klemperer's model, which is not the case in the model presented in this paper. Additionally, Klemperer (1987a) constructs a model of two competing firms rather than interconnected networks so that consumers of one product are not affected by the number of consumers who adopt the same product. Moreover, the consumers' utility are modeled by simply prices so that consumers make their decisions based on the price of firms just as in Hotelling (1929)'s model. On the other hand, Klemperer (1987a) does not restrict firms to charging the same price in every period so that they would be able to exert the monopoly power that switching costs give them. As a result he finds that firms would like to raise their prices in the second period to take advantage of customers locked in to the firms through the first-period purchase choice. Klemperer (1987a) concludes that increasing the fraction ρ of consumers whose tastes change between the periods increases the market's competitiveness. However, if all consumers' tastes remain constant such that $\rho = 0$, prices and profits of the firms are higher in both periods.

Then, Klemperer (1987b) analyzed the relationship between the level of switching costs and entry deterrence in a classic entry deterrence game setting where a potential entrant observes the period-one output (or the market price) of the incumbent firm and decides whether to enter the market by incurring a fixed cost. As a result, he showed that the incumbent would like to serve only to repeat consumers rather than new ones and would encourage entry under high switching costs. An important point of this article has been that the incumbent monopolist will charge lower prices in the first period compared to the case that it has unthreatened by the entry. This is due to the fact that the incumbent would like to limit the effect of entry by offering low prices in the first period and obtaining a significant amount of consumers in the market and then serving only to those customers in the second period and not competing for the new ones aggressively. Similar to the articles of Klemperer (1987a) and (1987b), Klemperer (1987c) also examines a two-period market where in this case the switching costs are not the same for each consumer so that he defines a distribution function that determined the proportion of a firm's consumers whose cost of switching to the other firm is less than a particular difference. In this setting, a firm sells only to its own consumers with switching costs greater than or equal to the difference of prices of the firms and to those of other firm's consumers with switching costs less than or equal to price difference. As a

result, he shows that switching costs lead to monopoly returns which in fact provide greater competition in the early stages of the market. In contrast, the total welfare is inferred to decrease so that the model provide support for the regulatory actions in lowering switching costs.

Similarly, Klemperer (1989) indicated that the incumbent would lower its price in the period before entry in order to lock-in customers and then undermine the effect of the entry. Moreover, in a comprehensive study, Klemperer (1995)analyze the choice of the incumbent firms between setting a low price to capture the whole market in the second period and setting a high price to harvest the profits from its locked-in customers under the effect of entry, interest rates, exchange rates expectations etc. In this setting he uses classical Klemperer model in a four-period market where in period 1 a dominant firm enters as a monopolist and in period 2 the dominant firm is again a monopolist. Whereas, in period 3 the dominant firm faces an entry so that it chooses a quantity which causes the new entrants taking this quantity as given and acting competitively and in the last period, the dominant firm again chooses its quantity first and the period-3 entrants then choose quantities taking the dominant firm's output as given. Klemperer tests various scenarios such that he imposes small switching costs first and then larger later. As a result, the entry of new firms are proven to lead price wars which is assumed to be caused by the entry of new consumers who are not yet committed to any firm. If a small fraction of consumers leaves the market and is replaced by new consumers in each period, price wars arise.

Furthermore, Farrell and Shapiro (1988) extends the model into a multi-period overlapping generations environment and discovered that the incumbent firm with attached customers would have incentive to serve them and leave new buyers to its rival. However, these works are just extended forms of price competition with in a two (or multi) period Hotelling setup. Therefore, the concepts of interconnected firms, call externalities, price discrimination are not included in those works.

Recently, Lopez (2007) introduced the concept of switching costs to the model of LRT(1998a) in which price discrimination and call externalities were not also taken into consideration but the model represents interconnected networks. He assumed that each consumer's second-period preferences are independent of his first-period preferences, so that consumers' preferences may change over time. Under reciprocal access charges set by a regulator or negotiated between operators at the beginning he models a two-period dynamic market where second period prices and profits affect the first period decisions of the firms and also switching costs exist for both

firms. However, he does not specify a utility function form for the consumers and behaves utility as a welfare variable whereas the consumers are not myopic so that they recognize that if a network decreases its first-period fixed fee, it will build market share in order to exploit in the second period by increasing its second-period fixed fee due to the existence of switching costs. Lopez (2007) mainly analyzes the effects of mark-up over access charges so that in his study Lopez (2007) showed that firms profits increase as access charges depart from the marginal costs. His article shows that when there is dynamic competition and operators are non-myopic, then they would use access charges to soften competition.

The model studied in this thesis is most similar to that presented by Hoernig (2007) due to the fact that he analyzed the pricing behavior of the firms under the concepts of interconnected asymmetric networks, call externalities, price discrimination. In mentioned paper, Hoernig followed the CPP version of the model generated by JLT (2004) and introduced a pre-defined asymmetry to the consumers' utility functions for one of the networks following Carter and Wright (1999, 2003) similar to switching costs in this thesis and analyzed a limited form of predatory pricing within firms' pricing strategies. This thesis will differ from Hoernig (2007) in a single point such that there will be a mass of consumers exiting the market and new ones replacing them in the second period.

4 The Model

This model has been constructed over the common framework used in the literature so that interconnected networks are positioned at the two ends of a Hotelling line according to product characteristics and consumers place themselves along the same line according to their preferences. Thus, the position of firm 1 is the point 0 and the position of firm 2 is the point 1 which are denoted as $x_1 = 0$ and $x_2 = 1$. This model follows a joint framework composed of the models constructed by LRT (1998b), Carter and Wright (2003) and JLT (2004). Therefore, a customer located at x and choosing to subscribe to network i has a transportation cost of $t|x - x_i|$.

The utility of a customer with income y and located at x from joining network i is determined by the following equation in the models mentioned above:

$$y + v_0 - t|x - x_i| + w_i.$$

where v_0 is the utility gained from being joined to a network, t represents per-unit transportation cost along the Hotelling line which is measured by $\frac{1}{2\sigma}$ where σ stands for the substitutability measure between two networks and w_i is the net surplus of customers from calls made and received when joined to the network i.

At the retail level, the firms will be allowed to make price discrimination in their tariffs and then I will restrain the firms' pricing strategies by non-discrimination obligation as a policy option. Thus, in the existence of price discrimination the firm i will offer a three part tariff $\{F_i, p_{ii}, p_{ij}\}$ following the notation of JLT(2004). Here, F_i is the fixed fee of the tariff package, p_{ii} represents the retail price of on-net calls and p_{ij} stands for the retail price of off-net calls where $i \neq j$.

Demand function of customers is denoted by $q(\cdot)$. Thus, the demand of callers from network i is given by $q(p_{ii})$ for on-net calls and $q(p_{ij})$ for off-net calls. Following this notation, indirect utility function of a customer from making on-net or off-net calls can be denoted as

$$v(p) = max_q\{u(q) - pq\}.$$

Since the derivative of consumer surplus is expected to give the demand function of consumers, then I add the following assumption for the indirect utility such that $v'(p) = -q(p)$.

Furthermore, there will be customers in the market with a mass of 1 and I make the assumption that the market is fully covered by the networks such that $s_1 + s_2 = 1$ where s_i denotes the market share of network i. Moreover, the market is assumed to be fully owned by the incumbent and a new entrant comes into the market in the second period. Meanwhile, customers with a mass of μ stays in the market while the rest of customers with a mass of $1 - \mu$ leave the market at the beginning of the second period and new customers with the same population replace leaving customers. Therefore, there exists attached customers with a mass of μ who have already been subscribed to the incumbent and face switching cost of s in the case of subscribing to the new entrant in the second period. As well, there will be unattached new customers who do not face any switching costs whichever network they subscribe. In addition, throughout my model I will assume the balanced calling

pattern such that the customer of each network makes on-net and off-net calls proportional to the market share of networks. Henceforth, the following equation will represent the net surplus of an unattached customer:

$$w_i = s_i(v(p_{ii}) + \beta q(p_{ii})) + (1 - s_i)(v(p_{ij}) + \beta q(p_{ji})) - F_i \tag{1}$$

In the above, $v(p_{ii})$ and $v(p_{ij})$ represent the indirect utilities from making calls where s_i of them will stay inside the network and $1 - s_i$ of them will be outgoing to the other network. Additionally, the utility of receiving a call with duration q has been included in the above equation as βq for either on-net or off-net calls. Here I use the assumption developed by Armstrong and Wright (2007) such that each subscriber gets a linear utility from receiving calls from other subscribers. The last term in the equation stands for the retail fixed fee paid by customers. Moreover, attached customers will receive an extra disutility of s from switching in the case of subscribing to the new entrant and then w_1 and $w_2 - s$ will represent their net surpluses from subscribing to the incumbent and the new entrant respectively.

The location of indifferent customer along the Hotelling line will provide for the market share of network 1 due to the fact that all customers from the point 0 to the location of indifferent customer will strictly prefer network 1 and the rest beyond this point will subscribe to network 2. According to the Hotelling's model, before making the purchase (or here subscription) decision, consumers make expectations regarding the market shares of the firms since market shares influence their utilities directly. If these expectations of consumers are rational then the resulting market share determined by the location of indifferent customer should be equal to the expected market shares. This concept is called as "rational expectations" which is a necessary condition for an equilibrium to exist. Since there will be two types of customers either attached or unattached, then I will solve for the locations of indifferent customers for these two groups separately. First of all, the location of indifferent customer among attached customers, which is represented by x_s where s denotes the existence of switching costs, would be calculated by equating utilities offered by two networks such that,

$$y + v_0 - t|x_s - x_1| + w_1 = y + v_0 - t|x_s - x_2| + w_2 - s \tag{2}$$

where $x_1 = 0$ and $x_2 = 1$ as stated earlier. Therefore, by substituting $t = \frac{1}{2\sigma}$the location of indifferent attached customer can be solved as

$$x_s = \frac{1}{2} + \sigma(w_1 - w_2 + s) \tag{3}$$

Then, the location of indifferent customer among unattached customers, which is represented by x_n where n denotes the non-existence of switching costs, would be similarly calculated by equating utilities offered by two networks such that,

$$y + v_0 - t|x_n - x_1| + w_1 = y + v_0 - t|x_n - x_2| + w_2 \tag{4}$$

where again $x_1 = 0$ and $x_2 = 1$ as stated earlier and similarly I solve for the location of indifferent unattached customer by substituting $t = \frac{1}{2\sigma}$ such as

$$x_n = \frac{1}{2} + \sigma(w_1 - w_2) \tag{5}$$

As a result of the distribution of both attached and unattached customers to the networks, the market share of the incumbent firm can be determined by $s_1 = \mu x_s + (1 - \mu)x_n$. Therefore, the resulting market share of the incumbent can be solved as the following:

$$s_1 = \frac{1}{2} + \sigma(w_1 - w_2) \ + \mu\sigma s \tag{6}$$

Remember that equation (1)indicates that w_i is dependent on the market share s_i. Thus, if I substitute the equation (1) into the equation (6)and solve for s_1 with the early assumption of $s_2 = 1 - s_1$ then I obtain the following equation for s_1.

$$s_1 = \frac{1/2 + \mu\sigma s + \sigma(h_{12} - h_{22} - F_1 + F_2)}{1 + \sigma(h_{12} + h_{21} - h_{11} - h_{22})} \tag{7}$$

where $h_{ij} = v(p_{ij}) + \beta q(p_{ji})$ for simplifying the notation as suggested by Hoernig (2007). Similarly, the results obtained in (6) and (7) resemble to the results of Hoernig, thus I would be able to conduct analyses similar to those of Hoernig(2007). First of all, in order to obtain a well defined s_1, the denominator of the equation (7) should be positive since the market share should be decreasing by F_1. This assumption eliminates the corner solution so that the market can not be penetrated by only one of the operators.

In this setting, both firms bear fixed cost f for providing communication to each customer and have constant marginal costs c for both call origination and termination. Here, I make two essential assumptions that both networks have the same costs and additionally call origination and termination costs are equal. On the other hand, each call-receiving firm charges an access price a from the caller firm in order to terminate calls. Moreover, two significant assumptions have been made such that the access prices of both firms are equal to each other reciprocally and in addition equal to the cost of termination, c. Since I do not analyze how firms and regulators should choose the access prices within the context of this paper, then those assumptions are valid for the setting of this paper. Additionally, it has been shown that pricing equilibrium exists when a is sufficiently close to c, then I impose this assumption for both simplicity and a stable equilibrium.

As stated earlier, the profit functions of networks are adopted from the framework initiated by LRT(1998b) and developed in JLT(2004). In line with those works, mobile networks will decide $\{F_i, p_{ii}, p_{ij}\}$ in order to maximize their profits. However, for the simplification of the optimization process I would make a change of variables so that the networks will decide market shares s_i instead of fixed fees F_i and then the equilibrium values for fixed fees will be obtained through the first order conditions for market shares.

Mobile networks' profit functions will be composed of the components of on-net and off-net revenues, access revenues and costs of calls. The following equation represents profit function of a mobile network which is particularly adopted from JLT(2004).

$$\pi_i = s_i[s_i(p_{ii}-2c)q(p_{ii})+(1-s_i)(p_{ij}-c-a)q(p_{ij})+(1-s_i)(a-c)q(p_{ji})+(F_i-f)] \quad (8)$$

where

(i) the first term stands for the profit from on-net calls, which constitute s_i percent of all calls, with the price of p_{ii}, the cost of $2c$ for both origination and termination, and the length of $q(p_{ii})$;

(ii) the second term represents the profit from off-net calls, which constitutes $1 - s_i$ percent of whole calls, with the price of p_{ij}, the cost of c for origination and a for termination, and the length of $q(p_{ij})$

(iii) the third term represents the profit from access charges with the price of a, the cost of c for termination, and the length of $q(p_{ji})$ received from the other operator.

(iv) the fourth term represents the profit from fixed fee with the price of F_i, the cost of f.

Before moving onto the optimization phase, I would obtain the responses of fixed fees for the changes in on-net and off-net prices due to the fact that fixed fees are determined by the firms according to their prices as well. Thus, I would regard fixed fee F_i as a function of on-net and off-net prices which would be denoted by $F_i(p_{ii}, p_{ij})$.

First of all, the rate of change of fixed fee F_i with respect to market share s_i would be obtained through the equation (6). Taking the derivative of this equation with respect to both fixed fee and market share, I will be able to obtain $\frac{\partial F_i}{\partial s_i}$ as the following:

$$\frac{\partial F_1}{\partial s_1} = -\frac{1}{\sigma} + (h_{11} + h_{22} - h_{12} - h_{21}) \tag{9}$$

similarly, substituting $s_2 = 1 - s_1$ in the equation (6) and conducting the same operations made for $\frac{\partial F_1}{\partial s_1}$, the following gives us $\frac{\partial F_2}{\partial s_2}$:

$$\frac{\partial F_2}{\partial s_2} = -\frac{1}{\sigma} + (h_{11} + h_{22} - h_{12} - h_{21}) \tag{10}$$

Furthermore, I require the rate of change of fixed fees with respect to on-net and off-net prices. The equations for the derivatives of fixed fees with respect to

on-net and off-net prices would be obtained with the same operations through the equation (6). The results are as follows:

$$\frac{\partial F_1}{\partial p_{11}} = s_1[\ \frac{\partial}{\partial p_{11}} v(p_{11}) + \beta(\ \frac{\partial}{\partial p_{11}} q(p_{11})\ )\ ] \tag{11}$$

$$\frac{\partial F_1}{\partial p_{12}} = (1 - s_1)[\ \frac{\partial}{\partial p_{12}} v(p_{12})\ ] - s_1\beta[\ \frac{\partial}{\partial p_{12}} q(p_{12})\ ] \tag{12}$$

moreover, substituting $s_2 = 1 - s_1$ in the equation (6) and making the same operations, I obtain the following results:

$$\frac{\partial F_2}{\partial p_{22}} = (1 - s_1)[\ \frac{\partial}{\partial p_{22}} v(p_{22}) + \beta(\ \frac{\partial}{\partial p_{22}} q(p_{22})\ )\ ] \tag{13}$$

$$\frac{\partial F_2}{\partial p_{21}} = s_1[\ \frac{\partial}{\partial p_{12}} v(p_{12})\ ] - (1 - s_1)\beta[\ \frac{\partial}{\partial p_{12}} q(p_{12})\ ] \tag{14}$$

In this context, profit maximizing on-net prices by keeping the market share and off-net prices constant would be obtained from the first order condition $\frac{\partial \pi}{\partial p_{ii}} + \frac{\partial \pi}{\partial F_i}\frac{\partial F_i}{\partial p_{ii}} = 0$ under the assumption that other firm's market share, on-net price and off-net price are given. Therefore the following expression gives the partial derivative of networks' profits with respect to on-net prices:

$$s_i^2(\ \frac{\partial}{\partial p_{ii}} q(p_{ii})\ )[\ p_{ii} - 2c + \beta\ ] = 0$$

Solving the above first order condition for on-net prices of both firms, I obtain the following equations:

$$p_{11} = p_{22} = 2c - \beta \tag{15}$$

Furthermore, similar to on-net prices, profit maximizing off-net prices by keeping the market share and on-net prices constant would be obtained from the following first order condition under the assumption that other firm's market share, on-net price and off-net price are given.

$$s_i(\ \frac{\partial}{\partial p_{ij}} q(p_{ij})\ )[\ (1-s_i)p_{ij} + (s_i - 1)(a+c) - s_i\beta\ ] = 0$$

If the above first order condition is solved for off-net prices of both firms, equilibrium off-net prices result as follows:

$$p_{12} = a + c + \frac{s_1}{1-s_1}\beta \tag{16}$$

$$p_{21} = a + c + \frac{1-s_1}{s_1}\beta \tag{17}$$

The equilibrium fixed fees can be calculated by using the method of change of variables so that I would like to optimize networks' profits with respect to market shares first by keeping the on-net and off-net prices constant under the assumption that other firm's market share, on-net price and off-net price are given. In this manner, the expression $\frac{\partial \pi}{\partial s_i} + \frac{\partial \pi}{\partial F_i}\frac{\partial F_i}{\partial s_i} = 0$ will provide for the first order condition for market shares. (Please see the appendix for the full expression of FOC of market shares.) Thus, the case is such that I have two FOCs for s_1 and s_2 and the implicit equation 7 for the market share and on the other hand equilibrium values for F_1, F_2 and s_1 should be obtained. Then, solving the first order condition of market shares for fixed fees, the equilibrium fixed fees would be obtained.

The equilibrium fixed fees for both firms, F_1 and F_2, obtained through the expression

$$\frac{\partial \pi}{\partial s_i} + \frac{\partial \pi}{\partial F_i}\frac{\partial F_i}{\partial s_i} = 0 \tag{18}$$

will help us with solving the equilibrium market shares.(Please see the appendix for the full expressions of equilibrium fixed fees.) Therefore, it will be sufficient to substitute the equilibrium fixed fees into the implicit equation of market share (7) in order to obtain the equilibrium market shares.

To conclude this section, the equilibrium values of on-net and off-net prices, fixed fees and market shares of the mobile telecommunications networks have been derived under the existence of asymmetric switching costs. Therefore, I would be able to conduct analyses regarding the effects of switching costs on the decisions of firms in the next section.

5 Equilibrium Under Price Discrimination

In this section, I will be providing my findings regarding the equilibrium pricing strategies of firms under the existence of switching costs and discuss the results obtained in the previous section. Moreover, the change in equilibrium price levels with respect to the access charges will also be provided in the subsection.

5.1 Equilibrium Pricing Strategies

Within the context of this section, I will investigate how switching costs affect equilibrium prices. In particular, the reaction of prices to switching costs will analyzed when switching costs are very small, hence close zero. Additionally, I will make analyses at the point $a = c$ as mentioned in the earlier paragraphs since it has been shown that equilibrium exists when a is sufficiently close to c.

As a starting point, I could analyze the equilibrium on-net and off-net pricing decisions of the firms regarding equations (15), (16), and (17). First of all, the equation (15) suggest that the equilibrium on-net prices of firms will be equal to each other as long as two firms incur the same call origination and termination costs of c and on-net calls will be priced below the marginal cost $2c$ with a reduction corresponding to the call externality β due to the fact that firms would like internalize the call externality.

Second, equations (16) and (17) reveal that the off-net prices of firms are correlated with their market shares so that the firms would like to charge higher off-net

prices as their market shares increase. Here, I would obtain following two results significant for my further analyses.

Lemma 1 *For any equilibrium market share $s_i \in (0,1)$, off-net prices of the networks will increase (decrease) as their (competitor's) market share increases:*

$$\frac{\partial p_{ij}}{\partial s_i} = \frac{\beta}{(1-s_i)^2} > 0 \tag{19}$$

With reference to *Lemma* 1 (19), under the assumption that market share of the incumbent is greater than the entrant's market share so that it's more than 1/2, I would conclude that the incumbent's off-net price will be greater than the entrant's off-net price. This solution could be explained by the fact that the incumbent firm seizes the opportunity of having a bigger network so that it internalizes the call externality more by applying a bigger mark-up over the cost while determining off-net prices stated in the equation (16). However, with reference to equation (15), it would be seen that on-net prices are not affected by the switching costs. Furthermore, *Lemma* 1 (19) implies that the operators apply a mark-up for call externality so that in the case that $\beta = 0$ there will not be such a mark-up for call externality in the equilibrium off-net prices.

Lemma 2 *For any equilibrium on-net and off-net prices, p_{11} and p_{12} respectively, for switching cost close enough to zero market share of the incumbent firm will increase as the switching cost s increases:*

$$\frac{\partial s_1}{\partial s} \mid_{s=0} > 0 \tag{20}$$

Proof. With reference to the equation (7) that gives the equilibrium market share of the incumbent firm, I infer that s_1 will decrease as fixed fee F_1increases when on-net and off-net prices are set at the equilibrium values determined by the equations (15), (16) and (17. Then the following result will hold:

$$\frac{\partial s_1}{\partial F_1} = \frac{-\sigma}{1+\sigma(h_{12}+h_{21}-h_{11}-h_{22})} < 0$$

Let $B = 1+\sigma(h_{12}+h_{21}-h_{11}-h_{22})$ for the simplicity. Then, obviously $B > 0$ from the above equation for small enough σ. Since the networks will be symmetric without switching cots ($s = 0$) under the initial assumption of $a = c$, then I would make further assumptions of $p_{11} = p_{22}$, $p_{12} = p_{21}$ and $s_1 = s_2 = 1/2$. Thus, B turns

into a new equation under the assumptions just mentioned. Let this new equation is called A.

The derivative of the incumbent's market share s_1 with respect to the switching cost s with the substitutions of $a = c$ and $p_{11} = p_{22}$, $p_{12} = p_{21}$ and $s_1 = s_2 = 1/2$ is as follows:

$$\frac{\partial s_1}{\partial s}|_{s=0} = \frac{(1-s_1)^2 {s_1}^2 \sigma\mu}{3A + 4\sigma\beta[q(p_{21}) + q(p_{22})]} > 0$$

Then, further conclusions can be derived from *Lemma*2 literally such that a small increase in the switching costs in favor of the incumbent firm will cause an increase in the incumbent firm's market share.

Proposition 1 *For switching costs very close to zero, equilibrium off-net prices of the incumbent firm increases with a small increase in switching costs.*

$$\frac{\partial p_{12}}{\partial s}|_{s=0} > 0 \tag{21}$$

Proof 1 *By using the results of Lemma* 1 *and Lemma* 2*, such that*

$$\frac{\partial p_{12}}{\partial s_1}|_{s=0} > 0$$

and

$$\frac{\partial s_1}{\partial s}|_{s=0} > 0$$

hold for switching costs small enough. Then,

$$\frac{\partial p_{12}}{\partial s}|_{s=0} = \frac{\partial p_{12}}{\partial s_1} \frac{\partial s_1}{\partial s}|_{s=0} > 0$$

which implies that equilibrium off-net price of the incumbent firm increases with an increase in switching costs in favor the incumbent firm.

With reference to the findings above, *Proposition* 1 (21) suggests that the incumbent will seize the opportunity of having an already-established customer base where subscribers incur switching costs when they leave the incumbent and would like to subscribe to the other network. Even though higher off-net prices of an operator undermines the attractiveness of the operator, this situation creates indirect effects such as traffic imbalance in favor of the larger network and consumers' disincentive for subscribing to the smaller network with the concern of not receiving

much calls from the larger operators' subscribers. First, higher off-net prices of larger network will cause less outgoing calls and more incoming calls due to lower off-net price of smaller network so that an interconnection traffic imbalance in favor of the incumbent operator will be observed in the market. Regarding *Proposition* 1 (21) it would be argued that the late entrant operator's interconnection traffic and payment deficit will be widened if switching costs increase. Thus, one may argue that absence of necessary regulations that cause asymmetric switching costs in the market will further distort the competition through interconnection payments. Second, higher off-net prices of the incumbent operator discourages the potential subscribers against subscribing to the smaller operator so that the late entrant operator will face difficulties in subscriber acquisition process.

Proposition 2 *For switching costs very close to zero, equilibrium fixed fee of the incumbent firm increases with a small increase in switching costs.*

$$\frac{\partial F_1}{\partial s}|_{s=0} > 0 \tag{22}$$

Proof 2 *Using the equilibrium fixed fees (Please see the appendix for the full expression.), the following expression can be obtained:*

$$\frac{\partial F_1}{\partial s_1}|_{s=0} = \frac{1 + 2\sigma[v(p_{22}) - v(p_{21}) + 2\beta q(p_{21})]}{\sigma} \tag{23}$$

which could be re-written as

$$\frac{\partial F_1}{\partial s_1}|_{s=0} = \frac{A + 2\sigma\beta[q(p_{21}) + q(p_{22})]}{\sigma} > 0 \tag{24}$$

where the result of $A > 0$ has been obtained in the proof of Lemma 2*. Furthermore, by using the result of Lemma* 2*, such that*

$$\frac{\partial s_1}{\partial s}|_{s=0} > 0$$

hold for switching costs small enough. Then,

$$\frac{\partial F_1}{\partial s}|_{s=0} > 0$$

which indicates that equilibrium fixed fee of the incumbent firm increases with an increase in switching costs in favor the incumbent.

The result obtained in *Proposition* 2 (22) imply that the ability of the incumbent firm at taking excess consumer surplus through fixed fees increases with the switching costs. This situation could also be explained by demand elasticities such that demand gets more inelastic as switching costs get higher. Therefore, by using the advantage of switching costs, the incumbent firm charges more fixed fee and obtains more consumer surplus.

In the context of regulatory policy, in the next section, I will try to show the effects of a remedy against price discrimination such that on-net and off-net prices should be set equal to each other by both of the firms.

5.2 The Effects of Access Charges

This section mainly investigates how access charges affect equilibrium prices under the existence of switching costs. One would argue that incumbent operator favors higher access charges as long as it is above cost due to the favorable traffic imbalance created by higher off-net price.

The analysis will concentrate around the point $a = c$ so that I will try to examine the effects of an increase in access charges. In this context, the rate of changes at this point will reveal us how the equilibrium prices will change when access charges deviate from cost. Since I am going to deal with the responses of off-net prices, the results presented in *Lemma* 1 (19) will provide a solid starting point for the analysis. As mentioned in the previous section, the equation (15) indicates that on-net calls will be priced below the marginal cost $2c$ with a reduction corresponding to the call externality β so that on-net prices are not affected by the changes in access charges.

Since it has been shown that $\frac{\partial p_{12}}{\partial s_1} > 0$ in *Lemma* 1 (19), then I need to show that $\frac{\partial s_1}{\partial a} > 0$ in order to meet the assumptions made in the beginning of this subsection.

Proposition 3 *For any equilibrium on-net and off-net prices, p_{11} and p_{12} respectively and for any switching costs $s > 0$, market share of the incumbent firm will increase as the access charge a increases under a linear demand function when a is close to the call termination (and origination) cost c:*

$$\frac{\partial s_1}{\partial a} \mid_{a=c} > 0, \quad \forall s_1 > 1/2 \tag{25}$$

Proof 3 *With reference to the equation (6) that gives the equilibrium market share of the incumbent, derivative of the market share with respect to access charge can be determined by*

$$\frac{\partial s_1}{\partial a} \mid_{a=c} + \frac{\partial s_1}{\partial p_{12}} \frac{\partial p_{12}}{\partial a} \mid_{a=c} + \frac{\partial s_1}{\partial p_{21}} \frac{\partial p_{21}}{\partial a} \mid_{a=c} \tag{26}$$

where the term s_1 includes the equilibrium values of F_1 and F_2 obtained by solving the equation (18) so that there is no need to examine the rate of change of fixed fees with respect to access charge. The above equation yields the following result:

$$\frac{\partial s_1}{\partial a} \mid_{a=c} = \frac{-\sigma s_1^3(-1+s_1)^3(s_1 q(p_{21}) - (1-s_1)q(p_{12})) + C}{3A + 4\sigma\beta[q(p_{21}) + q(p_{22})]} \tag{27}$$

where C represents the following part of the equation:

$$C = s_1^2\sigma(-1+s_1)^2\beta[(s_1 - 3s_1^2 + s_1^3)\tfrac{\partial q(p_{12})}{\partial p_{12}} + (-2s_1 + s_1^3 + 1)\tfrac{\partial q(p_{21})}{\partial p_{21}}]$$

In the equation (27), the first part other than C is positive since $-\sigma s_1^3(-1+s_1)^3$ is obviously positive, and additionally $s_1 > (1-s_1)$ and $q(p_{21}) > q(p_{12})$ make the term in parenthesis positive. The crucial point is the sign of C which turns out to be certainly positive for any kind of demand curve on the region $s_1 > 0.62$ which ensures that both the term $s_1 - 3s_1^2 + s_1^3$ and the term $-2s_1 + s_1^3 + 1$ are negative. This is due to the fact that $s_1 > 0.38$ guarantees that the term $s_1 - 3s_1^2 + s_1^3$ is negative and $s_1 > 0.62$ implies that the term $-2s_1 + s_1^3 + 1$ is negative. However, if the demand curve is assumed to be the standard constant-slope demand curve, then I would assume that $q'(p_{12}) = q'(p_{21})$ for all points on the demand curve, then the term $(s_1 - 3s_1^2 + s_1^3) + (-2s_1 + s_1^3 + 1)$ is negative on the region $s_1 > 1/2$. Furthermore, this result also holds for any demand function which is convex such that $q''(\cdot) > 0$. (Please see the appendix for the graphical results)

With regards to the result obtained in *Proposition* 3 (25), I would claim that market share of the dominant firm will increase as the access charge increases. Therefore, this result satisfies the expectations made in the beginning of this subsection such that the incumbent firm will prefer setting higher symmetric access charges. This incentive may be sustained by the incumbent firm even under asymmetric access charges depending on the level of asymmetry in interconnection traffic between the firms. Similarly, the incumbent firm sets higher off-net prices by seizing the opportunity of switching costs, which in turn results traffic imbalance between

the operators in favor of the incumbent firm. Thus, the incumbent firm will always prefer higher symmetric access charges so that a payment imbalance is created in favor the incumbent firm in interconnection payments between the operators.

Using the result obtained in the *Proposition* 3 (25),the following inference could be made obviously:

Lemma 3 *Off-net price of the incumbent firm increases as the access charge increase at the point* $a = c$.

$$\frac{\partial p_{12}}{\partial a} \mid_{a=c} + \frac{\partial p_{12}}{\partial s_1} \frac{\partial s_1}{\partial a} \mid_{a=c} > 0 \tag{28}$$

Proof. With regards to the equation (16) $\frac{\partial p_{12}}{\partial a} \mid_{a=c} = 1$ and additionally, using *Lemma* 1 (19) which proves that the off-net price of the incumbent firm increases with its market share and *Proposition* 3 (25) which implies that the market share of incumbent firm increases with the access charges, then it would be proven that the derivative of off-net price with respect to access charge turns out to be positive. Therefore, it would be concluded that off-net price of the incumbent firm will increase as the access charge increases.

The result of *Lemma* 3 satisfies the expectation that the incumbent firm will set higher off-net prices as long as access charges increase in order to create a traffic imbalance and enjoy the advantage of payment imbalance in favor of itself.

6 Equilibrium Under Non-discriminatory Prices

In this section, I will analyze the results of price non-discrimination if it would be imposed as a remedy in order to eliminate the effects of switching costs so that effective competition would be established in the market. The same model presented in Section 3 will be used in this section with a deviation such that the firms will be obliged to set equal on-net and off-net prices.

Therefore, the retail level pricing decisions of firm i will consist of a two-part tariff $\{F_i, p_i\}$ where F_i is the fixed fee of the tariff package and p_i stands for the retail price of both on-net and off-net calls. Thus, the firms' pricing strategies will be restrained by non-discrimination obligation as a policy option.

Similar to the demand function presented in Section 3, demand function is denoted by $q(\cdot)$. Thus, the demand of callers from network i is given by $q(p_i)$ for

on-net and off-net calls. Indirect utility function of a customer from making on-net or off-net calls will be similarly denoted as $v(p) = max_q\{u(q) - pq\}$ such that $v'(p) = -q(p)$ in order to ensure that consumer surplus gives the demand function of consumers.

The market will be again assumed to be fully covered by the incumbent in the first period and a new entrant comes into the market in the second period. Similar to the market introduced in Section 3, customers with a mass of μ will remain in the market while the rest of customers leave the market at the beginning of the second period and new customers with the same population $(1 - \mu)$replace the leaving customers. Thus, the remaining customers with a mass of μ, who have already been subscribed to the incumbent, will be attached to the incumbent network and face switching costs of s if they subscribe to the new entrant in the second period. On the other hand, unattached new customers do not face any switching costs whichever network they subscribe. Therefore, the following equation will represent the net surplus of an unattached customer:

$$w_i = v(p_i) + s_i\beta q(p_i) + (1 - s_i)\beta q(p_j) - F_i \tag{29}$$

where $v(p_i)$ represents the indirect utilities from making on-net and off-net calls. Moreover, the utility derived from receiving a call with duration q is represented as βq similar to the original model. Again, the assumption of Armstrong and Wright (2007) such that each subscriber gets a linear utility from receiving calls will be used. Additionally attached customers will bear an extra disutility of s from switching if they subscribe to the new entrant such that w_1 and $w_2 - s$ will represent their net surpluses from subscribing to the incumbent and the new entrant respectively.

Since the customers are located along the Hotelling, then according to the concept of "rational expectations" the location of indifferent customer among attached customers, x_s, would be again given by the following equation,

$$x_s = \frac{1}{2} + \sigma(w_1 - w_2 + s) \tag{30}$$

Then, similarly the location of indifferent unattached customer would be solved

as

$$x_n = \frac{1}{2} + \sigma(w_1 - w_2) \tag{31}$$

As a result, the market share of the incumbent firm can be determined by $s_1 = \mu x_s + (1-\mu)x_n$. Therefore, the resulting market share of the incumbent can be solved as the following:

$$s_1 = \frac{1}{2} + \sigma(w_1 - w_2) \ + \mu\sigma s \tag{32}$$

Even though the equation (29) includes the term market share s_i, the resulting equation for s_1 does not contain any term with the market share. In addition, call externality terms cancel each other in the equation (29) so that there is no call externality terms either in the resulting formula. Then, the following equation would be obtained for s_1.

$$s_1 = \frac{1}{2} + \mu\sigma s + \sigma(v(p_1) - F_1(p_1) - v(p_2) + F_2(p_2)) \tag{33}$$

Furthermore, the profit functions of networks are adopted from the framework initiated by LRT(1998a) for the case of non-discrimination such that mobile operators will decide $\{F_i, p_i\}$ for their profit maximization. However, for the simplification of the optimization process, the same change of variables method will be used such that the networks will decide market shares s_i instead of fixed fees F_i and then the equilibrium values for fixed fees will be obtained through the first order conditions for market shares.

Mobile operators' profit functions will be composed of the components of revenues from calls, access revenues and costs of calls. The following equation represents a mobile operator's profit function adopted from LRT(1998a).

$$\pi_i = s_i[s_i(p_i - 2c)q(p_i) + (1-s_i)(p_i - c - a)q(p_i) + (1-s_i)(a-c)q(p_j) + (F_i - f)] \tag{34}$$

where again

(i) the first term represents the profit from on-net calls, which constitute s_i percent of all calls, with the price of p_i, the cost of $2c$ for both origination and termination, and the length of $q(p_i)$;

(ii) the second term stands for the profit from off-net calls, which constitutes $1 - s_i$ percent of whole calls, with the non-discriminated price of p_i, the cost of c for origination and a for termination, and the length of $q(p_i)$

(iii) the third term represents the profit from access charges with the price of a, the cost of c for termination, and the length of $q(p_j)$ received from the other operator.

(iv) the fourth term stands for the profit from fixed fee with the price of F_i, the cost of f.

Similar to the methodology followed in Section 3 the responses of fixed fees for the changes in prices would be obtained since the fixed fees are determined by the firms according to their prices as well. Therefore, fixed fee F_i will be represented as a function of prices which would be denoted by $F_i(p_i)$.

First, the derivative of fixed fee F_i with respect to market share s_i would be obtained from the equation (33). Taking the derivative of this equation with respect to both fixed fee and market share for both firms, $\frac{\partial F_i}{\partial s_i}$ and $\frac{\partial F_2}{\partial s_2}$, will be obtained as the following:

$$\frac{\partial F_1}{\partial s_1} = \frac{\partial F_2}{\partial s_2} = -\frac{1}{\sigma} \tag{35}$$

Moreover, the derivatives of fixed fees with respect to the non-discriminated prices would be obtained with the same operations through the equation (33). The results are as follows:

$$\frac{\partial F_1}{\partial p_1} = \frac{\partial}{\partial p_1} v(p_1) = -q(p_1) \tag{36}$$

moreover, substituting $s_2 = 1 - s_1$ in the equation (32) and making the same operations, the following results are obtained:

$$\frac{\partial F_2}{\partial p_2} = \frac{\partial}{\partial p_2} v(p_2) = -q(p_2) \tag{37}$$

Within the similar methodology used in Section 3, profit maximizing prices by keeping the market share and off-net prices constant will be obtained from the first order condition $\frac{\partial \pi}{\partial p_i} + \frac{\partial \pi}{\partial F_i}\frac{\partial F_i}{\partial p_i} = 0$ under the assumption that other firm's market share and non-discriminated price are given. Thus, the partial derivative of the firms' profits with respect to non-discriminated price would be given by the following expression:

$$s_1(\frac{\partial}{\partial p_1} q(p_1))[\, p_1 - (1 + s_1)c - (1 - s1)a \,] = 0$$

$$(s_1 - 1)(\frac{\partial}{\partial p_2} q(p_2))[\, s_1(a - c) - p_2 + 2c \,] = 0$$

Solving the above first order conditions for non-discriminated prices of both firms, the following equations are obtained:

$$p_1 = s_1(c - a) + c + a \tag{38}$$

$$p_2 = s_1(a - c) + 2c \tag{39}$$

As mentioned earlier the method of change of variables will be used for the equilibrium fixed fees so that networks' profits will be optimized with respect to market shares first by keeping the non-discriminated price constant under the assumption that other firm's market share, non-discriminated price are given. In this context, the expression $\frac{\partial \pi}{\partial s_i} + \frac{\partial \pi}{\partial F_i}\frac{\partial F_i}{\partial s_i} = 0$ will provide for the first order condition for market shares. In this setting, both firms own the same cost structure as mentioned in the Section 3. Therefore, I will assume that the access prices of both firms are set symmetrically, and equal to the cost of termination c for both simplicity and a stable equilibrium. Since the equation (33) represents a rational expectations

equilibrium, then keeping the values of fixed fees at the level which satisfies the rational expectations equilibrium and maximization of networks' profits with respect to market shares will ultimately provide the equilibrium profit maximizing fixed fees through a method of change of variables. Thus the first order conditions of market shares would be solved for fixed fees, the equilibrium fixed fees would be obtained as follows with the early assumption $a = c$:

$$F_1 = f + \frac{s_1}{\sigma} \tag{40}$$

$$F_2 = f + \frac{s_1}{1-\sigma} \tag{41}$$

Within the context of this section similar to Section 4, I will investigate how switching costs influence the equilibrium prices. Particularly, the reaction of prices to switching costs will be analyzed when switching costs are very small, very close zero, and switching costs tend to increase. Moreover, the analyses will be made at the point $a = c$ as mentioned earlier since the stable equilibrium exists when a is sufficiently close to c.

Similarly,the equilibrium pricing decisions of the firms will be analyzed regarding equations (38) and (39). First of all, it would be inferred that under the symmetric market shares, the equilibrium non-discriminated prices of firms will be equal to each other as long as two firms incur the same call origination and termination costs of c.

Second, equations (38) and (39) indicate that non-discriminated prices of firms are correlated with their market shares as access charges a are assumed to be slightly bigger than the cost of origination and termination c. As a result, two significant findings will help for further analyses.

Lemma 4 *For any equilibrium market share $s_i \in (0, 1)$, non-discriminated prices of the incumbent (new entrant) operator will decrease (increase) as their market share increases:*

$$\frac{\partial p_1}{\partial s_1} = -a + c < 0 \tag{42}$$

With reference to *Lemma* 4 (42), under the assumption that access charges a are slightly bigger than the cost of origination and termination c, it would be concluded that the incumbent's non-discriminated price will be lower than the entrant's non-discriminated price. This finding would be explained by the fact that the incumbent firm would offer lower unit prices since it has more on-net calls so that it would bear lower weighted average cost per minute. Furthermore, *Lemma* 4 (42) implies that the effect of switching costs over the non-discriminated price will be removed if the access charges are set at cost ($a = c$)and an obligation of price non-discrimination is imposed on the operators.

Lemma 5 *In equilibrium, market share of the incumbent firm will increase as the switching cost s increases at the point where switching cost is close enough to zero:*

$$\frac{\partial s_1}{\partial s} \mid_{s=0} = \frac{-\mu\sigma}{-3 + \sigma(a-c)(q(p_1) - q(p_2))} > 0 \tag{43}$$

Proof. Regarding the above equation, the analysis is made around the point that switching cost is close enough to zero so that a certain asymmetry is granted in market shares, thus in prices. Therefore, denominator is obviously negative since $q(p_2) > q(p_1)$ makes the term in parenthesis negative under the assumption that access charges is set slightly above costs $a > c$. This conclusion clearly holds when access charges are set at cost, i.e. when $a = c$ we have:

$$\frac{\partial s_1}{\partial s} \mid_{s=0} = \frac{\mu\sigma}{3} > 0 \tag{44}$$

Then, similar to *Lemma* 2 the same conclusion would be reached from *Lemma* 5 such that a small increase in the switching costs in favor of the incumbent firm will cause an increase in the incumbent firm's market share.

Lemmas (4) and (5) together imply the following proposition:

Proposition 4 *For switching costs very close to zero, equilibrium non-discriminated price of the incumbent firm decreases with a small increase in switching costs.*

$$\frac{\partial p_1}{\partial s}|_{s=0} < 0 \tag{45}$$

Proof 4 *By using the results of Lemma* 4 *and Lemma* 5*, such that*

$$\frac{\partial p_1}{\partial s_1}|_{s=0} < 0$$

and

$$\frac{\partial s_1}{\partial s}|_{s=0} > 0$$

hold for switching costs small enough and access charges are set slightly higher than the costs. Then,

$$\frac{\partial p_1}{\partial s}|_{s=0} = \frac{\partial p_1}{\partial s_1}\frac{\partial s_1}{\partial s}|_{s=0} < 0$$

which implies that equilibrium non-discriminated price of the incumbent firm decreases with an increase in switching costs in favor the incumbent firm.

Notice, however, that a regulatory remedy such that the operators are obliged to set access charges at cost, $a = c$, would help removing the effects of switching costs over the prices of the operators such that;

$$\frac{\partial p_1}{\partial s_1}|_{s=0} = -a + c = 0$$

Therefore, the derivative of non-discriminated prices for both firms with respect to the switching costs will be equal to zero and non-discriminated prices of the firms will be equal to the costs $p_1 = p_2 = 2c$.

Concerning the above result, it would be inferred that the effect of call externality is not taken into consideration in the pricing decision of the firms due to the balanced calling pattern under non-discriminated prices. With reference to the findings above, *Proposition* 4 (45) suggests that the incumbent will use the advantage of having a larger customer base due to the early entry and switching costs and then will be able to offer lower per-minute price. This result indicates that the incumbent firm will have incentive to decrease its non-discriminated price as the switching costs increase so that it would lock-in more consumers with the attractive lower prices while taking the consumer surplus through fixed fees. The case of lower per-minute prices for the incumbent will obviously cause traffic and payment imbalance in favor of the new entrant operator, however the new entrant will not receive any profit from the interconnection payments since the access charges are set at cost. In contrast, if the access charges are set slightly above costs, the incumbent firm will continue lowering its per-minute price and the level will decrease as long as switching costs increase so that the traffic imbalance in favor of the new entrant will arise in this situation also. However, the new entrant will be able make profits from interconnection payments since the access charges include some mark-up.

Since the incumbent offers lower price, then consumer surplus is expected to be greater compared to the consumers of the new entrant. Thus, the incumbent firm is expected to take whole excess surplus through fixed fee so that it would be argued that the fixed fee of the incumbent firm will be higher. I will try to confirm this expectation in the next proposition.

Proposition 5 *For switching costs very close to zero, equilibrium fixed fee of the incumbent firm increases with a small increase in switching costs.*

$$\frac{\partial F_1}{\partial s}|_{s=0} > 0 \tag{46}$$

Proof 5 *Using the equilibrium fixed fee obtained in (40), the following expression can be obtained:*

$$\frac{\partial F_1}{\partial s_1}|_{s=0} = \frac{1}{\sigma} \tag{47}$$

Furthermore, by using the result of Lemma 5*, such that*

$$\frac{\partial s_1}{\partial s}|_{s=0} > 0$$

holds for switching costs small enough. Then,

$$\frac{\partial F_1}{\partial s}|_{s=0} > 0$$

which indicates that equilibrium fixed fee of the incumbent firm increases with an increase in switching costs in favor the incumbent.

The above result of *Proposition* 5 (46) implies that the ability of the incumbent firm at taking excess consumer surplus through fixed fees increases with the switching costs. Therefore, by using the advantage of lower weighted average cost of calls, the incumbent firm charges lower non-discriminated price and obtains more consumer surplus through higher fixed fee.

In the context of regulatory policy, there would be the following remedy options:

(i) Policy Option 1: Non-discrimination in retail prices. The regulatory body imposes the obligation of setting non-discriminated prices for the operators which enable the incumbent operator to lower the per-minute price as switching costs

increase. This option enables the new entrant to receive profit from the interconnection payments, however the incumbent holds the advantage of increasing its market share through lower per-minute prices.

(*ii*) Policy Option 2: Cost-based access charges together with non-discriminated retail prices. The regulatory authority imposes the obligation of setting cost-based access charges together with the obligation of setting non-discriminated prices. This remedy results symmetric per-minute prices and fixed fees for both operators, and remove the incentive of the incumbent operator for decreasing prices and obtaining market share through it.

7 Welfare Analysis

With reference to the concept of consumer surplus, the obligation of setting non-discriminated prices would be welfare-improving depending on the functional form of the consumers' demand. However, it turns out that it is quite difficult to obtain clear results without simplifying the model and eliminating some of the interesting market characteristics such as asymmetry resulting from switching costs and call externalities. Intuitively, one would infer that consumer surplus obtained through lower per-minute prices is taken by the incumbent operator by setting higher fixed fee so that this situation may not improve the consumers' surplus. On the other hand, with a general form demand function under symmetric networks in terms of market share (so that the switching costs is equal to zero) and very small call externality, price discrimination becomes welfare-improving for the consumers. However, these assumptions are quite strong so that the core interest of this paper is fully eliminated. Therefore, it would be logical to state that under a symmetric market equilibrium with lower call externalities, price discrimination would be a welfare-improving alternative in terms of consumer surplus.

In order to conduct an analysis over consumers' surplus, it would be beneficial to use the following equation (see Hoernig (2007) pg. 174):

$$CS = \mu\{\int_0^{x_s} w_1(z)\,dz + \int_{x_s}^1 (w_2(z)-s)\,dz\} + (1-\mu)\{\int_0^{x_n} w_1(z)\,dz + \int_{x_n}^1 w_2(z)\,dz\}$$

First, regarding price discrimination case, plugging the equation (1) for $i = 1, 2$ into the above equation, the following result would be obtained:

$$CS_d = s_1 w_1 + (1 - s_1) w_2 - \mu s (1 - x_s) + \frac{1}{4\sigma}(2s_1 - 1 - 2(\mu x_s^2 + (1 - \mu) x_n^2)) \quad (48)$$

where implicit forms of x_s and x_n are denoted in the equations (3) and (5), respectively. In addition, consumer welfare functions w_1 and w_2 are in the general form denoted by the equation (1)which includes p_{ii}, p_{ij} and p_{ji} whose equilibrium values are represented by the equations (15), (16) and (17) respectively. In order to obtain a straightforward result regarding the consumer surplus, I would impose the following functional forms for consumers demand and indirect utility functions:

$$d(p) = r - p$$

$$v(p) = \frac{(r - p)^2}{2}$$

where r is y-intercept of the demand function. Then, I will evaluate implicit forms of x_s and x_n and general forms of welfare functions by introducing demand function and indirect utility function whose functional forms have been stated above and I will insert those functions into the consumer surplus equation with equilibrium prices. As a result, the equation (48) remains including the parameters $a, c, \beta, \mu, \sigma, r$ and s together with the incumbent's market share s_1.

Here, I would like to conduct a comparative statics analysis with the following values for the parameters: $a = 0.1, c = 0.1, \beta = 0.8, \mu = 0.5$ and $\sigma = 1$. These values imply that consumers attach value to the incoming calls to a high extent ($\beta = 0.8$), half of the consumers leave the in the second period ($\mu = 0.5$)and then mobile telecommunication operators are highly substitute to each other $\sigma = 1$. Therefore, the resulting formula for the consumers surplus remains including only switching costs s and the market share of the incumbent firm s_1. Starting with a symmetric equilibrium $s_1 = 1/2$ which can be satisfied with no switching costs $s = 0$, my analysis will show the effect of increasing switching costs from the point $s = 0$ over the whole consumer surplus. The following figure shows the change in consumer surplus with the switching cost in the range of $s = 0$ to $s = 1$:
As the Figure (1) indicates, introducing small switching costs in favor of the incumbent firms (such that $s > 0$) causes consumer surplus to decrease under symmetric equilibrium $s_1 = s_2 = 1/2$ for the case that operators are allowed to discriminate on-net and off-net prices.

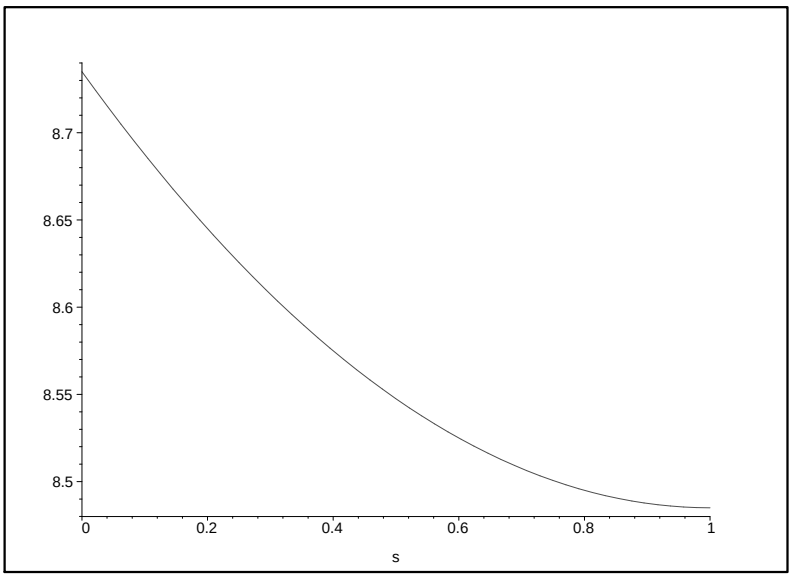

Figure 1: Change in Consumer Surplus with respect to Change in Switching Costs for Price Discrimination Case

After finding out that an increase in switching costs cause a decrease in consumer surplus for price discrimination case, it would be beneficial to analyze whether the effects of switching costs would be reversed in the case that operators are not allowed to price discriminate. In this context, analyses for the consumer surplus conducted for price discrimination case will be repeated for the case of non-discriminatory prices. Therefore, the consumer surplus will be measured with the equation (48) and the same conversion will be done for the equilibrium values of variables and parameters, and forms of functions such that the method is as follows again.

Implicit forms of x_s and x_n are denoted in the equations (30) and (31), respectively. In addition, welfare functions w_1 and w_2 are in the general form denoted by the equation (29)which includes p_{ii} and p_{jj} whose equilibrium values are represented by the equations (38) and (39) respectively. Concerning a straightforward result regarding the consumer surplus, similar to price discrimination case, the following functional forms for consumers demand and indirect utility functions would be imposed:

$$d(p) = r - p$$

$$v(p) = \frac{(r-p)^2}{2}$$

where r is again y-intercept of the demand function. Then, implicit forms of x_s and x_n and general forms of welfare functions will be evaluated by introducing demand function and indirect utility function whose functional forms have been stated above and those functions will be inserted into the consumer surplus equation with equilibrium prices. At the end, the consumer surplus equation will remain including the parameters $a, c, \beta, \mu, \sigma, r$ and s together with the incumbent's market share s_1.

Then, it would be beneficial to conduct a comparative statics analysis with the following values for the parameters similar to the price discrimination case: $a = 0.1, c = 0.1, \beta = 0.8, \mu = 0.5$ and $\sigma = 1$. Thus, the consumers surplus equation remains including only switching costs s and the market share of the incumbent firm s_1. Starting with a symmetric equilibrium $s_1 = 1/2$ which can be satisfied with no switching costs $s = 0$ that makes analysis less complicated, my analysis will show how an increase in switching costs from the point $s = 0$ affects the whole consumer surplus. The following figure shows the change in consumer surplus with the switching cost in the range of $s = 0$ to $s = 1$:

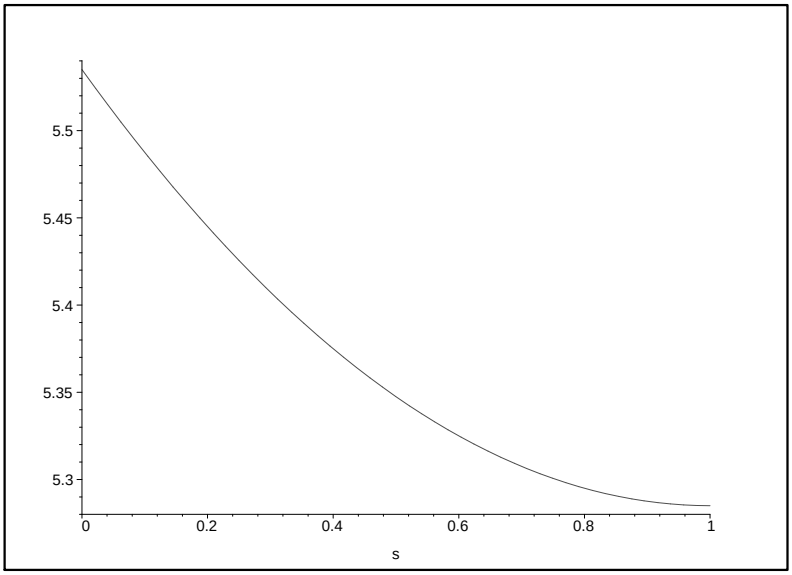

Figure 2: Change in Consumer Surplus with respect to Change in Switching Costs for non-Discriminatory Prices Case

Similar to price discrimination case the Figure (2) indicates the same result such that introducing small switching costs in favor of the incumbent firms (such that $s > 0$) causes consumer surplus to decrease under symmetric equilibrium $s_1 = s_2 =$

1/2 for the case that operators are not allowed to charge discriminated prices.

This chapter states that consumer surplus decreases if switching costs are introduced into the market in both price discrimination and non-discriminatory prices cases. Moreover, it would be inferred that increasing switching costs from any particular point would cause a decrease in consumer surplus. One of the results that can be deducted from the values in y-axis in Figures (1) and (2) is indicating that consumer surplus is decreasing if non-discriminatory prices are imposed. However, regarding consumer surplus I have conducted all the analyses stated in this chapter under symmetric equilibrium the simplicity of the results due to the fact that symmetric equilibrium requires zero switching costs. This assumption eliminates one of the core interests of my paper which is asymmetric networks in size. As a result, it would be suggested that the best practice could be imposing remedies which eliminate switching costs in the market so that the negative effects of switching costs over the consumer surplus could be removed.

8 Conclusion

This paper has been prepared with the motivation created by the effects of switching costs over the mobile telecommunications operators' pricing strategies in the Turkish Mobile Telecommunications Market where long incumbency period caused high switching costs. Under the interconnected competing networks model developed by Laffont, Rey and Tirole (1998b), the market has been modeled with consumers' switching costs, call externalities, asymmetric networks and price discrimination between on-net and off-net calls.

In this setting, I showed that the incumbent mobile operator will have incentive to set higher off-net prices in order to modify the traffic balance between operators while attaining its subscribers due to the switching costs so that the network of new entrant lose its attractiveness due to the fact that its subscribers receive lower amount of calls from the other operator. This situation causes the existing subscribers to lock-in to the incumbent mobile operator and moreover avoids the new subscribers from subscribing the new entrant mobile operator. Furthermore, the analysis regarding the level of access charges indicates that the incumbent operator's incentive to set higher access charges increases as the switching costs increase.

Regarding the effects of pricing strategies of the firms over the competitiveness

of the market, price non-discrimination has been suggested as a regulatory remedy. In this context, the result of price non-discrimination implies that the incumbent will prefer setting lower per-minute prices and then it takes the consumer surplus created by lower per-minute prices through higher fixed fee. However, this remedy will enable traffic and payment surplus for the new entrant in terms of interconnection. As a final point, I have not been able to obtain general conclusions about the impact of a non-discrimination remedy on consumer welfare. In contrast, by eliminating some of the core concepts dealt in this paper such as call externalities and asymmetry between the operators resulting from the switching costs so that symmetric equilibrium is reached at the end, the price discrimination has been found as a welfare-improving alternative for the consumers. However, comparative statics results indicate that the existence of switching costs in the market decreases consumer welfare under both price-discrimination and non-discriminatory prices. Therefore, the best practice to increase consumer welfare would be suggested as imposing remedies which eliminate or reduce the switching costs in the market such as the implementation of number portability, prohibition of penalty fees taken by the operators in the case of cancelation of contracts by subscribers.

In conclusion, I would argue that the incumbent would set higher fixed fee and off-net price in the case of price discrimination in order to increase its market share, generate interconnection surplus and create consumer lock-in by seizing the opportunity of switching costs. Moreover, the incumbent firm will prefer higher symmetric access charges in the case of price discrimination since the incumbent firm will enjoy interconnection surplus due to higher off-net prices. On the other hand, the incumbent firm will continue to use the advantage of switching costs by setting lower per-minute prices and taking the consumer surplus through higher fixed fee.

A APPENDIX

A.1 Market Concentration and Market Shares of the Incumbent Firms in EU and Turkey:

	Market Concentration	Market Share of Incumbent Firm
UNITED KINGDOM	2282	25.2%
GERMANY	2972	37.1%
DENMARK	3039	43.4%
ITALY	3087	39.8%
NETHERLANDS	3118	44.7%
FINLAND	3134	37.6%
SWEDEN	3157	44.8%
IRELAND	3187	42.6%
AUSTRIA	3336	42.7%
GREECE	3351	36.3%
BELGIUM	3453	42.0%
SPAIN	3540	45.4%
PORTUGAL	3624	43.9%
FRANCE	3708	45.7%
TURKEY	4154	56.0%
LUXEMBOURG	4362	56.4%

Source: Wireless Intelligence

▪Market Concentration is calculated with the following formula:

$$\sum_{i=1}^{N} s_i^{\,2}$$

where N is the number of mobile operators in the market and s_i is the market share of the firm i

Figure 3: Market Concentration and Market Shares of the Incumbent Firms in EU and Turkey

A.2 First Order Condition for The Firms' Profits with respect to Market Shares

$$\frac{\partial \pi}{\partial s_i} = \{s_i + 2\sigma v(p_{ii})s_i^2 - f_i\sigma + \sigma v(p_{ij})s_i + F_i\sigma s_i - s_i^2 + 3\sigma q(p_{ji})as_i - 2\sigma q(p_{ji})as_i^2$$

$$-3\sigma q(p_{ji})cs_i + 2\sigma q(p_{ji})cs_i^2 + \sigma\beta q(p_{ji})s_i - \sigma\beta q(p_{ji})s_i^2 + f\sigma - f\sigma s_i - \sigma q(p_{ji})a +$$
$$\sigma q(p_{ji})c - 2\sigma v(p_{ii})s_i + \sigma v(p_{ji})s_i - \sigma v(p_{ji})s_i^2 - \sigma v(p_{ij})s_i^2 + s_i^2\beta q(p_{ij})\sigma\}/\{(-1+s_i)\sigma\}$$

A.3 Equilibrium Fixed Fees in Price-Discrimination Case

$$F_i^{eq} = \{-s_i - 2\sigma v(p_{ii})s_i^2 - \sigma s_i v(p_{ij}) + s_i^2 - 3\sigma q(p_{ji})as_i + 2\sigma q(p_{ji})as_i^2 + 3\sigma q(p_{ji})cs_i - 2\sigma q(p_{ji})cs_i^2$$
$$-\sigma s_i\beta q(p_{ji}) + \sigma\beta q(p_{ji})s_i^2 - f\sigma + f\sigma s_i + \sigma q(p_{ji})a - \sigma q(p_{ji})c + 2\sigma v(p_{ii})s_i - s_i\sigma v(p_{ji}) + \sigma v(p_{ji})s_i^2$$
$$+\sigma v(p_{ij})s_i^2 - s_i^2\beta q(p_{ij})\sigma\}/\{(-1+s_i)\sigma\}$$

A.4 Graphical Expressions for Section 5.2

Change in the value of $s_1 - 3s_1^2 + s_1^3$ with respect to market share s_1 which has been indicated in the first part of C in the Equation (27)

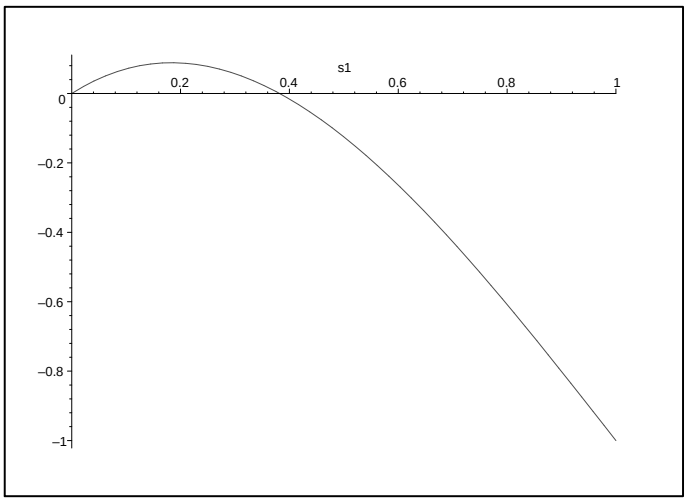

Figure 4: Change in the value of $s_1 - 3s_1^2 + s_1^3$ with respect to market share s_1

Change in the value of $-2s_1 + s_1^3 + 1$ with respect to market share s_1 which has been indicated in the second part of C in the Equation (27)

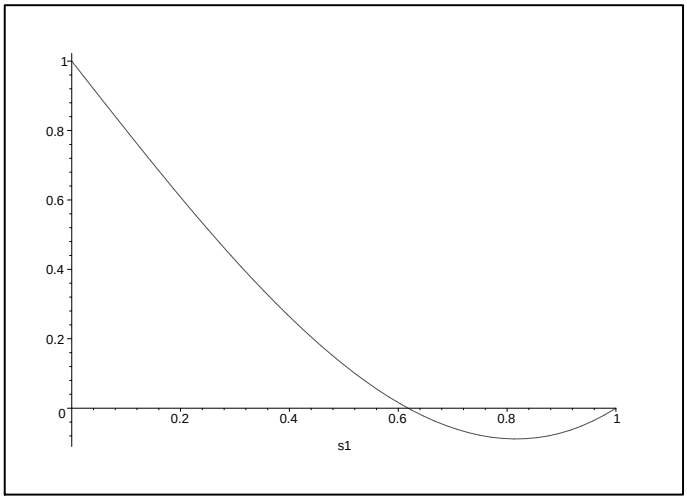

Figure 5: Change in the value of $-2s_1 + s_1^3 + 1$ with respect to market share s_1

Change in the value of C in the Equation (27)with respect to market share s_1 if demand function is linear so that $\frac{\partial q(p_{12})}{\partial p_{12}} = \frac{\partial q(p_{21})}{\partial p_{21}}$

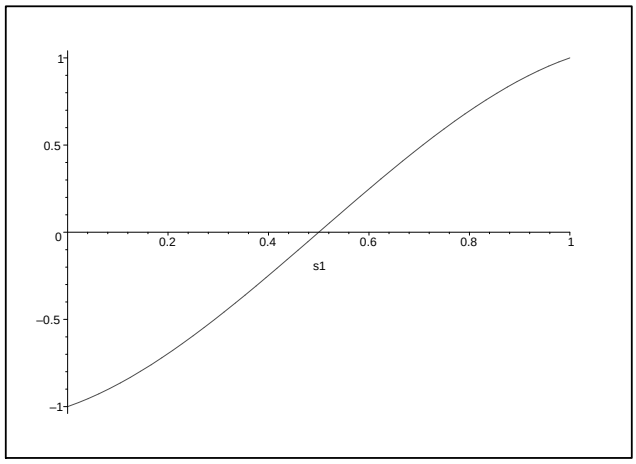

Figure 6: Change in the value of C with respect to market share s_1 if demand function is linear

Change in the value of C in the Equation (27)with respect to market share s_1 if demand function is convex so that $\frac{\partial q(p_{12})}{\partial p_{12}} > \frac{\partial q(p_{21})}{\partial p_{21}}$

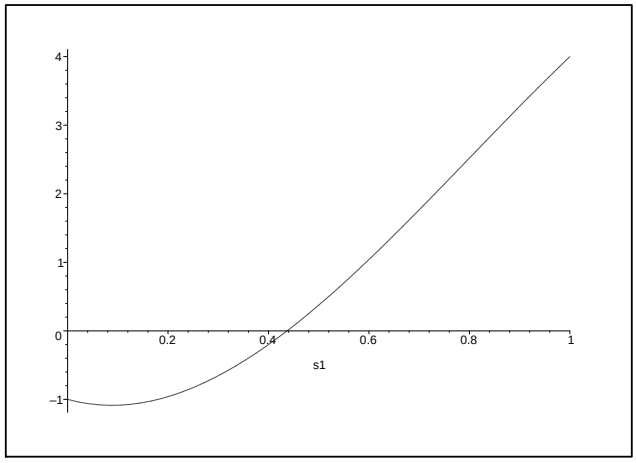

Figure 7: Change in the value of C with respect to market share s_1 if demand function is convex

With reference to Figures (6) and (7), it would be inferred that for all $s_1 > 1/2$ C gets positive if demand function is convex.

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