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Versioning in the Norwegian telecommunications market

Limiting mVoIP access

Jens Petter Sognnes

Advisor: Lars Sørgard

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Abstract

If a company is unable to distinguish individual consumers by observable characteristics, but has some aggregate knowledge regarding unobservable consumer characteristics, versioning might be a successful pricing strategy. This thesis takes an in-depth look into different forms of versioning theory to gain a richer understanding of the theories' underlying mechanisms. The theory is then used to construct a model of consumer demand for mobile phone subscriptions with internet access. The purpose is to figure out whether it would be profitable for Telenor to attempt a versioning strategy where two distinct quality versions of mobile phone subscriptions are offered: one with mVoIP access, and one without mVoIP access.

The Benchmark Monopolist model shows that versioning is potentially profitable in a monopolist setting depending on the implementation cost. The profitability of versioning is driven by a market expansion effect. When a new low-quality product version is introduced, new customers with low willingness to pay for quality are included in the market. Limiting mVoIP access will also help to diminish the cannibalization of telephony services.

In a competitive setting, the success of versioning is conditioned on the ability of the market actors to cooperate. If all telecom companies in the market implement a versioning strategy, they are all better off. However, incentives to deviate from cooperation complicates the prospects of reaching a stable versioning equilibrium in a market with intense price competition. Strong and clear signaling and the threat of retaliation are necessary to hold market actors in line.

Foreword

This master thesis is written as part of my Master in Economics and Business Administration at the Norwegian School of Economics (NHH). It constitutes 30 credits of my major in Economic Analysis.

The thesis explores a specific form of price discrimination called versioning in the context of the Norwegian telecommunications market. My goal when starting this project was to provide a thorough review of versioning theory, and to show how the theory may be applied to problems that many businesses are facing today.

I would like to take this opportunity to thank my advisor, Lars Sørgard. His advice and constructive criticism have improved my thesis considerably. He is also the one who suggested using the telecom industry as a case study of versioning as a pricing strategy. This idea let me combine my academic interest in industrial organization and price discrimination with a current issue facing a rapidly changing telecom market. I also wish to thank my fellow students and friends, who have helped me by providing motivation, comments and insight along the way.

Bergen 20 December 2012,

Jens Petter Sognnes

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1. Introduction

Many telecommunications companies are expressing concern with the rise of free Voice over Internet Protocol (VoIP) services, such as Skype and Viber, in recent years. In an article published by the financial news agency E24 (2012), Swedish telecom companies say they are developing the capability to block access to VoIP programs on mobile phones (mVoIP), claiming such services are costing them too much in lost revenues. With this option in hand, it would be possible to change the terms of mobile phone subscriptions. Consumers will have a choice between a subscription allowing access to programs like Skype or an alternative subscription without such access. If consumers vary in their willingness to pay for access to mVoIP, telecom companies could exploit this heterogeneity among consumers to segment the market and price discriminate.

The Chief Information Officer for the Norwegian telecom company Telenor, Anders Krokan, said in the same article (E24, 2012) that they are monitoring the situation closely. Telenor has no official plans to do what their Swedish counterparts are trying to do, but they are considering possibilities of a solution through a shared initiative with other market actors. In this master thesis, I wish to test the viability of a strategy based on versioning mobile phone subscriptions by limiting mVoIP access to consumers. The thesis question is:

Is it profitable for Telenor to pursue a strategy of versioning by creating two types of mobile phone subscriptions: one with access to mVoIP services, and one without access to mVoIP services?

Due to the somewhat limited scope of a master thesis in economic analysis, I will keep my main focus on the economics of the problem. In the analysis it is assumed that restricting mVoIP access would be both legal and technically feasible. However, it is worth noting that the European Commission is currently exploring issues surrounding the restriction of access to legal services, like Skype, on the internet (E24, 2012). It could be considered a breach of the net neutrality principle, so the question of legality is not fully settled.

We start by taking a look at some important terms and the characteristics of the telecom market in Norway. After having established the industry conditions, we move on to the relevant economic theory. Versioning and theories closely related to this form of price discrimination will make up the majority of the theory section. The main body of the paper is the theoretical analysis and the application of the analysis to the thesis question. In conclusion, the most important points of the analysis are summarized and an answer to the thesis question is presented.

2. Industry terms and market characteristics

In this section we first give a short description of what VoIP actually is and of this technology's potential. Moving on from there, characteristics of the Norwegian telecom market are presented. This will include trends in subscriptions, traffic, revenues and market shares. Finally, the most important trends in the industry with relation to the thesis question are summarized.

2.1 VoIP

Voice over Internet Protocol, or VoIP, itself is a technology that allows for speech to be turned into digital data packets. This type of technology is commonly used to make phone or video calls. By transforming speech into a digital format, it can easily be sent over the Internet to other devices with internet access. The digital format also allows for easy manipulation of the content and flexibility in what kind of phone services can be provided. With this technology service, providers can develop a variety of applications that are not possible or practical over the traditional telephone network (Werbach 2005). The term mVoIP simply refers to VoIP used on mobile devices (Picard 2011).

2.2 Subscriptions

According to the Norwegian Post and Telecommunications Authority (NPT) the traditional fixed-line telephony market is currently shrinking in Norway. From the end of the first half of 2010 to the end of the first half of 2011, the number of fixed-line telephony subscriptions fell by 115 000. In table 1 we see that there has been a decline in subscriptions of about 7% per year from 2009 to 2011. The drop was driven by a sharp decline in PSTN and ISDN subscriptions, which fell by about 10% per year over the same period (NPT 2011, page 10).

Fixed-line telephony subscriptions	2010-2011	2009-2010
Change in number of subscriptions	- 6.8%	-7.0%

Table 1: Data taken from NPT report (2011, page 10).

The drop in PSTN and ISDN subscriptions was only slightly offset by a small increase in VoIP subscriptions. The overall negative trend in the fixed-lined market has persisted since 2001 and has been increasingly negative over time (NPT, page 10). Approximately 4-in-10 households did not have a fixed-line subscription at the end of the first half of 2011 (NPT, page 12). Based on these trends, it would seem that consumers are moving away from fixed telephony to other forms of voice services, i.e. mobile telephony or non-fixed-line VoIP, or to other forms of communications altogether.

Given the trends we see in the fixed-line telephony market, what is happening in the mobile telephony market? From the end of the first half of 2010 to the end of the first half of 2011 the number of mobile telephony subscriptions grew by 2.7%, or by 148 000 subscriptions. The year before, the percentage increase was twice as large. Overall there were more than 5.67 million mobile telephony subscriptions by the end of the first half of 2011 (NPT, page 12).The increase in mobile telephony subscriptions is primarily driven by an increase in post-paid subscriptions, as illustrated bellow (NPT, page 13):

Mobile telephony	2010-2011	2009-2010
Change in number of subscriptions	2.7%	5.3%

Table 2: Data taken from NPT report (2011, page 12).

Growth in mobile telephony subscriptions

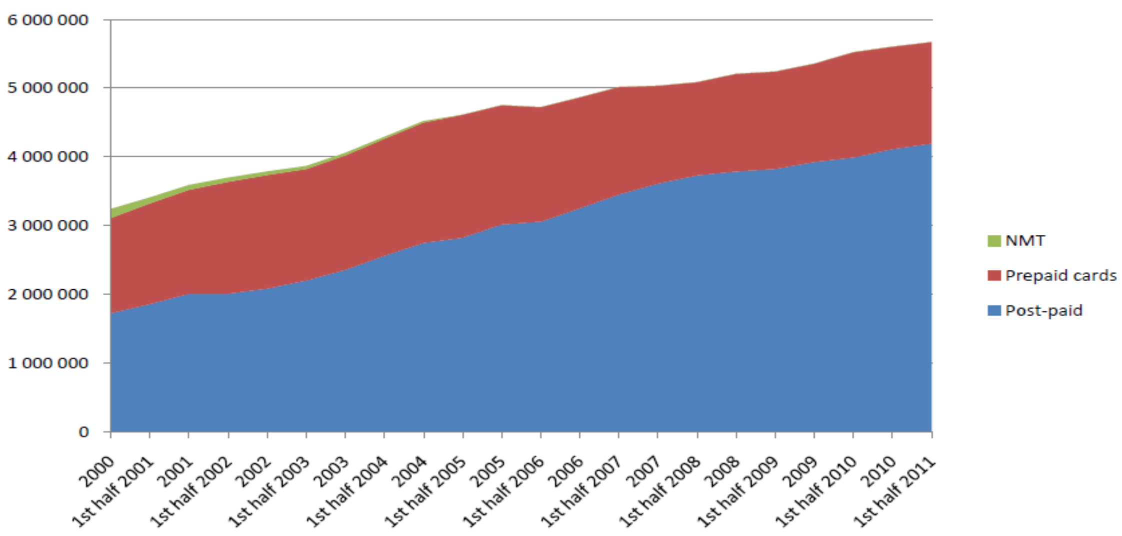

Figure 1: Graphic taken from NPT report (2011, page 13, figure 2) shows the highly persistent growth in mobile telephony subscriptions.

Moreover, the residential segment constituted 77% of the subscriptions at the end of the first half of 2011, and this customer group has roughly held that same market share in mobile phone subscriptions in recent years (NPT, page 13).

Moving on to mobile data, NPT divides this market into three segments (page 13):

- Dedicated mobile broadband subscriptions
- Internet access via ordinary mobile telephony subscriptions
- Telematics subscriptions

The dedicated mobile broadband subscriptions are not a part of the mobile telephone subscriptions, but purely used for data traffic purposes. Internet access via ordinary mobile telephony subscriptions is data use related to mobile phone subscriptions. For some subscriptions, consumers pay a fixed fee per month and get a “free” data packet included in that deal. Consumers then have a specific quota of data they can use per month for free, and only pay extra for data used in excess of that quota. Although this is part of the - internet access via ordinary mobile telephony subscriptions - category, the NPT keeps track of such data packet subscriptions as an individual category as well, sometimes separating them from ordinary mobile telephony subscriptions. The telematics subscriptions are used for machine to machine (M2M) communication (NPT, page 13).

By the end of the first half of 2011, there were over 640 000 dedicated broadband subscriptions with an increase of 144 000 subscriptions since the end of the first half of 2010. The residential customers made up 60.3% of the market. Looking at the mobile telephony subscriptions with data packets, there were 474 000 such subscriptions by the end of the first half of 2011. The number of these subscriptions grew by 235 000 since the same time the year before, i.e. the segment doubled in size over the space of one year. Residential customers made up 37.0% of this mobile data segment. If you combine these two segments of the mobile data market, the division between residential and business customers is about 50/50 (NPT 2011, page 14).

In NPT's report we find a clear illustration of the high growth in mobile data subscriptions:

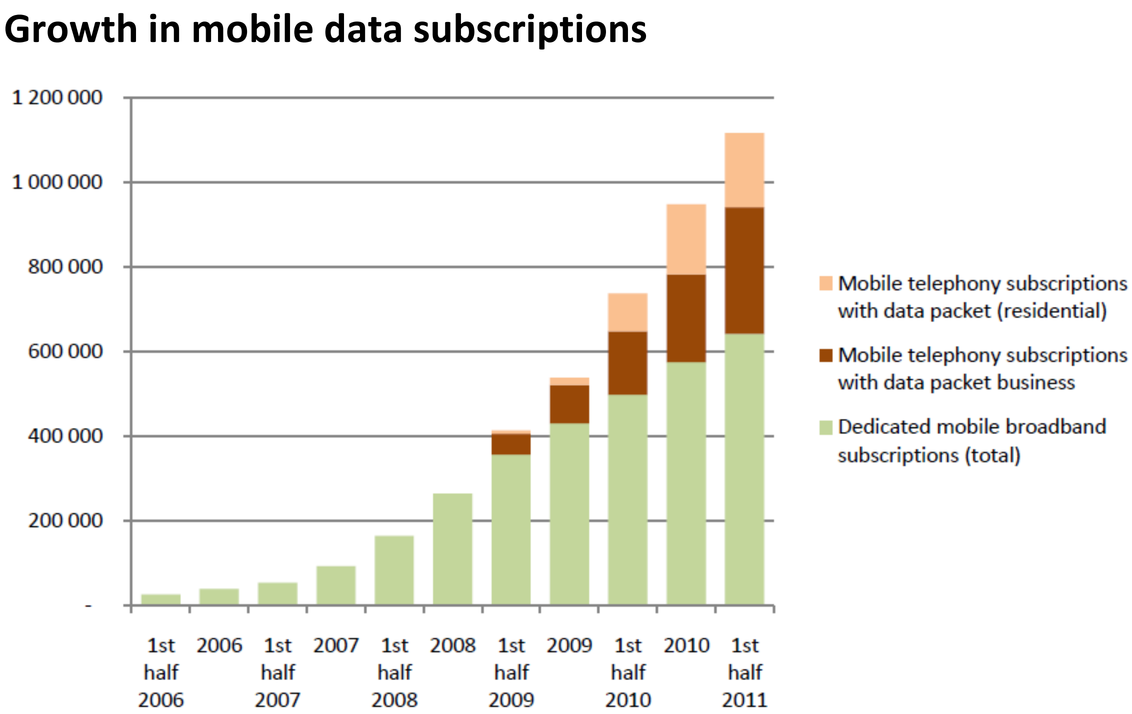

Figure 2: Graphic taken from NPT report (2011, page 15, figure 4) shows the rapid growth in mobile data subscriptions over recent years.

The telematics market is more or less shared between Telenor and Netcom. According to the NPT, the number of SIM cards used for M2M communication has grown significantly, and this market seems to have a high potential for future growth. By the end of the first half of 2011, the number of such SIM cards were about 600 000, with a growth of 108 000 from the same time the year before (NPT, page 15).

As we can see from these numbers, the mobile telephony market is growing as the fixed telephony market is shrinking. In addition, the market for mobile data is increasing at a rapid pace. We will continue with a more thorough look at the traffic volumes from the fixed and mobile telephony markets in Norway.

2.3 Traffic

Within fixed-line telephony, the time-charged calls, which makes up most of this market, have been declining since 2001. In table 3 we see a sharp decline in call minutes between 2009 and 2011. According to the NPT (page 22), the drivers behind the decline in traffic are the rise of mobile telephony, social media messaging services and the transition from dial-up internet to fixed broadband. Fixed network to fixed network traffic is responsible for the majority of the decline in the fixed-line telephony market. The residential customers are responsible for 61.0% of the fixed network traffic, but this group's share of traffic has been declining since 2006 (NPT, page 22).

Fixed-line telephony	2010-2011	2009-2010
Change in call minutes	- 14.0%	-13.0%

Table 3: Data taken from NPT report (2011, page 22).

Mobile-originated traffic measured in call minutes increased by 3.3% from the first half of 2010 to the first half of 2011. The prior year, the percentage increase was more than twice as large. According to the NPT (page 24), data from the past decade or so indicates that the growth in mobile call minutes is in the process of leveling out. Average voice traffic increased each year from 2003 to 2010. In the first half of 2011, there was a slight but not significant decline compared to the first half of 2010. The data also shows that the vast majority of calls from mobile phones are within the mobile network, i.e. to other mobile phones (NPT, page 24).

Mobile telephony	2010-2011	2009-2010
Change in call minutes	3.3%	7.7%

Table 4: Data taken from NPT report (2011, page 24).

Mobile-to-mobile traffic is also responsible for most of the growth in mobile phone calls:

Growth in mobile-originated traffic

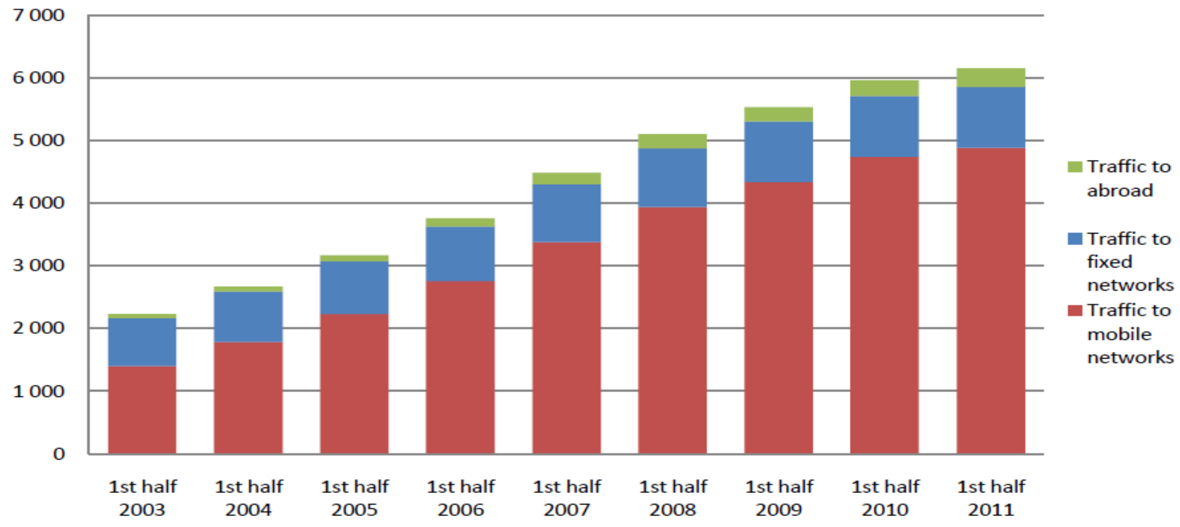

Figure 3: Graphic taken from NPT report (2011, page 24, figure 12) shows increase in mobile-originated traffic.

Looking at messages sent by mobile telephony we include SMS, MMS and content messages. Content messages are made up of ringtones, logos and other content. Total number of messages peaked in 2009, and then declined each year until 2011, by 75 and 123 million messages respectively. SMS messages make up the majority of messages with a 92.0% share. As we can see in table 5, the average number of messages sent per month per user has been declining from 2009 to 2011 (NPT, page 24-25):

Mobile phone messages	2011	2010	2009
Average number of messages sent per month per user	97	105	112

Table 5: Data taken from NPT report (2011, page 25).

Total data traffic, combining dedicated mobile broadband subscriptions and ordinary mobile telephony, increased sharply between 2009 and 2011:

Total data traffic (w/o telematics)	2010-2011	2009-2010
Increase in data traffic (in million Gbytes)	2.32	1.5
Growth in data traffic	53.0%	53.0%

Table 6: Data taken from NPT report (2011, page 25).

Of the total data traffic in the first half of 2011 dedicated mobile broadband subscriptions made up the majority with a share of 77.0%. In this dedicated mobile broadband segment, the residential customers constituted 78.4% of the traffic. The share of total data traffic related to the mobile telephony subscriptions with data packets was 4.4 %, up from 1.7% from the first half of 2010. The data traffic associated with other ordinary mobile telephony subscriptions was 1.24 million Gigabytes in the first half of 2011, which was 18.6% of total data traffic. The amount of this type of traffic is up from 430 000 Gbytes in the first half of 2010 (NPT, page 25-26).

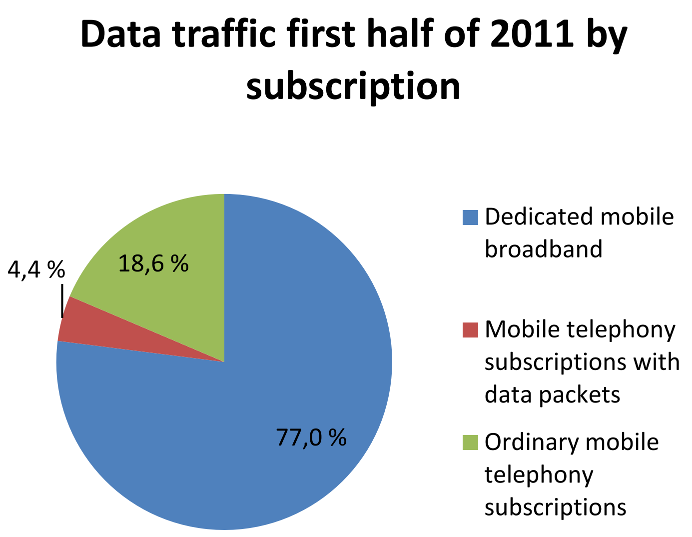

Figure 4: Graphic is a rendering of graphic found in NPT report (2011, page26, figure 15).

Of the total traffic charged per minute from both mobile and fixed-line telephony, mobile traffic is increasing its share. In table 8 below, we can see how mobile's share has changed between 2009 and 2011. Total traffic fell from 2010 to 2011 as mobile traffic increased. In summary, the total traffic from mobile and fixed-line telephony has fallen by 63 million minutes from the first half of 2001 to the first half of 2011 (NPT, page 26-27). Behind this overall trend, fixed-telephony has been in decline while mobile telephony has grown, as table 7 illustrates.

Change in traffic	2010-2011
Change in overall traffic	-3.0%
Change in mobile-originated traffic	3.0%

Table 7: Data taken from NPT report (2011, page 27).

Trends in traffic	2011	2010	2009
Mobile's share of total traffic charged per minute from both mobile and fixed telephony	68.0%	54.0%	59.0%

Table 8: Data taken from NPT report (page 26) shows an increasing mobile share of total traffic.

2.4 Revenues

After looking at both subscriptions and traffic we, now move on to the revenue side. In fixed-line telephony, there has been revenue decline of 12.7% from the first half of 2010 to the first half of 2011. In monetary terms, this was a drop from NOK 3.013bn to NOK 2.630bn between these two periods. Table 9 provides a breakdown of the revenue changes in fixed-line telephony. When we

Changes in fixed-line revenues	2010-2011
Overall	-12.7%
Traffic to fixed	-24.0%
Traffic to mobile	-18.0%
Calls abroad	-13.0%

Table 9: Data taken from NPT report (2011, page 28).

look at where the decline was most pronounced, we find that traffic to fixed networks is responsible for most of the revenue loss. Of the decline in revenues, NOK 200m came from the residential market and NOK 183m from the business segment. (NPT 2011, page 28).

According to NPT's numbers, over the period from 2003-2011 the growth of revenues from mobile services, not including dedicated mobile broadband subscriptions, seems to be leveling out. The increase in revenue from the first half of 2010 to the first half of 2011 was only NOK 35m compared to a NOK 308m increase over the previous year. Furthermore, revenues from both SMS traffic and time-charge calls declined. As a share of total mobile services revenue, subscription revenues are increasing as both SMS and time-charged calls are decreasing their shares. Time-charged calls still make up the biggest share of total revenue (NPT 2011, page 30).

Total mobile data revenue in the first half of 2011 was NOK 1.39bn, up from NOK 983m in the first half of 2010. Of the total mobile data revenue, dedicated mobile broadband subscriptions make up the majority share with NOK 612m, followed by ordinary mobile telephony subscriptions and mobile subscriptions with a data packet. Telematics' share is the smallest. Mobile subscription with a data packet increased its revenue from NOK 71m in the first half of 2010 to NOK 243m in the first half of 2011. Among the dedicated mobile broadband and data packet subscriptions, residential customers generate 51.0% and 36.0% of revenues respectively. As table 10 shows, combined mobile telephony and mobile data revenue increased from the first half of 2010 to the first half of 2011, but mobile telephony revenue alone fell at the same time. This shows that it is mobile data driving the revenue growth in the mobile segment, as other mobile telephony services seems to be stagnating or perhaps just leveling out (NPT 2011, page 31-32).

Revenue changes (NOK million)	2010-2011
Mobile telephony and mobile data	143
Mobile telephony (w/o mobile data)	-264

Table 10: Data taken from NPT report (2011, page 32) shows that mobile telephony revenue, excluding mobile data, is declining.

Trends in the mobile segment are illustrated in figure 5 below:

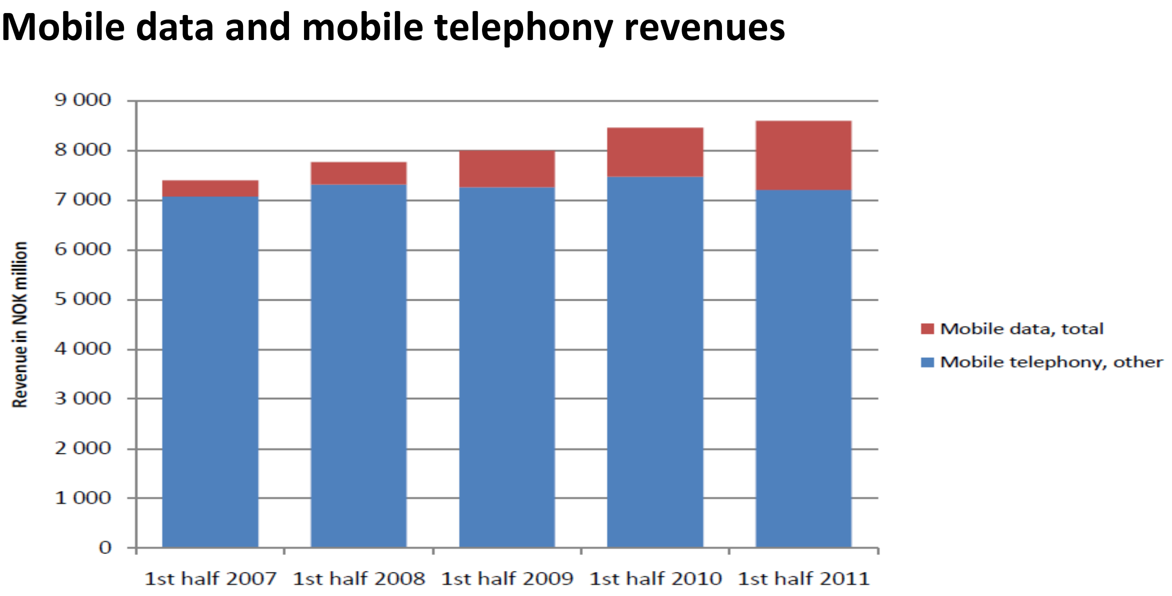

Figure 5: Graphic from NPT (2011, page 32, figure 20) showing the trends for mobile data and mobile telephony revenues.

2.5 Market shares

After looking at the big picture for the entire telecom market and its various market segments, we now take a closer look at the companies who compete for market shares in this changing industry. In the fixed telephony segment, Telenor is the dominant player with the biggest market shares. This is true for traffic, revenues and subscriptions. However, Telenor's competitors have been successful in gradually chipping away at the company's dominant position in recent years. In the table below you can see how Telenor has lost ground in all of the three categories mentioned above between the first half of 2003 and the first half of 2011 (NPT 2011, page 35-36):

Telenor's market shares in fixed telephony	2011	2003
Subscriptions	65.0%	96.0%
Revenues	66.6%	81.8%
Call minutes	58.5%	68.0%

Table 11: Data taken from NPT report (2011, page 35-36) showing Telenor losing ground in the fixed telephony market.

It seems that in fixed telephony Telenor, is being affected by both a shrinking fixed telephony market and increased competition.

We move on to look at the mobile telephony segment. Telenor is less dominant in this area. In the first half of 2011, Telenor had roughly a 50 % share in ordinary subscriptions, call minutes, SMS messages and revenues. Its closest rival is Netcom, with market shares around 18-22% in the above mentioned categories. For a more detailed look at the market shares, please take a look at table 12 (NPT 2011, page 37).

Market shares in mobile telephony	2011
Ordinary subscriptions - Telenor	49.4%
Ordinary subscriptions - Netcom	17.7%
Call minutes – Telenor	50.4%
Call minutes – Netcom	19.1%
SMS messages – Telenor	53.2%
SMS messages - Netcom	21.6%
Revenues - Telenor	53.6%

Table 12: Data taken from NPT report (2011, page 37) shows Telenor and Netcom's market shares.

In the mobile data segment, including both residential and business customers, Telenor had a market share of 54.7% of dedicated mobile data subscriptions by the end of the first half of 2011. Netcom had a market share of 25.2%. The second largest competitor would be ICE, who had a market share of 12.0 %. Looking at the residential and the business segments separately, we see that Telenor is doing better among business customers than with residential customers. The opposite is the case for both Netcom and ICE. In table 13 we see that Telenor had around 53% and Netcom about 22% of mobile data revenues in the first half of 2011. Mobile data revenues include dedicated mobile broadband, mobile telephony with data packets, ordinary mobile telephony and telematics (NPT 2011, page 38-39).

Market shares of mobile data revenue	2011
Telenor	53.2%
Netcom	22.3%
ICE	6.4%

Table 13: Data taken from NPT report (2011, page 39) shows Telenor with the highest share mobile data revenue.

2.6 Industry summary

According to international comparison done by NPT (2011, page 49-51), Norway has the cheapest fixed telephony services among OECD countries. This analysis is based on consumption levels set by OECD baskets and adjusted for purchasing power parity (PPP). In the mobile telephony segment, Norway is ranked among the five cheapest countries in the OECD. Norway's position in this segment depends on the assumptions that are made regarding consumption levels. For 30 calls per month, Norway is the cheapest; for 100 calls Norway is number 3; and for 300 calls Norway is number 5. Given these statistics, it would seem that the Norwegian telecommunications market is highly competitive compared to other telecom markets in developed countries.

It seems clear that the telecom industry in Norway is rapidly changing. One very pronounced trend is consumers moving away from fixed-line telephony and towards mobile, and mobile data is growing particularly fast. Telenor is losing ground in areas where they have historically dominated. In both fixed and mobile telephony, Telenor has had a declining market share as other telecom companies like Netcom have challenged them.

Given that consumers are becoming more concentrated in the mobile segment, the potential market for free mVoIP services is growing and becoming a more serious threat to the telecom industry's revenue streams. As revenues from mobile data and mobile telephony combined are increasing, mobile telephony revenue alone is declining. Time-charged calls and SMS revenues in the mobile segment are driving the decline. With laptops and tablets that come with built-in video cameras and microphones, and the growth of smart phones, all consumers have to do is decide to download mVoIP software, which is usually free. Apple already includes an mVoIP application called FaceTime, which allows for video calling, as a built-in feature in their newest iPhone models.

With intense competition in the Norwegian telecom market, it is hard for telecom providers like Telenor to capture more consumer surplus without being punished by competitors. The pressure to keep prices low seems to be strong, at least compared with other OECD markets. It is very easy for a consumer to switch providers, so Telenor must tread carefully or risk losing customers to Netcom or other telecom companies. Even so, some adjustment by Telenor to the new reality of how people communicate seems vital to maintain a competitive edge in the future. Could versioning be at least part of the answer for how telecom companies can successfully adapt to a changing world of communication?

3. Theory

In this section we will go through some of the important economic theories relevant to the thesis question. We start by taking a general look at price discrimination before focusing on versioning, which is a specific form of price discrimination. The intuitive Varian (2000) model offers a simple illustration of how versioning may be profitable for a company and also increase consumer welfare. Afterward I present a more detailed versioning model by Belleflamme (2005) is presented, which is based on a slightly different set of assumptions than the Varian model. Towards the end of the theory section, we take a look at some basic game theory, and how competition may affect the outcome of versioning.

3.1 Price Discrimination

There are a variety of definitions for the term price discrimination. According to Stole (2007, page 2224):

"Price discrimination exists when prices vary across customer segments in a manner that cannot be entirely explained by variations in marginal cost."

This definition of price discrimination allows for the possibility that the marginal cost of providing a product or service may differ between certain consumer groups. Varying marginal cost would justify the price not being identical for all consumer groups. For instance, first class passengers on planes get better in-flight service and more flexibility with their ticket. They pay more for the same basic service of being transported from A to B in order to receive these extra conveniences. But if the extra cost of accommodating a first-class passenger, compared to accommodating an economy class passenger, is less than the difference in ticket prices for these two groups, we have price discrimination by Stole's definition.

Two important conditions that determine when price discrimination is feasible are:

1) Arbitrage is too costly to enforce the "law of one price" (Tirole 1988, pages 134-135)
2) The seller has at least some market power (Pindyck & Rubinfeld 2005, page 381)

Number one states that it is not profitable or practical for a consumer who is offered a cheaper product version to resell it to a consumer who is offered a more expensive product version. In other words, the transaction costs are too high for someone to be able to buy low and sell high. Number two says that the seller must have some market power to be able to influence prices. We know that in a market with perfect competition, the seller has no influence over prices, and has to set output so that marginal cost is equal to the market price. Any price higher than the market price would lead to the seller losing all customers to competitors (Pindyck and Rubinfeld 2005, page 267). Therefore, there has to be imperfect competition for the seller to have market power.

A common way to look at price discrimination is to divide it into three categories: first-, second-, and third-degree price discrimination. First-degree price discrimination, also called perfect price discrimination, allows the seller to capture the entire consumer surplus. With perfect information about every customer, the seller sets a different price for each individual consumer equal to the consumer's reservation price. The reservation price for a consumer is the maximum amount of money the consumer is willing to pay for the product. First-degree price discrimination is not a pricing strategy that is easy to implement in practice. The reasons for this are the lack of information about consumers, and the fact that such widely divergent pricing tend to create arbitrage opportunities (Tirole 1988, page 135).

With the more realistic assumption of having imperfect information about consumers, the seller could attempt to design product packages to incentivize consumers to self-select the package intended for them. This pricing strategy is based on an aggregate knowledge about consumer preferences, which are unobservable on an individual basis. It is called second-degree price discrimination. Versioning is a form of second-degree price discrimination, and we will shortly explore this strategy in detail (Tirole 1988, page 135).

Sometimes the seller may be able to distinguish some characteristics regarding the consumers that might be useful, such as age or gender. The seller may then try to price discriminate based on these observable characteristics. This is known as third-degree price discrimination (Tirole 1988, page 135). Typical examples of third-degree price discrimination include student and senior discounts on various products and services. We now move on to Varian's (2000) versioning model.

3.2 Varian's model of Versioning

To clearly describe the theory of versioning, I will start with perhaps the simplest and most intuitive model. Varian's (2000) work on versioning of information goods shows how this form of price discrimination may both increase profits for a monopolist and increase welfare for consumers. In this rendition of the Varian (2000) model, my main focus is on versioning's effect on the monopolist, as this aspect is most relevant for my thesis question.

According to Varian (2000, page 190), versioning, also referred to as quality discrimination, occurs when the seller offers different versions of the same good, each with a different quality and price level. By versioning, the seller may be able to segment the market based on customers' willingness to pay (WTP) for quality. An important condition for versioning to work is that the consumers are heterogeneous in their WTP for quality. If the opposite were true, and each consumer valued quality equally, then versioning would not be more profitable than a simple one-price strategy for the monopolist.

Versioning as a pricing strategy makes sense particularly for information goods. As Varian explains (2000, page 190), information goods often have low to near-zero marginal cost of reproduction but high fixed costs of production. These goods are therefore not well suited for the traditional cost-based pricing model, which is more useful for goods with a positive marginal cost. A better pricing strategy for information goods would be a price based on the consumers' valuation of the product, i.e. value-based pricing.

Varian (2000, page 192) assumes that the monopolist is unable to segment the market by observable characteristics, like age, gender, or likewise. In other words, the monopolist cannot simply charge different prices to each individual customer based on their appearance. This leaves out the possibility of both first- and third-degree price discrimination. The monopolist is then left with the self-selection method of second-degree price discrimination. To succeed in segmenting the market, the seller must design the different product versions such that they satisfy the self-selection constraint described by Varian (2000, page 193):

“the seller wants to choose price/quality packages so that the consumers with high WTP choose the high-price/high-quality package, and the consumers with low WTP choose the low-price/low-quality package.”

The self-selection constraint is the crux of versioning. The essential part is that the high-WTP consumers sees the alternative low-price/low-quality package as an unacceptable alternative to the high-price/high-quality package. By creating a low-quality version, and reducing the quality of this version sufficiently, the monopolist is able to charge a higher price for the high-quality version to the high-WTP consumers, without risking that they instead choose to buy the low-quality version.

We now move on to an illustration of Varian’s (2000, page 191-194) versioning model with two distinct consumer groups. A certain fraction of the population, π, represents high-WTP consumers, and the rest, $1 - \pi$, represents the low-WTP consumers. Varian (2000, page 194) assumes that the parameter $\pi = \frac{1}{2}$, which means that the low- and high-WTP consumer groups are equal in size. However, I will take a more general approach and also analyze how different values of π will influence the results of versioning in this model.

The monopolist has information regarding the aggregate distribution of the WTP among consumers, but he is unable to distinguish which group an individual consumer belongs to. In other words, the monopolist knows something about the value of π and makes his decisions on how to design the price/quality packages based on this information. Varian (2000, page 191) also assumes that the marginal cost of adjusting, either improving or degrading, quality is zero. However, the model can be altered for cases where the marginal cost of quality is not zero. The zero marginal cost of quality assumption is not unreasonable for information goods, since format or quality of digitalized information can easily be manipulated at low or approximately zero marginal cost.

Figure 6 illustrates the versioning model with two distinct consumer groups:

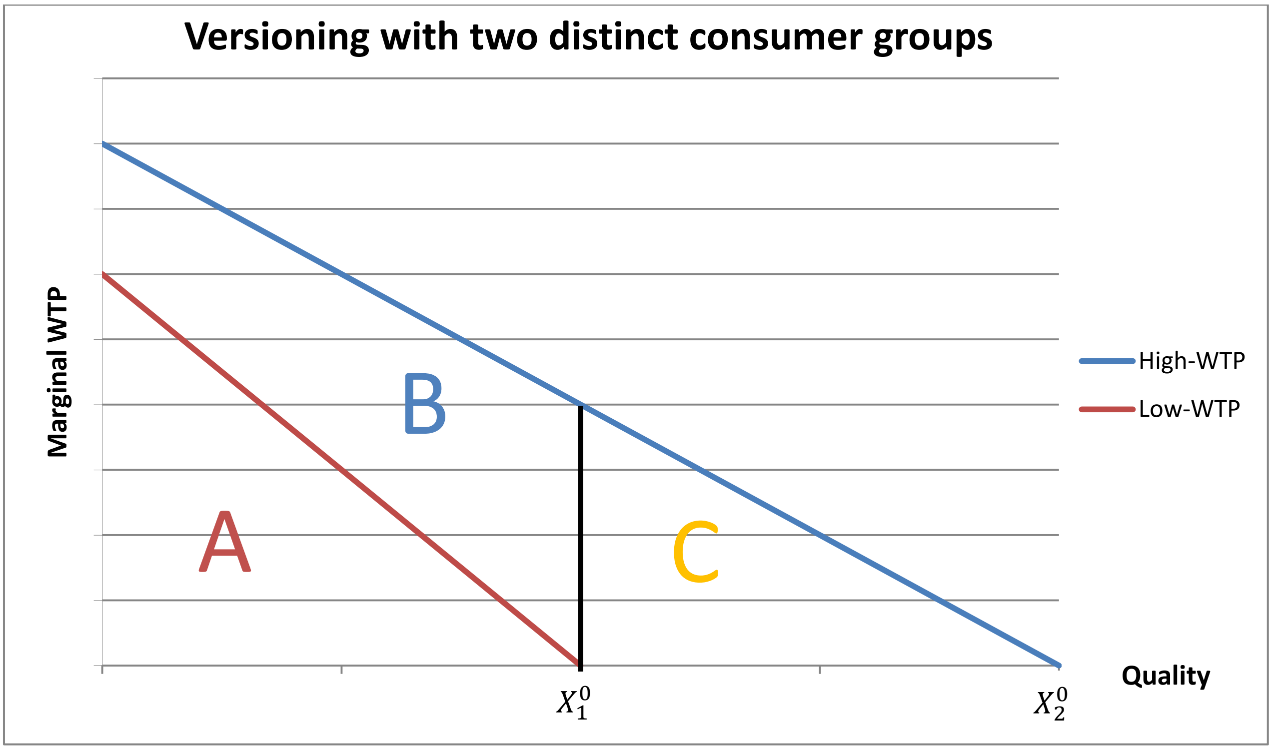

Figure 6: This is a rendering of the graphic used by Varian to illustrate his model (2000, page 194).

In figure 6 we see two distinct marginal WTP-curves. The blue and red curve represents the high- and low-WTP consumers respectively. On the x-axis, the quality level of the good is described. The further away from origin we move along the x-axis, the better the quality of the good becomes. On the y-axis, the marginal WTP for quality is described. The further we move away from the origin along the y-axis, the higher is the marginal WTP for quality. The blue and red curve illustrates the relationship between the two dimensions, quality and marginal WTP for quality, for the consumer groups.

The WTP-curves intersects with the x-axis at the quality level where the consumers have a zero marginal WTP for quality. We can see that the red curve crosses the x-axis at the X_1^0 quality level, i.e. the low-WTP consumers gain no additional value from improving quality beyond this level. Similarly, the high-WTP consumers have zero marginal WTP for quality beyond a level of X_2^0, where the blue curve crosses the x-axis. Between the origin and X_1^0, the low-WTP consumers have a positive marginal WTP for quality. This means that the monopolist could improve the quality of the product within this interval and charge a higher price, as the consumers would then value the product more. Conversely, if the monopolist reduced quality within this interval, the consumers would be willing to pay less. The same is true for the high-WTP consumers in the interval between the origin and X_2^0.

To find the prices the monopolist can charge for the different product versions, we need to look at the area beneath the marginal WTP-curves. The area beneath the marginal WTP-curves, bound by the y-axis and a given quality level, represents the reservation price the consumer has for that particular quality level. To clarify, the low-WTP consumer has a reservation price equivalent to the area A for a product version of quality X_1^0. Similarly, the high-WTP consumer has a reservation price equivalent to the area A + B + C for a product of quality X_2^0 (Varian 2000, page 193).

3.2.1 One price/quality strategies

Varian (2000, page 193-194) goes on to describe various scenarios for both one price/quality and two price/quality strategies. We start by examining one price/quality strategies:

1) Set one price/quality → produce one product with X_2^0 quality and charge A + B + C → sell only to high-WTP consumers
2) Set one price/quality → produce one product with X_2^0 quality and charge A → sell to both consumer groups

Lets first look at the outfall of strategy one. If the seller only produces one high-quality product with quality X_2^0, and sells it at a price A + B + C, only the high-WTP consumers will buy the product. The low-WTP consumers will not buy the product since it would give them a negative consumers surplus in this case. Therefore the profit made by this strategy is equal to (Varian 2000, page 192):

$$\pi(A + B + C)$$

This equilibrium is clearly not Pareto efficient since the seller could also sell to the low-WTP consumers without being worse off (Varian 2000, page 192). A Pareto efficient equilibrium refers to a state where none of the market actors, consumers or producers, could be made better off by another feasible resource allocation without making someone else worse off (Tirole 1988, page 6). However, by selling to both consumer groups the monopolist risks hurting his profit potential from the high-WTP consumers (Varian 2000, page 192). We will look closer at this complication for the two price/quality strategies later on.

In the second case, the seller only produces one high-quality product version with the same quality level, X_2^0, but sets a lower price at A. This is at no extra cost to the monopolist than selling one low-quality version, X_1^0, at price A, since the marginal cost of quality is assumed to be zero. In this case both high- and low-WTP consumers will choose to buy the product. The profit for the monopolist from this pricing strategy is (Varian 2000, page 192):

$$\pi A + (1 - \pi)A$$

$$= A$$

The high-WTP consumers now have a positive consumer surplus of value B + C, while the low-WTP consumers have zero consumer surplus. This solution is Pareto efficient since no one can be made better off without making someone else worse off. Note, however, that if the monopolist instead had produced one low-quality version, X_1^0, at price A, this would not be a Pareto efficient solution. The profit would still be the same for the monopolist but the high-WTP consumers would now only have a consumer surplus equal to B, ergo they are worse off.

Now we will analyze which one of these one price/quality strategies is the most profitable for the monopolist. The number one strategy of only selling to the high-WTP consumers is more profitable for the monopolist if:

$$\pi(A + B + C) > A$$

$$\pi(B + C) > (1 - \pi)A$$

$$\rightarrow \quad (B + C) > \frac{1 - \pi}{\pi} A$$

If this condition holds, the monopolist will choose to only sell to the high-WTP consumers. In other words, the low-WTP consumers will be excluded from the market. If the inequality is reversed:

$$(B + C) < \frac{1 - \pi}{\pi} A,$$

and this condition holds, the most profitable strategy is serving both consumer groups. We can see from this expression that the value of π is important in determining the direction of the inequality sign. As the value of π approaches zero, the expression on the right side of the inequality will approach infinity. This tells us that a low value of π will mean that it is more profitable to sell to both consumer groups. Since a low value of π indicates that there are very few high-WTP consumers relative to low-WTP consumers in the market, this is a reasonable conclusion. On the other side, if π approaches 1, indicating a high share of high-WTP consumers in the market, the expression on the right side approaches zero, and serving only the high-WTP consumers will be most profitable.

3.2.2 Two price/quality strategies

Let us consider the case of producing two versions of quality X_1^0 and X_2^0, at prices A and A + B + C, respectively. The high-WTP consumers will receive zero consumer surplus from buying the high-quality version, but they will receive a positive consumer surplus of B from buying the low-quality version. Therefore, the high-WTP consumers choose to buy the low-quality version. This is a violation of the self-selection constraint that was described earlier, as the monopolist fails to segment the market (Varian 2000, page 193).

To comply with the self-selection constraint and avoid risking the high-WTP consumers buying the low-quality product, the seller can set a maximum price of only A + C for the high-quality product. With the high- and low-quality product versions priced at A and A + C, respectively, the high-WTP consumers would be indifferent between them. Both versions now give them a consumer surplus of B. Therefore, the strategy including the quality pair X_1^0 and X_2^0 will gain the monopolist a maximum profit of (Varian 2000, page 193):

$$\pi(A + C) + (1 - \pi) * A$$

Maximum profit for quality pair $(X_1^0, X_2^0) \quad = A + \pi C$

It is however possible to increase the seller's profits even further through versioning. According to Varian (2000, page 194) the optimal strategy is defined as follows:

"The seller will continue to reduce the quality of the low-quality bundle until the marginal reduction in revenues from the low-WTP consumers just equals the marginal increase in revenues from the high-WTP consumers."

By reducing the quality of the low-quality product from X_1^0 to X_1^V , the seller can support a higher price for the high-quality product, X_2^0. This goes back to what was earlier referred to as the crux of versioning. The goal is to make the low-quality alternative sufficiently unacceptable for the high-WTP consumers. We degrade the quality of the low-quality product so that we do not have to reduce the price of the high-quality product to satisfy the self-selection constraint. As the quality of the low-quality product is reduced, the monopolist must also accept a lower price for this version. This gives us the two effects Varian mentioned in the quote above. As the monopolist reduces the quality of the low-quality product, he marginally increases his revenues from high-WTP consumers, as he can now charge a higher price for the high-quality product. At the same time, the monopolist marginally loses revenue from the low-WTP consumers, as he is forced to cut the price of the low-quality product when the quality of this version is degraded. The optimal amount of quality reduction is given by the equilibrium state where these two marginal effects equal out to zero.

Here is an illustration of the optimal versioning strategy:

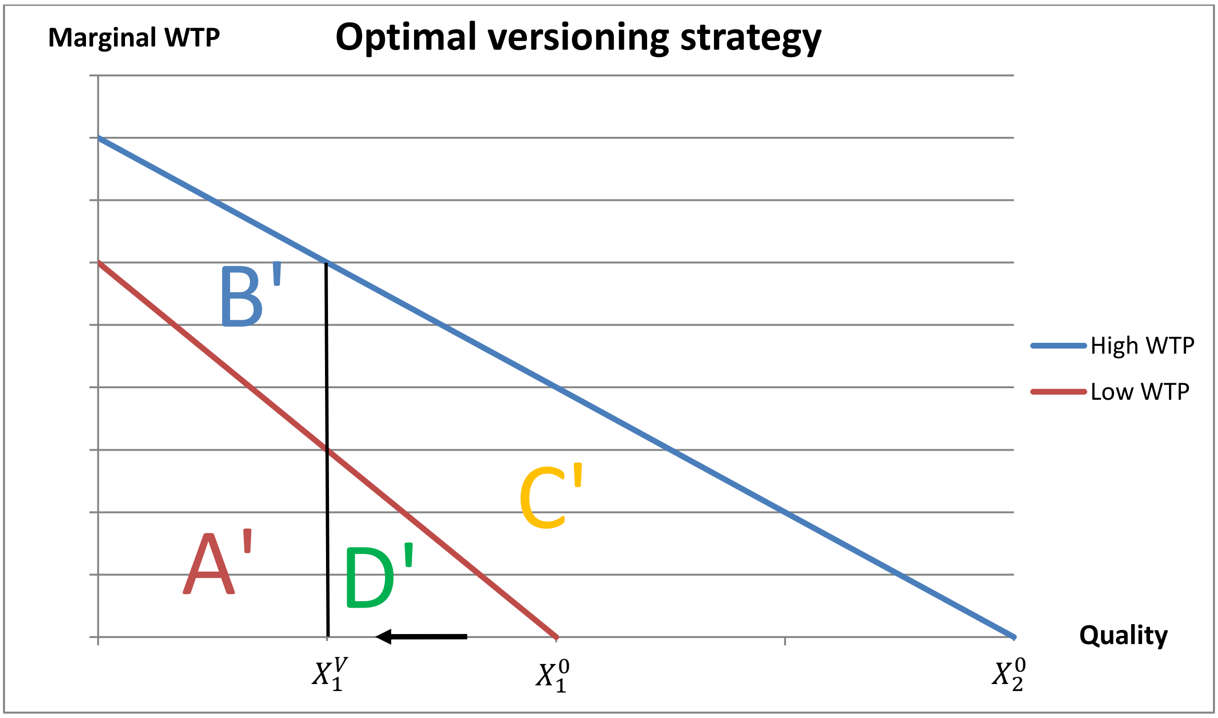

Figure 7: This is a rendering of the graphic used by Varian to illustrate his model (2000, page 194).

When the seller marginally reduces quality of the low-quality product from X_1^0, he loses revenue equal to the marginal increase of the area D’, but at the same time he gains revenue equal to the marginal increase of the area C'. This effect is illustrated by the vertical black line moving left from X_1^0. The marginal increase of the area D' represent the loss of revenue from low-WTP consumers, and the marginal increase of the area C' represents the increase in revenue from the high-WTP consumers, as the quality level of the low-quality product is diminished.

Starting at X_1^0, we see that the marginal increase in the area C' is larger than the marginal increase in the area D', as the vertical black line shifts left. This remains true all the way until the vertical black line reaches X_1^V, where these marginal effects even out to zero. Keep in mind that this particular equilibrium is only optimal when $\pi = \frac{1}{2}$. If $\pi > \frac{1}{2}$, then the equilibrium point would be to the left of X_1^V, and if $\pi < \frac{1}{2}$, it would be to the right. For $\pi = \frac{1}{2}$, any further degrading of the low-quality good beyond X_1^V would have a net negative effect on the monopolist's profit. By reducing the quality of the low-quality version to X_1^V, it is now possible for the seller to price the high-quality version at A' + C' + D', while he can only charge A' for the low-quality version. The profit for this versioning strategy would be (Varian 2000, page 197):

$$\pi(A' + C' + D') + (1 - \pi)A'$$

Maximum profit for quality pair (X_1^V, X_2^0) $\quad = A' + \pi(C' + D')$

The quality pair (X_1^V, X_2^0) priced at A' and A' + C' + D' respectively, would give the maximum profit possible from a versioning strategy with the given assumptions made by Varian (2000). This conclusion follows from the argument above:

$$\rightarrow \quad A' + \pi(C' + D') > A + \pi C$$

Varian (2000, pages 197-198) illustrates the conditions that must hold for versioning to improve overall social welfare. As I already stated, I will instead focus on the conditions that must be true for versioning to improve the monopolist's profit. However, it is worth noting that versioning may avoid the exclusion of the low-WTP consumers when it is most profitable to only sell to high-WTP consumers in a one price/quality market.

If the quality/price pair of $(X_1^V,\ X_2^0)$/(A', A' + C' + D') is the overall best strategy for the monopolist, it will be more profitable than both of the one price/quality strategies we looked at earlier. For the optimal versioning strategy to be more profitable for the monopolist than only selling to the high-WTP consumers, the following must be true:

$$A' + \pi(C' + D') > \pi(A + B + C)$$

$$\rightarrow \quad A' + \pi(C' + D') > \pi(A' + B' + C' + D')$$

$$\rightarrow \quad (1 - \pi)A' > \pi B'$$

$$\boldsymbol{A' > \frac{\pi}{1 - \pi} B'}$$

For the optimal versioning strategy to be more profitable for the monopolist than selling only one quality version to all consumers, the following must hold:

$$A' + \pi(C' + D') > A$$

$$\rightarrow \quad A' + \pi(C' + D') > A' + D'$$

$$\rightarrow \quad \pi(C' + D') > D'$$

$$\rightarrow \quad \pi C' > (1 - \pi)D'$$

$$\boldsymbol{C' > \frac{1 - \pi}{\pi} D'}$$

In figure 6, we can easily confirm visually that both these conditions hold for Varian's (2000) example, when it is assumed that $\pi = \frac{1}{2}$. Therefore, Varian's theory shows graphically that versioning may increase profits for a monopolist under certain circumstances. However, we can also see from the latter of the two conditions above that if π is sufficiently small in value it would undoubtedly be more profitable to have a one price/quality strategy that served both consumer groups. The former condition shows that a one price/quality strategy that only serves the high-WTP consumers is preferable when π is sufficiently close to 1. Moving on, we take a good look at a more mathematical model of versioning by Belleflamme (2005) with slightly different underlying assumptions.

3.3 What separates Belleflamme from Varian

Before we begin to explore Belleflamme's (2005) model of versioning, it is best to start by addressing some fundamental differences between this model and Varian's (2000) model of versioning. Contrary to Varian, Belleflamme assumes that the monopolist has a choice between two different quality versions which are exogenously given. In other words, the monopolist is not able to adjust quality freely along a dimension, but is limited to two specific quality options. Therefore, the monopolist maximizes profit by adjusting prices. This is a clear distinction from Varian, who lets the monopolist maximize profit with respect to the quality levels of the product versions, which the monopolist can adjust freely.

Belleflamme (2005) also expands the heterogeneity of the consumers. Instead of having just two different consumer groups like Varian (2000), Belleflamme (2005) assumes that each consumer has a preference parameter value, θ, which is on the interval $[0,1]$. This parameter tells us something about how much the consumer values quality, and it is assumed that consumers are uniformly distributed in terms of their θ-values along this interval. Belleflamme's approach gives a much more varied view of consumers and how they may differ in their valuation of quality.

Furthermore, Belleflamme (2005) assumes that in the case where the monopolist is producing only a single quality version, it is always more profitable to produce the high-quality version than the low-quality version. By this assumption, successful versioning will always expand the market in Belleflamme's model. This is an important distinction from Varian (2000). Belleflamme also allows the groups that buy the low-quality and high-quality versions to shrink and grow continuously as prices change, as long as demand is positive. In Varian's model however, demand does not continuously change, but rather jumps between predetermined demand levels defined by the given size of the high- and low-WTP groups.

The reason for this difference is that Belleflamme (2005) assumes a downward sloping demand curve. With a downward sloping demand curve, the demand for the product will rise as the price of the product goes down. Similarly, the demand will go down when the price goes up. This is true over the entire interval where demand is positive. But in Varian's (2000) model, the demand would stay the same over certain price intervals, holding the quality levels constant, even when the price is changing. When crossing the threshold between these price intervals, the demand will instantly jump to a new level. With given quality levels, the thresholds for a jump in demand is given by the reservation price for the two consumer groups. The Varian (2000) demand curve would have a shape like a two step staircase, the steps indicating the price threshold that triggers a jump in demand, and the drop between the steps indicating the price intervals where demand remains constant.

3.4 Belleflamme's simple model of Versioning

Belleflamme describes how to achieve successful versioning (2005, page 332):

" The key is to identify some dimensions of the product that are valued differently across consumers, and to design the product line so as to emphasize differences along those dimensions. The next step consists in pricing the different versions in such a way that consumers will sort themselves out by selecting the version that most appeals to them."

In many ways this is very similar to the core principle of Varian's (2000) model. But here we have a more mathematical build-up of how versioning works, and some important differences in the underlying assumptions addressed. Belleflamme (2005, page 333) starts with a case where a monopolist is choosing quality/price packages of an information good. Consumers are spread over a continuum based on their valuation, measured in θ, of a specific key quality dimension of the information good. The consumers' taste parameter θ is uniformly distributed on the interval [0,1], and consumers with high θ-values have a high valuation of quality and vice versa. The monopolist can produce two different levels of quality for the information good along the key dimension, and the two quality levels are exogenously given. The two quality levels are s_1 and s_2, where $s_2 > s_1$. Consumers are homogeneous with respect to their valuation of other quality dimension of the information good, and they have unit demands. The latter means that they buy a maximum of one unit each. The utility of consumers can be described in the following way, when consuming a unit with quality s_i, sold at price p_i and the consumer is of type θ (Belleflamme 2005, page 333):

$$U(\theta, s_i) = k + \theta s_i - p_i, \qquad i = 1, 2$$

Where: $k \geq 0$, is a measure of the common valuation for all other dimensions of the information good. A consumer's utility is equal to zero if she does not buy anything. It is also assumed that k < s_1. This implies that the consumer with the highest valuation of the key quality dimension ($\theta = 1$) values even the lowest quality version available, s_1, more than all the other dimensions of the good combined.

Belleflamme (2005, page 334) states the following situation for the monopolist:

"He knows the aggregate distribution of the taste parameters but is unable to identify a particular consumer's type."

The monopolist is faced with either making only one quality version and selling it at one price, or two quality versions and selling them at different prices, i.e. versioning. It is assumed that there is a constant marginal cost $c_i \geq 0$ of producing one unit of the good at quality s_i. Even a consumer with a low θ will buy either version if priced at marginal cost, meaning $c_i \leq k$. Here are two assumptions that summarize how the parameters relate to each other:

Assumption 1 $\quad 0 \leq c_1,\ c_2 \leq k < s_1 < s_2$

Assumption 2 $\quad c_2 < c_1 + x, with\ x \equiv k + s_2 - c_1 - \sqrt{\frac{s_2}{s_1}}(k + s_1 - c_1) > 0$

Assumption 2 clarifies the condition that the cost of producing the high-quality (s_2) version is not too large compared to the cost of producing the low-quality (s_1) version (Belleflamme 2005, page 334).

3.4.1 Selling a single quality

Given assumption 2 above, the monopolist will choose to make the high-quality information good, s_2, if he is only selling a single version. We let the consumer who is indifferent between buying the high-quality good and not buying anything be denoted as $\theta_{20}(p_2)$. If the consumer is indifferent it implies the following:

$$\rightarrow \quad k + \theta_{20}(p_2)s_2 - p_2 = 0$$

$$\rightarrow \quad \theta_{20}(p_2) = \frac{p_2 - k}{s_2}$$

We know that all consumers with higher valuation of the quality dimension than the indifferent consumer, $\theta > \theta_{20}(p_2)$, will choose to buy the good, and therefore the profit-maximization problem for the monopolist becomes:

$$\max_{p_2} \pi_{1q} = (p_2 - c_2)[1 - \theta_{20}(p_2)] = (p_2 - c_2)(1 - \frac{p_2 - k}{s_2})$$

Solving the optimization problem gives the optimal price and profit expressions (Belleflamme 2005, page 334):

$$\hat{p}_2 = \frac{k + s_2 + c_2}{2}$$

$$\hat{\pi}_{1q} = \frac{(k + s_2 - c_2)^2}{4s_2}$$

3.4.2 Selling the two qualities

When selling two different quality versions of the information good, Belleflamme (2005, page 334) states that the challenge is to find the profit maximizing price pair (p_1, p_2) that incentivizes some consumers to choose quality s_1 and other consumers to choose quality s_2. Given the price pair (p_1, p_2), the marginal consumer who is indifferent between consuming either of the two versions is called θ_{12}. The consumer that is indifferent between buying the low-quality, s_1, version and not buying anything at all is called θ_{10}. By definition we get the following expressions (Belleflamme 2005, page 335):

$$k + \theta_{12}s_1 - p_1 = k + \theta_{12}s_2 - p_2 \leftrightarrow \theta_{12}(p_1, p_2) = \frac{p_2 - p_1}{s_2 - s_1}$$

$$k + \theta_{10}s_1 - p_1 = 0 \leftrightarrow \theta_{10}(p_1) = \frac{p_1 - k}{s_1}$$

To be successful in segmenting the market the monopolist must set prices such that:

$$0 \leq \theta_{10} < \theta_{12} < 1$$

If satisfied, this constraint will divide the consumers into two or perhaps even three groups: those who buy the s_2 version, those who buy the s_1 version, and also perhaps some consumers who buy nothing. The consumers with $\theta \geq \theta_{12}$ will choose to buy the s_2, the consumers with $\theta_{10} \leq \theta < \theta_{12}$ buy the s_1 and, if $\theta_{10} > 0$, the consumers with $0 \leq \theta < \theta_{10}$ do not buy either of the two versions.

With these conditions we get two constraints that the prices must satisfy (Belleflamme 2005, page 335):

(A) $\theta_{12}(p_1, p_2) < 1 \leftrightarrow \; p_2 < p_1 + \; (s_2 - \; s_1),$

(B) $\theta_{10}(p_1) < \theta_{12}(p_1, p_2) \leftrightarrow \; \frac{s_1}{(p_1 - k)} > \frac{s_2}{(p_2 - k)}$

Belleflamme (2005, page 335) refers to these constraints as self-selection constraints, or "incentive-compatibility constraints". (A) states that the price of the high-quality version must be lower than the price of the low-quality version plus the quality gap (valued by the consumer with $\theta = 1$). This condition is required for any positive sales of the high-quality version. (B) demands that the low-quality version must give the best ratio of quality to price, $\frac{s_i}{(p_i - k)}$, of the two quality versions. This condition must be satisfied for there to be positive sales of the low-quality version (Belleflamme 2005, page 335).

The purpose of the self-selection constraints are (Belleflamme 2005, page 335):

"If the menu $(s_i, p_i)_{i=1,2}$ is to be feasible in the sense that it will be voluntarily chosen by the consumers, then consumers of each group must prefer consuming the package intended for them as compared to consuming the other group's package or not consuming any package."

The price of the high-quality version, p_2, may also be expressed like this:

$$p_2 = \; p_1 + \; \Delta$$

That gives us the monopolist's profit-maximization problem (Belleflamme 2005, page 335):

$$\max_{p_1, \Delta} \pi_{2q} = (p_1 - \; c_1)[\theta_{12}(\Delta) - \; \theta_{10}(p_1)] + \; (p_1 + \; \Delta - \; c_2)[1 - \; \theta_{12}(\Delta)]$$

s.t. (A) and (B) are satisfied.

First order conditions (FOCs) (2005, page 336):

$$\frac{\partial \pi_{2q}}{\partial p_1} = [1 - \; \theta_{10}(p_1)] - \; (p_1 - \; c_1)\frac{\partial \theta_{10}(p_1)}{\partial p_1} = \; 0$$

$$\frac{\partial \pi_{2q}}{\partial \Delta} = [1 - \theta_{12}(\Delta)] - (\Delta - c_2 + c_1)\frac{\partial \theta_{12}(\Delta)}{\partial \Delta} = 0$$

The first of the FOCs illustrates that an increase in p_1 has two separate effects on profits (Belleflamme 2005, page 336). First, revenues are increased from the consumers who buy either of the two versions. Second, revenue is lost on the consumers of the low-quality version who decide to leave the market when the price goes up. The second FOC shows that there are also two effects when increasing the premium for the high-quality version, Δ. Increasing the premium gives higher revenues from the consumers of the high-quality version, but some consumers will switch to buying the low-quality version instead. Since the low-quality version is sold on a different margin than the high-quality version, $p_1 - c_1$ instead of $p_2 - c_2$, this will also affect the monopolist's revenues.

Substituting the values of θ_{12} and θ_{10} into the FOCs and rearranging the terms Belleflamme (2005, page 336) solves for the profit-maximizing prices:

$$\dot{p}_1 = \frac{k + s_1 + c_1}{2}, \quad \dot{\Delta} = \frac{c_2 - c_1 + s_2 - s_1}{2} \rightarrow \dot{p}_2 = \frac{k + s_2 + c_2}{2}$$

The assumption that $s_1 > k$ implies that $\theta_{10}(\dot{p}_1) > 0$, which means that consumers with very low values of θ will not buy any version. Belleflamme (2005, page 336) explains for which values the parameters satisfy the self-selection criteria:

(A') $\dot{p}_2 < \dot{p}_1 + (s_2 - s_1) \leftrightarrow c_2 < c_1 + (s_2 - s_1)$

(B') $\frac{s_1}{(\dot{p}_1 - k)} > \frac{s_2}{(\dot{p}_2 - k)} \leftrightarrow \frac{s_1}{(c_1 - k)} > \frac{s_2}{(c_2 - k)}$

Conditions (A') and (B') are merely expressions of (A) and (B) when the monopolist is using marginal-cost pricing, meaning $p_1 = c_1$ and $p_2 = c_2$. When the conditions (A') and (B') are met, versioning is feasible (Belleflamme 2005, page 336). Bellow we will see what conditions must hold for versioning to be the most profitable strategy.

3.4.3 Cannibalization vs. market expansion

Belleflamme (2005, page 337) explains the contrasting effects versioning has on the monopolist's profits. When (A') and (B') are fulfilled the indifferent consumers are ranked:

$$0 < \theta_{10}(\dot{p}_1) < \theta_{20}(\hat{p}_2) < \theta_{12}(\dot{p}_1, \dot{p}_2) < 1$$

This ranking gives us an overview of the effects of versioning on the monopolist's profits, which can be illustrated:

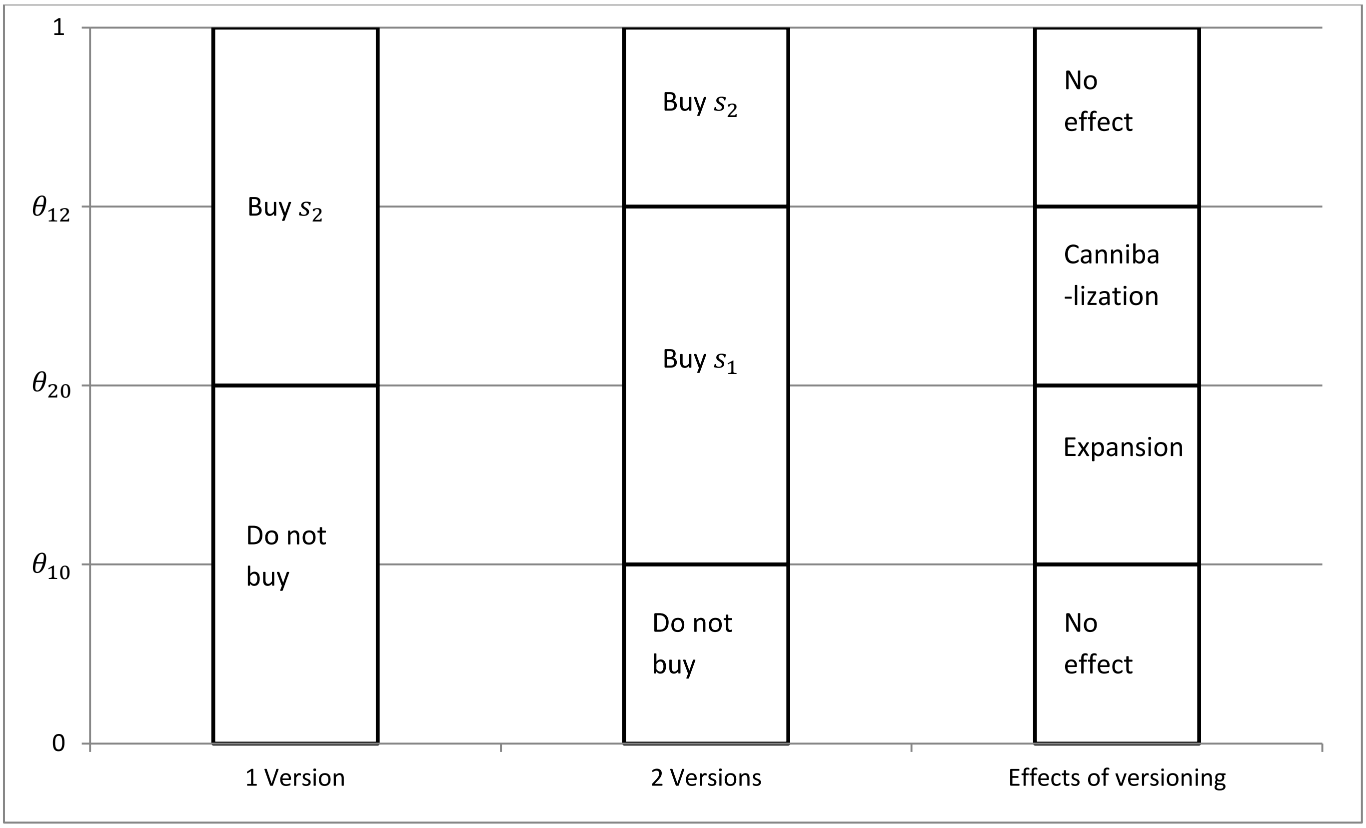

Figure 8: Rendering of Belleflamme (2005, page 337) graphic describing versioning's effect on monopolist's profits.

According to Belleflamme (2005, page 337):

"the effect of versioning on consumers' choices is twofold: because $\theta_{20}(\hat{p}_2) < \theta_{12}(\dot{p}_1, \dot{p}_2)$, fewer consumers buy the high-quality good; second, because $\theta_{10}(\dot{p}_1) < \theta_{20}(\hat{p}_2)$, some previous non-consumers now buy the low-quality good."

The former is a cannibalization effect where some consumers migrate from the high-quality version to the low-quality version when that version becomes available. The latter is a market expansion effect where some who would otherwise not buy anything when only the high-quality version is on the market, now choose to buy the low-quality version. Note that those who still buy the high-quality version after versioning takes place, the consumers with $\theta > \theta_{12}(\dot{p}_1, \dot{p}_2)$, have no effect on profits since they pay the same price before and after, i.e. $\dot{p}_2 = \hat{p}_2$. Belleflamme (2005, page 337) describes the negative effects due to cannibalization as follows:

$$d\pi_{ca} = [\theta_{12}(\dot{p}_1, \dot{p}_2) - \theta_{20}(\hat{p}_2)][(\dot{p}_1 - c_1) - (\hat{p}_2 - c_2)]$$
$$= -\frac{[s_2 - s_1 - (c_2 - c_1)][s_2(k - c_1) - s_1(k - c_2)]}{4s_2(s_2 - s_1)} < 0$$

Belleflamme (2005, page 338) defines the market expansion effect in this way:

$$d\pi_{me} = [\theta_{20}(\hat{p}_2) - \theta_{10}(\dot{p}_1)](\dot{p}_1 - c_1)$$
$$= \frac{[s_2(k - c_1) - s_1(k - c_2)](k + s_1 - c_1)}{4s_1 s_2} > 0$$

By summing up both the cannibalization and the market expansion effect, Belleflamme (2005, page 338) finds that versioning is the most profitable option given that the (A') and (B') conditions are met:

$$\pi_{2q}(\dot{p}_1, \dot{p}_2) - \pi_{1q}(\hat{p}_2) = d\pi_{ca} + d\pi_{me} = \frac{[s_2(k - c_1) - s_1(k - c_2)]^2}{4s_1 s_2(s_2 - s_1)} > 0$$

After having found this result for a very general versioning model, we look at some interesting cases where we know something more about the parameter values of the model.

3.4.4 Is versioning optimal for information goods?

As Belleflamme (2005, page 338) states, the perhaps most important characteristic regarding information goods is that the marginal cost of production remains constant for various product quality levels. In terms of the examples discussed so far this implies that $c_1 = c_2 \equiv c$, where c is often near zero. If c is near zero, then assuming $0 < k < s_1$ is adequate to assure that (A') and (B') hold, and versioning remains the optimal strategy for the monopolist. Belleflamme (2005, page 338) explains that in the case of $c_1 = c_2 = 0$ we have the following result, proving versioning is optimal in this case:

$$d\pi_{ca} + d\pi_{me} = -\frac{s_2 - s_1}{4s_2}k + \frac{(s_2 - s_1)(k + s_1)}{4s_1 s_2}k = \frac{s_2 - s_1}{4s_1 s_2}k^2 > 0 \leftrightarrow k > 0$$

Belleflamme's (2005, page 338) main result on versioning for information goods:

"Suppose the consumers' utility for the information good can be separated along two dimensions: a "key dimension" for which consumers have different valuations, and a "secondary dimension" for which all consumers have the same, positive, valuation. Suppose also that some consumers value the key dimension more than the secondary dimension, and that the marginal cost of producing any level of quality for the key dimension is near zero. Then versioning the information good along the key dimension is the most profitable option for the monopolist."

This conclusion is similar to Varian's result on versioning of information goods. Still, there are some important differences in how Belleflamme (2005) and Varian(2000) construct their respective models, as was discussed earlier. Both approaches prove that given certain conditions, versioning is a monopolist's optimal pricing strategy for information goods.

3.4.5 Damaged goods

Belleflamme (2005, page 339) also addresses Deneckere and McAfee's (1996) article Damaged Goods. Deneckere and McAfee (1996) is more focused on manufacturing goods like electronics and chemicals. Manufacturing goods distinguish themselves in some important ways from the information goods that Belleflamme (2005) and Varian (2000) focus on. When producers damage a portion of their manufacturing goods in an effort to price discriminate through versioning, it typically costs them extra to do so. The marginal cost of the low-quality "damaged" good, c_1, is in fact higher than the marginal cost of the high-quality good, c_2.

$$\rightarrow \; c_1 > c_2 \geq 0$$

This is usually the case because a manufacturer will start off by making a high-quality product. The cheapest way to create different versions of that good is to damage a portion of the high-quality products instead of creating a new low-quality product version from scratch.

We assume that:

$$0 < k < s_1$$

According to Belleflamme (2005, page 339):

"versioning can be feasible, and thus optimal, even if it is more costly to produce the low-quality version of the product."

This is true since when $c_2 - c_1 < 0$ condition (A') is satisfied, and if the cost of degrading the product ($c_1 - c_2$) is not too large then (B') may also be satisfied.

Belleflamme (2005, page 339) goes on to propose a different perspective where instead of assuming a higher marginal cost of degrading the product, we instead assume that there is a higher fixed cost associated with making the low-quality product, s_1. This approach might be more relevant in the case of information goods, where there might be some extra fixed costs associated with making a low-quality product, whereas reproducing that version has no extra cost once it has been created. Let $c_1 = c_2 = 0$ and let $F > 0$ denote fixed costs for making the low-quality product, s_1, by damaging the high-quality product, s_2. Given these assumptions versioning will be optimal if:

$$\pi_{2q}(\dot{p}_1, \dot{p}_2) - F > \pi_{1q}(\hat{p}_2) \leftrightarrow F < \frac{s_2 - s_1}{4s_1 s_2} k^2$$

The expression above illustrates the maximum amount it is worth investing in the creation of a low-quality version. If this fixed investment cost exceeds the additional profit gained from versioning, it is more profitable to produce one version.

3.4.6 A specific case of Functional degradation

Functional degradation is common, particularly in the software industry. Cheap or free reader software versions are often offered while consumers have to pay for the full-version to be able to create and edit content. Belleflamme (2005, page 346) bases this model on Csorbe and Hahn (2003), describing it as a combination of: "versioning, damaged good strategy, network building through free version, and unbundling."

In this case we look at a software product with a read and a write function. The software is offered in two versions: one read-and-write version and one read-only version. It is assumed that consumers have unit-demand, i.e. they buy at most one unit of the good. The consumers are described by a parameter, θ, which is uniformly distributed from [0,1], and describes the consumer's valuation of the two software functions, read and write. It is also assumed that demand for the two versions is positively correlated. θ is the valuation for the write function, and $\beta\theta$ is the valuation of the read function, where $\beta > 0$. In short, this particular case implies that a consumer who highly values one of the two functions will also highly value the other function (Belleflamme 2005, page 346).

Belleflamme (2005, page 347) explains that the software product has two-sided network effects, due to the fact that consumers' utility from having the reading function increases with the number of people who have the writing function. In other words, the more people who create content the more valuable it is to have the option of viewing that content. The other parameters used in the model: p_f and p_r are the price for the full version, with both read-and-write functions, and the read-only version, and n_f and n_r denotes the number of consumers who buy the full version and the read-only version respectively.

Here is an illustration of the net utility of consumer θ (Belleflamme 2005, page 347):

$$U(\theta) = \begin{cases} \theta\left(n_f + n_r\right) + \beta\theta n_f - p_f & if\ buying\ the\ full\ version \\ \beta\theta n_f - p_r & if\ buying\ the\ read-only\ version \\ 0 & if\ not\ buying \end{cases}$$

The utility of buying the full version may be seen as a bundle of the two functions. The model assumes utility is (Belleflamme 2005, page 347):

"additively separable in the two functions."

The first term in this utility function describes the utility the user receives from having access to the writing function. This utility is augmented through a network effect related to the number of people being able to read the content that the user can write with the full version. It seems reasonable that the more people who are able to read content created by this software, the more valuable it is to be able to write content. The second term in the full version utility function shows the utility of having the read function. This utility is increasing in the number of people who have the write function, as this would imply more content being created that the user could read. Finally, the overall utility of buying the full version is reduced by the price of this version. The higher the price the less net utility the user will get from buying the full version (Belleflamme 2005, page 347).

For the read-only version utility only comes from this particular function of the software. The price of this version reduces the overall utility. There is zero utility for the consumer if she buys nothing. According to Belleflamme (2005, page 347) there are two options for the software firm, either sell the full version only (pure bundling) or sell both the full version and read-only version (versioning or mixed bundling).

Sell the full version only

Belleflamme (2005, page 347) points out that if the read-only version is not on the market we have that: $n_r = 0$, which in turn gives the following utility function for buying the full version:

$$(1+\beta)\theta n_f^e - p_f$$

The n_f^e variable has superscript e to indicate that it is an expectation of the number who will choose to buy the full version. Consumers make their buying decision simultaneously and base their decision on expected network size. This example is according to Belleflamme (2005, page 347) a case of a monopolist who is pricing a good with network effects. We find the consumer who is indifferent between buying the full version and not buying anything, θ_f, by setting utility of buying the full version equal to zero (Belleflamme 2005, page 348):

$$(1+\beta)\theta_f n_f^e - p_f = 0 \leftrightarrow \theta_f = \frac{p_f}{(1+\beta)n_f^e}$$

Belleflamme (2005, page 348) assumes that consumers have rational expectations, i.e. $n_f^e = 1 - \theta_f$. This gives us the following expression for the price of the full version:

(6) $$p_f = n_f^e(1+\beta)(1-n_f^e)$$

“Because of the presence of network effects, there might be more than one n_f (that is, more than one quantity) that satisfies the equilibrium condition (6) for a given price” (Belleflamme 2005, page 348).

Given the possibility of multiple solutions, Belleflamme (2005, page 348) uses the Pareto criterion to pick out the solution. This means that the optimal solution will be the largest possible n_f which satisfies the price condition (6), as a larger number of consumers will increase the network effect, and therefore the value of the product, and make everyone better off. Assuming everyone recognizes that they are better off in the Pareto optimal solution, consumers expect this outcome and therefore it will become the equilibrium. In other words, the Pareto optimal equilibrium becomes a self-fulfilling expectation.

The optimization problem for the software firm can be described like this (Belleflamme 2005, page 348):

$$\max_{n_f} p_f n_f = n_f^2(1+\beta)(1-n_f)$$

FOC:

$$n_f(2-3n_f) = 0$$

$$\rightarrow Solution\ 1: n_f = 0$$

$$\rightarrow Solution\ 2: n_f = \frac{2}{3}$$

Belleflamme (2005, page 348) states that after checking the second-order condition, it is clear that solution 1 is a minimum and solution 2 is a maximum. Using the Pareto criterion, we assume solution 2 will be the outcome, and solve for the equilibrium price and profit (Belleflamme 2005, page 348):

$$p_f^F = \frac{2(1+\beta)}{9}, \quad \pi^F = \frac{4(1+\beta)}{27}$$

Superscript F stands for full version only. It should be noted that solution 1 is a real possibility where consumers expect no one to buy the software. As a side note to the theory, it is important to acknowledge that the assumption Belleflamme makes about consumers coordinating towards the Pareto optimal solution is not necessarily a realistic assumption for all cases. If there are coordination problems which prohibit consumers from reaching the Pareto optimal equilibrium, we cannot rule out an outcome with zero customers and zero profits.

Introduce the read-only version

Now we have a scenario with two different product versions on the market, one full version and one read-only version. The consumer who is indifferent between the full version and the read-only version is denoted as θ_{fr}, and the consumer who is indifferent between buying the read-only version or not buying anything is denoted as θ_{ro}. The expressions for these consumers are as follows (Belleflamme 2005, page 349):

$$\theta_{fr}\left(n_f^e + n_r^e\right) + \beta\theta_{fr}n_f^e - p_f = \beta\theta_{fr}n_f^e - p_r \leftrightarrow \theta_{fr} = \frac{p_f - p_r}{n_f^e + n_r^e}$$

$$\beta\theta_{ro}n_f^e - p_r = 0 \leftrightarrow \theta_{ro} = \frac{p_r}{\beta n_f^e}$$

For versioning to be successful the following must hold:

$$0 \leq \theta_{ro} < \theta_{fr} < 1$$

Belleflamme (2005, page 349) assumes that the condition above holds and that the consumers have rational expectations about demand. Therefore we get the following demand expressions:

$$n_f = 1 - \theta_{fr}$$

$$n_r = \theta_{fr} - \theta_{ro}$$

With the equations we now have we can solve for the equilibrium price conditions (Belleflamme 2005, page 349):

(8) $$p_f = \left(n_f + n_r\right)\left(1 - n_f\right) + \beta n_f(1 - n_f - n_r)$$

(9) $$p_r = \beta n_f(1 - n_f - n_r)$$

Just like the one version case we looked at earlier we now have the possibility for multiple solutions that meet the price conditions. Belleflamme (2005, page 349), referring to Csorba and Hahn (2003), states that the solutions may be ordered by the largest n_f, as a larger n_f

will also imply a larger n_r. Due to the Pareto criterion the solution with the largest pair of (n_f, n_r) will be expected by the consumers and therefore be the solution in equilibrium. However, we should again keep in mind that this assumption by Belleflamme may not hold in the real world so we cannot rule out other possible equilibrium.

Belleflamme (2005, page 350) then states the firm's optimization problem in this way:

$$\max_{n_f, n_r} p_f n_f + p_r n_r = n_f(n_f + n_r)((1+\beta)(1-n_f) - \beta n_r)$$

$$s.t. \quad 0 \leq \theta_{ro} < \theta_{fr} < 1$$

Belleflamme (2005, page 350) solves for the unconstrained profit-maximizing values of n_f and n_r in three steps. Number one, find the FOC with respect to n_r:

(10) $$n_r = \left(\frac{1}{2\beta}\right)(1 + \beta - (1+2\beta)n_f)$$

Number two, plug the expression in (10) into the FOC with respect to n_f. This gives us:

$$\left(\frac{1}{4\beta}\right)(n_f - 1 - \beta)(3n_f - 1 - \beta) = 0$$

The third step is to evaluate the two roots that are solution candidates for the equation we found in step two:

$$Solution\ 1: n_f = 1 + \beta$$

$$Solution\ 2: n_f = \frac{1+\beta}{3}$$

Solution 1 implies a negative n_r which defies our constraint. Solution 2 gives the following expressions (Belleflamme 2005, page 350):

$$\rightarrow n_f = \frac{1+\beta}{3}, \quad n_r = \frac{1-\beta^2}{3\beta}$$

This will satisfy the constraint of the optimization problem if (Belleflamme 2005, 350):

$$n_r > 0 \leftrightarrow \beta < 1$$

$$n_f + n_r = \frac{1 + \beta}{3\beta} \leq 1 \leftrightarrow \beta \geq \frac{1}{2}$$

Based on these criteria, we have two completely different outcomes to consider based on the value of β, and the second scenario has two sub-categories as well. Remember, β measures the positive relationship between the valuations of the reading and the writing functions of the software product (Belleflamme 2005, page 350).

1. The first case is that $\beta \geq 1$, which means that the reading function is valued higher relative to the writing function (Belleflamme 2005, page 350). In this case there is no interior solution and it is not profitable for the firm to proceed with versioning. Therefore they will rather chose to just sell the full version, excluding the read-only product from the market.
2. The second case is that $\beta < 1$, which means that the reading function is less valued relative to the writing function. This means that versioning is profitable. Belleflamme (2005, page 350) details two separate scenarios if this is the case:

   a) If $\frac{1}{2} < \beta < 1$, then $n_f = \frac{1+\beta}{3}$, and $n_r = \frac{1-\beta^2}{3\beta}$ satisfy the constraints of the optimization problem. We then get strictly positive solutions for equilibrium prices (superscript V for versioning):

   $$p_r^V = \frac{(1 + \beta)(2\beta - 1)}{9}$$

   $$p_f^V = p_r^V + \frac{(1 + \beta)(2 - \beta)}{9\beta}$$

   This leads to the profit expression (Belleflamme 2005, page 351):

   $$\pi^V = \frac{(1 + \beta)^3}{27\beta}$$

   Belleflamme (2005, page 351) confirms that $\pi^V > \pi^F \quad \forall \frac{1}{2} < \beta < 1$, which means that for this particular case versioning is more profitable than selling just the full version.

b) If $0 < \beta \leq \frac{1}{2}$, then the consumer has a very low valuation of the reading function relative to the writing function (Belleflamme 2005, page 351). In this case it is optimal for the firm to cover the entire market, which means that $n_f + n_r \leq 1$ becomes a binding constraint.

$$\rightarrow n_f + n_r = 1$$
$$\rightarrow p_r = 0, \ \ see\ (9)$$
$$\rightarrow p_f = 1 - n_f, \ \ see\ (8)$$

In other words, it is optimal for the firm to give away the read-only version. This means that the firm is facing the following optimization problem:

$$\max_{n_f} \pi = n_f(1 - n_f)$$

$$\rightarrow n_f = \frac{1}{2}, \quad \rightarrow n_r = \frac{1}{2}$$

Based on these values Belleflamme defines the optimum for $0 < \beta \leq \frac{1}{2}$:

$$p_r^0 = 0, \qquad p_f^0 = \frac{1}{2}, \qquad \pi^0 = \frac{1}{4}$$

Superscript 0 refers to the read-only version being free to all consumers.

Belleflamme (2005, page 351) points out that it is easy to check that:

$$\pi^0 > \pi^F \quad \forall 0 < \beta \leq \frac{1}{2}$$

Belleflamme (2005, page 351) makes the following conclusion to this case of functional degradation:

“Consider a software that combines a read and a write function. Suppose that consumers’ valuations for the two functions are proportional. As long as the reading function is valued relatively lower than the writing function, the seller finds it profitable to engage in versioning by selling a read-only version along with the full (read + write) version of the software. If the relative valuation of the reading function is sufficiently low, it is even profitable to give away the read-only version for free.”

3.5 Game theory

The theory that has been reviewed so far assumed that the firm in question is a monopolist. The market power of having a monopoly may allow a company to adjust prices more or less freely to maximize profit. However, assuming that a company has this type of strong market power is more often than not an unrealistic assumption. Most companies have to adapt to competitors' actions and behavior. To gain an understanding of the dynamics of competition, we will now review some basic game theory.

An important corner stone of game theory is the Nash equilibrium which can be defined as follows (Pindyck and Rubinfeld 2005, page 445):

"in a Nash equilibrium, each firm is doing the best it can given what its competitors are doing. As a result, no firm would individually want to change its behavior."

The last part of the quote is very important. Since each firm is choosing the best possible action given its competitors' actions, there is no incentive for anyone to change their action, creating the equilibrium state.

3.5.1 The Prisoners' Dilemma

A classic case in game theory is called the Prisoners' Dilemma. The name comes from the fact that two prisoners are often used as an example to illustrate this particular game, although the result is transferrable to a whole host of situations. The story goes that two prisoners are separated, and have to choose individually whether to confess to their crime. Their actions will affect each other. If one prisoner chooses to confess to their crime and the other one does not, the one that did confess will receive a very short sentence and the one that did not confess will receive a very long sentence. If both prisoners choose to confess they both get a medium sentence. On the other hand, if neither confess, they both get short sentences, but not as short as if they were the only one to confess. There is therefore an incentive to confess, not knowing what action the other prisoner has chosen.

Here is an illustration of the game in the form of a payoff matrix (Pindyck and Rubinfeld 2005, page 455):

Prisoners' Dilemma		**Prisoner B**	
		Confess	Do not confess
Prisoner A	Confess	-5, -5	-1, -10
	Do not confess	-10, -1	-2, -2

Figure 9: Prisoner A and B can both choose between two actions: confess and not confess. For each possible outcome Prisoner A's sentence is to the left and prisoner B's sentence to the right.

No matter what the other prisoner does, the best option for each of them is to confess, ergo confessing is the dominant strategy (Pindyck and Rubinfeld 2005, page 476). Because both prisoners have an incentive to confess, the Nash equilibrium in this game is that both prisoners confess and receive five year sentences. We can clearly see that if they both do not confess they are better off with only a two year sentence each. This is the core of the prisoners dilemma: how can they reach that better outcome? If they are able to coordinate it can be done. In business we sometimes see that firms refrain from aggressive competition because they know that it will hurt themselves. They are all better off by implicitly colluding to keep the prices at a higher level, which means higher profits for everyone (Pindyck and Rubinfeld 2005 page 455).

3.5.2 Dynamic games

In the Prisoners' Dilemma game discussed above the game is only played once, i.e. it is a static game. However, in business many games are played over and over again creating dynamic games, which may result in different Nash equilibriums. As was briefly mentioned in the paragraph above, when firms compete on prices they have to consider the long term effects of their actions. Setting a low price today will give your competitor the incentive to undercut you by setting a low price tomorrow, and it might be difficult to get the price back up again. In lengthy price wars all the players could suffer bad losses in profits.

What is the outcome of the Prisoners' Dilemma game, if it is a repeated game? Based on Tirole's (1988, page 432) theory I use an example where the players are two companies competing in a duopoly. Every period, t, each company has to decide between two actions: to keep the prices high, or to cut prices. Here is the payoff matrix:

Duopoly price competition		**Company B**	
		Cut price	Maintain Price
Company A	Cut price	1, 1	10, -10
	Maintain price	-10, 10	5, 5

Figure 10: Prisoner A and B can both choose between two actions: cut price or maintain price. For each possible outcome Company A's payoff is to the left and Company B's payoff is to the right.

In a matrix we see that to cut price is the dominant strategy for both companies. No matter what action the competitor chooses, cutting prices will give either company the highest possible profit. When they both cut price, they receive one in profit, and when they both maintain prices they receive five in profit. On the other hand, if one company cuts the price while the other company does not, the price reducing company receives ten in profit while the other company receives a loss in profit of negative ten. Assuming the game is played an infinite number of times, we can say that each company's payoff is equal to the discounted value of the payoffs they receive in each period into the future. Let the discount factor be denoted as δ. We assume that both companies have perfect information, so in period t they both know what action their competitor choose in period t-1, and in all previous periods back to period 1 (Tirole 1988, page 432).

Assume that the players come to an understanding that they will cooperate by maintaining the price at a higher level if, and only if, the other player never cuts their price. If either company deviates even once, the other company will respond by cutting prices and keeping them low forever. In a market with few competitors, such scenarios could easily arise, as each company realizes that the other actors are watching them closely, and are ready to respond to their actions at a moment's notice (Tirole 1988, page 240). Each company now has a choice to make: if you deviate you receive payoff:

$$Deviation\ payoff = 10 + 1(\delta + \delta^2 + \delta^3 \ldots) = 10 + \frac{\delta}{1-\delta}$$

First period, the deviating company receives 10 in profit since he tricks the competitor. In every subsequent period though, he can only expect to receive 1 in profit, as the competitor punishes his deviation by cutting his price as well. On the other hand, if you do not deviate and your competitor keeps the agreement, you receive payoff (Tirole 1988, page 432):

$$Keeping\ agreement\ payoff = 5(1 + \delta + \delta^2 \ldots) = \frac{5}{1-\delta}$$

So for a company being willing to cooperate the following must hold:

$$\frac{5}{1-\delta} > 10 + \frac{\delta}{1-\delta} \quad \rightarrow \quad \delta > \frac{5}{9}$$

As we can see in the condition above, if $\delta > \frac{5}{9}$ it is profitable to cooperate to keep prices high. This result allows for a new Nash equilibrium where both companies' maintain high prices through collusion. However, it should be noted that both companies cutting prices is still a Nash equilibrium as it was in the static game. It is in no way certain that the companies would be successful in developing an understanding of keeping prices high. To achieve a Nash equilibrium of both companies maintaining high prices, a firm must be able to send a credible signal of its intention to keep high prices if the competitor complies. The competitor must also believe the threat that any sudden price cut will be punished harshly, with a punishment strong enough to outweigh any gains by deviating from the agreement (Tirole 1988, page 432).

3.6 Competition and versioning

In all the versioning theory that was presented above, we assumed the firm was a monopolist. Now we will branch out to a competitive setting and see how this may change the results from versioning. However, this theory section will consist of more verbal argumentation as opposed to the mathematical approach earlier. The goal is to get a feeling for which direction competition will push the previous results of the monopolist based models.

We start by acknowledging that versioning in fact does occur in competitive markets. Steen and Sørgard (2002) discuss versioning in the highly competitive and volatile airline industry. One might expect that, with fierce competition, the prices of airline tickets would be pushed down to marginal cost, often referred to as the Bertrand paradox of price competition. The paradox is that this form of equilibrium in price competition, which theory predicts, is not common to find, even in highly competitive markets. The simplified model by Steen and Sørgard (2002) states that the airlines offer two types of tickets: cheap restricted tickets to leisure travelers, and more expensive flexible tickets to business travelers. Steen and Sørgard (2002) assumes that, with competition, there will be more capacity in the air travel market, and the main fear of the airlines is to have idle capacity, i.e. empty seats.

Two approaches of responding to competition are outlined (Steen and Sørgard, page 10):

1) Lower prices
2) Focus on increased sales of low-quality leisure tickets

Looking more closely at the latter, the firms can either lower the prices of leisure tickets and increase the number of such tickets on offer, or they can make them more attractive by improving the flexibility of the leisure tickets. Steen and Sørgard (2002) say that these actions should increase demand for the low-quality tickets. The increase in demand happens through both consumer migration from the business segment down to the leisure segment, and due to market expansion caused by new consumers entering the market to buy leisure tickets.

With the consumer migration between the different customer segments, it is expected that demand for the business tickets will drop. In addition, the prices for business tickets may also drop due to the price competition in this segment, and because firms wish to limit the migration of consumers from the business down to leisure class. Steen and Sørgard (2002) concludes by saying that the size of these effects are unclear and hard to predict accurately. However, it seems logical to assume that, barring collusion between the airlines, the element of competition is likely to provide a downward pressure on prices for both the low- and high-quality ticket versions.

4. Analysis

We have now established the theory needed to address the thesis question, and it is time to move on to the analysis section. A starting point is to create a benchmark model for a monopolist. After calculating and discussing the results of the benchmark model, we will in the next chapter apply these results to the Telenor case.

4.1 The Benchmark Monopolist Model

The purpose of this model is to show the optimal way a monopolist should set prices in relation to quality of mobile phone subscriptions with a data plan. Consumers have unit demand, meaning they will only buy one subscription each at most. A clear distinction is made between the data and telephony side of mobile phone subscriptions. The data side represents functions requiring internet access, and this is the key quality dimension that is used to differentiate the product versions. One subscription version has a data plan with access to mVoIP programs, and another version has a data plan without such access. The telephony side consists of all non-data functions of the subscription, like regular time-charged calls, sms and mms. It is assumed that internet access may be viewed as an information good. So the marginal cost of providing data plans as part of the subscription is zero.

However, there may be a fixed cost associated with developing a degraded version without mVoIP access. The term: F, will refer to any fixed cost that could be associated with developing the technology to block mVoIP access from mobile phones, or costs of lobbying to make this type of versioning an acceptable practice. In addition, there is also a cannibalization effect between the data side and the telephony side. The parameter β represents the cannibalization effect each consumer with mVoIP access have on the revenues from the telephony side. For every consumer who choose to buy a subscription with access to mVoIP, we assume that a certain amount of telephony revenue, β, is lost, as mVoIP is used instead of regular time-charged calls.

There are two quality levels, which are exogenously given, for the mobile phone subscriptions with a data plan. We assume that the monopolist may either block or allow access to mVoIP, but that these are the only two available options for quality levels. The quality level without access to mVoIP is denoted as s_D, subscript D referring to this version being degraded. The quality level of the full subscription with mVoIP access is represented by s_V, the subscript V referring to the mVoIP access for this version. Since having full internet access would provide more choice for consumers, the full version is ranked higher than the degraded version, $s_D < s_V$.

The term, θ, describes the consumers' valuation of quality with regards to the data plan included in mobile phone subscriptions. It is assumed that consumers' individual values of θ are uniformly distributed over the interval $[0, 1]$. To clarify, the consumer with $\theta = 1$ has the highest possible valuation of quality, and the consumer with $\theta = 0$ has the lowest possible valuation of quality. The assumption that consumers' θ-values are uniformly distributed implies that the consumers are heterogeneous in their valuation of the data plan's quality, which is an essential assumption for versioning to be a viable strategy. If all consumers valued every quality dimension equally, they would all buy the same version, making it impossible to segment the market through versioning.

The term k refers to the valuation that the consumers have of all the functions on the telephony side of the subscription. In order to simplify the model, it is assumed that k is the same for all consumers. Like Belleflamme (2005), this model also assumes that $k < s_D$. This means that the consumer with the highest valuation of quality will value the degraded subscription, s_D, more than all the other non-data related functions combined. The $k < s_D$ assumption guarantees a positive demand for mobile phone subscriptions with a data plan.

The utility associated with having access to mVoIP is also augmented by the number of people who have access to VoIP. A clear logical argument can be made for why there is a network effect associated with mVoIP access: the more people that use VoIP services in general, on mobile devices or otherwise, the more people a consumer can reach when using mVoIP software, increasing the value of mVoIP services as a communication tool. The variable, n_V, represents the value of the network effect that consumers' receive from having mVoIP access. When the number of VoIP users increases, n_V also increases. We know $n_V > 0$, since many are using programs like Skype and Viber already, and it will grow with time if the user base of VoIP services continue to grow.

The prices for the subscriptions with and without mVoIP access are p_V and p_D, respectively. The prices represents a fixed payment for a subscription. Consumers will receive a free data packet in the subscription and self-ration their data use to not extend beyond that free data amount. So even though a consumer who buys a full subscription with mVoIP access may have a tendency to use more data than someone who buys the degraded subscription, it is assumed that the price paid for either subscription will cover the data usage for the consumers. This assumption is important to the outcome of the model, as it guarantees that mVoIP users impose a net negative cannibalization effect, β, on the monopolist from reducing revenue on the telephony side, which is not offset by any increased revenue on the data side.

Below is a representation of the utility function for consumers:

$$u(\theta) = \begin{cases} k + \theta(s_V + n_V) - p_V & \text{the full subscription version with mVoIP} \\ k + \theta s_D - p_D & \text{the degraded subscription version w/o mVoIP} \\ 0 & \text{buying nothing} \end{cases}$$

This utility function, $u(\theta)$, shows consumers' utility for three different options. The top line is a representation of the utility a consumer receives when buying a subscription that includes access to mVoIP. The middle line illustrates the utility a consumer will receive when buying a subscription without access to mVoIP. Finally, the bottom line shows that the consumer is assumed to receive zero utility if she does not buy any mobile phone subscription with a data plan. We continue by first finding the equilibrium results of this model in the case where the monopolist is only selling one subscription version.

4.1.1 Selling only one quality version

Similarly to Belleflamme (2005), we assume that in the case where the monopolist is not versioning, he will choose to only sell the high-quality version. In other words, when only selling one version of a mobile phone subscription with a data plan, the monopolist will choose to sell a full version including mVoIP access, s_V. To find the price and profit for the monopolist in this scenario, we start by finding an expression for the consumer who is indifferent between buying the full version with mVoIP access, and not buying anything.

We denote the indifferent consumer as θ_{V0}, and find the expression for this term:

$$\mathrm{k} + \theta_{\mathrm{V0}}(s_{\mathrm{V}} + \mathrm{n_V}) - \mathrm{p_V} = 0$$

$$\theta_{V0} = \frac{p_V - k}{s_V + n_V}$$

Any consumer with a $\theta \geq \theta_{V0}$ will choose to buy the subscription. Therefore, the lower the value of θ_{V0}, the more consumers will choose to buy the subscription. A lower price or an increase in the number of people who use VoIP will lower θ_{V0} and increase the number of consumers who buy the full subscription. Since consumers' individual θ-values are uniformly distributed over the interval $[0, 1]$, we can now find a demand expression for the full subscription:

$$Demand\ for\ \mathrm{s_V} = 1 - \theta_{V0}$$

With an expression for demand we can now define the profit function:

$$\pi_{1q} = (p_V - \beta)(1 - \theta_{V0})$$

The subscript, 1q, refers to this being the profit function for the case where the monopolist is selling only one quality version. The term β represents, as was explained earlier, mVoIP's cannibalization effect on the revenues from the telephony side. As the model also assumes no extra revenue from any increase in data usage, the net effect is a loss in revenue equal to: $\beta > 0$, for every consumer that choose to purchase the full subscription, s_V. The cannibalization effect between the data and the telephony side of the business is the chief cause of concern that telecom companies have with the growing use of programs like Skype.

To find the equilibrium price we maximize the profit function:

$$\max_{p_V} \pi_{1q} = (p_V - \beta)(1 - \theta_{V0}(p_V))$$

Differentiating with respect to p_V gives the following FOC:

$$\frac{\partial \pi_{1q}}{\partial p_V} = \big(1 - \theta_{V0}(p_V)\big) - (p_V - \beta)\frac{\partial \theta_{V0}(p_V)}{\partial p_V} = 0$$

Looking at the FOC, we see two distinct marginal effects on profit when the price, p_V, of the full subscription increases. First, the monopolist gains revenue from increasing the price on everyone who buys the subscription, represented by the term: $\big(1 - \theta_{V0}(p_V)\big) > 0$. At the same time, the monopolist also loses revenue by pushing some customers out of the market when increasing the price, illustrated by: $-(p_V - \beta)\frac{\partial \theta_{V0}(p_V)}{\partial p_V} < 0$. The optimal equilibrium price is given by the price level where these two marginal effects cancel each other out to zero.

The next step is to substitute in for $\theta_{V0}(p_V)$ and $\frac{\partial \theta_{V0}(p_V)}{\partial p_V}$, then solve for p_V (Appendix part A):

$$\hat{p}_V = \frac{k + s_V + n_V + \beta}{2}$$

The equilibrium price equation shows that the price of the full subscription is increasing in the number of people who use VoIP, and in the cannibalization cost, β, per consumer that choose to buy the subscription. The price is also increasing in the common valuation, k, of the telephony functions and in the quality level of the high-quality subscription, s_V. These last two parameters are however assumed to be exogenously given constants. Having found the expression for $\hat{p}_V$, we can find the expression for equilibrium profit (Appendix part A):

$$\hat{\pi}_{1q} = \frac{(k + s_V + n_V - \beta)^2}{4(s_V + n_V)}$$

The equilibrium profit expression shows that profit from selling full subscriptions is increasing in the number of people who use VoIP, as this boosts the value of the network effect, n_V. A higher n_V will allow the monopolist to charge a higher price for product that is now more valuable in the eyes of consumers. On the other hand, profit is decreasing in the cannibalization cost, β, per consumer with mVoIP access. The higher β is, the more damage is done to revenues from the telephony side of the business per consumers with access to mVoIP services. Indeed, we can see from the profit function that if: $\beta = k + s_V + n_V$, the profit is zero. This means that for the monopolist to earn a positive profit on mobile phone subscriptions with mVoIP access, the cannibalization cost cannot be equal to or greater than the utility the consumer with the highest valuation of quality, $\theta = 1$, receives from buying the full subscription. After having found the expressions for both equilibrium price and profit when selling only the high-quality version, we move on to the two version case.

4.1.2 Selling two quality versions

With two versions on the market we need to find the consumer that is indifferent between buying the s_V or the s_D subscription, and the consumer that is indifferent between buying the s_D subscription or not buying any subscription. The former indifferent consumer is denoted as, θ_{VD}, and the latter as, θ_{D0} (Appendix part B):

$$\theta_{VD} = \frac{p_V - p_D}{s_V + n_V - s_D} = \frac{\Delta}{s_V + n_V - s_D}$$

$$\Delta = price\ premium\ paid\ for\ access\ to\ mVoIP$$

$$\theta_{D0} = \frac{p_D - k}{s_D}$$

We can now define the demand expressions for the s_V and the s_D version:

$$Demand\ for\ s_V = 1 - \theta_{VD} \qquad Demand\ for\ s_D = \theta_{VD} - \theta_{D0}$$

From the expressions above we see that the demand for the s_V version is decreasing as the price difference between s_V and s_D increases and vice versa. However, the demand for s_V is increasing as the number of people who use VoIP increases. The demand for the s_D version is increasing as the price difference between the s_V and s_D increases and vice versa. The demand for the s_D version is also decreasing when the number of people who use VoIP goes up.

As we now proceed to find the equilibrium prices, please note that the price of the s_V version may be written as $p_V = p_D + \Delta$. With the information we now have, we can move on to the profit maximization problem, the subscript 2q indicating that this is the two quality versions case:

$$\max_{p_D,\Delta} \pi_{2q} = p_D\big(\theta_{VD}(\Delta) - \theta_{D0}(p_D)\big) + (p_D + \Delta - \beta)\big(1 - \theta_{VD}(\Delta)\big) - F$$

$$s.t.\ \ 0 \le \theta_{D0} < \theta_{VD} < 1$$

The constraint written below the profit function above is the versioning constraint. If the versioning constraint is satisfied, we know that the solution is successful in segmenting the market, and that there are either two or three separate consumer groups.

To find the equilibrium prices the first step consists of differentiating the profit equation with respect to p_D and Δ, giving us the FOCs (Appendix part B):

(I)	$\frac{\partial \pi_{2q}}{\partial p_D} = \left(1 - \theta_{D0}(p_D)\right) - p_D \frac{\partial \theta_{D0}(p_D)}{\partial p_D} = 0$

(II)	$\frac{\partial \pi_{2q}}{\partial \Delta} = \left(1 - \theta_{VD}(\Delta)\right) - (\Delta - \beta) \frac{\partial \theta_{VD}(\Delta)}{\partial \Delta} = 0$

In the FOCs above we see the various marginal effects of changing the prices. Examining FOC (I), we see two distinct marginal effects when the price, p_D, of the s_D version is increased. The first one is a positive increase in revenue from increasing the price on every consumers who buys either version, represented by the term: $\left(1 - \theta_{D0}(p_D)\right) > 0$. Remember that: $p_V = p_D + \Delta$, so increasing p_D also effectively increases p_V, as Δ remains constant. The fact that a marginal increase in p_D also increases p_V, will cause the monopolist to set a higher p_D then he would have done if prices were not linked in this way. By setting a higher p_D the degraded subscription becomes a less attractive alternative for consumers of the full subscription, which allows the monopolist to keep p_V at a higher level without losing too many s_V customers to the s_D version. The second marginal effect is negative, and it comes from the fact that some consumers will decide to leave the market and not buy any subscription when the price, p_D, increases. This effect is illustrated by: $-p_D \frac{\partial \theta_{D0}(p_D)}{\partial p_D} < 0$. The optimal equilibrium price is again given by the price level where the two distinct marginal effects cancel each other out to zero.

Looking at FOC (II), where the price premium, Δ, on the s_V version marginally increases, there are also two distinct marginal effects. The first one is the increase in revenue from increasing the price on everyone who purchases the s_V version, represented by: $\left(1 - \theta_{VD}(\Delta)\right) > 0$. The second marginal effect comes from the consumers who choose to buy the s_D version instead of the s_V version, when the price on the s_V version goes up. This marginal effect is illustrated by: $-(\Delta - \beta)\frac{\partial \theta_{VD}(\Delta)}{\partial \Delta} < 0, \ if \ \Delta > \beta$. The latter marginal effect of FOC (II) is ambiguous, due to the cannibalization that the s_V subscription inflicts on revenues from telephony services. If we assume that $\Delta > \beta$, the price premium for the s_V version outweighs the cannibalization costs. Therefore, the monopolist loses revenue when consumers choose to switch from the s_V version to the s_D version, i.e. the marginal effect is negative. On the other hand, if $\Delta < \beta$, then both marginal effects of FOC (II) are positive, and it would actually be profitable for the monopolist when consumers switch to the s_D version. The optimal price premium is the premium where the two marginal effects equal out to zero.

The second step is to plug in the expressions for θ_{D0}, θ_{VD}, $\frac{\partial \theta_{D0}(p_D)}{\partial p_D}$ and $\frac{\partial \theta_{VD}(\Delta)}{\partial \Delta}$ into FOCs (I) and (II), and solve for the equilibrium prices (Appendix part B):

$$\dot{p}_D = \frac{k + s_D}{2}$$

$$\dot{\Delta} = \frac{s_V + n_V - s_D + \beta}{2}$$

$$\dot{p}_V = \frac{k + s_V + n_V + \beta}{2}$$

Looking at the expressions for the equilibrium prices we see that price for the full subscription, $\dot{p}_V$, is still the same as in the one version case we looked at earlier. This is parallel to the result that Belleflamme (2005) found in his Simple model of versioning. By increasing p_D the monopolist allows for p_V to remain unchanged, i.e. $\hat{p}_V = \dot{p}_V$, without risking too many consumers switching from the s_V version to the s_D version. It is increasing in the number of people who use VoIP and in the cannibalization cost per consumer that buys this version. The price premium, Δ, is increasing in the quality difference between the full and the degraded subscription, and in the cannibalization cost of the full subscription. The price for the degraded version, $\dot{p}_D$, is determined by the valuation of the telephony functions, k, and the quality level of the degraded data plan, s_D. Both of these parameters, along with s_V, are assumed to be exogenously given constants.

After having found the equilibrium prices when the monopolist is versioning, we can plug these expressions into the expressions for θ_{VD} and θ_{D0}, and check what parameter values are allowed under the versioning constraint (Appendix part B):

$$versioning\ constraint = \ 0 \leq \theta_{D0} < \theta_{VD} < 1$$

$$\theta_{VD} < 1 \quad \rightarrow \quad p_V < p_D + (s_V + n_V - s_D) \quad \rightarrow \quad \beta < s_V + \ n_V - \ s_D$$

The expression above states that the cannibalization factor, β, cannot be greater than the additional utility that mVoIP access gives the consumer with the highest valuation of quality, i.e. $\theta = 1$. The term, $s_V + \ n_V - \ s_D$, is also the same as the maximum price premium, Δ, that a consumer with, $\theta = 1$, is willing to pay for mVoIP access. If $\beta > s_V + \ n_V - \ s_D$, the price premium on the s_V version would not be able to recover the losses from cannibalization of telephony revenues, even when charging the reservation price for the consumer with the highest valuation of quality. This would mean that versioning is not profitable and it would be better to only sell the s_D version, and block mVoIP access altogether. So the assumption: $\beta < s_V + \ n_V - \ s_D$, is necessary for the monopolist choosing to sell the s_V version, when only selling one quality version.

We continue to look at the conditions that must hold to satisfy the versioning constraint (Appendix part B):

$$\theta_{D0} < \theta_{VD} \quad \rightarrow \quad \frac{s_V + n_V - s_D}{p_V - p_D} < \frac{s_D}{p_D - k} \quad \rightarrow \quad \beta > k(1 - \frac{s_V + \ n_V}{s_D})$$

The inequality in the middle above, shows that the quality to price ratio has to be higher for the degraded subscription than the mVoIP subscription, in order to guarantee positive demand for the s_D version. The term, $k\left(1 - \frac{s_V + n_V}{s_D}\right) < 0$, to the right of the inequality to the right above is negative given the previous assumption, $s_D < s_V$, and $n_V > 0$. So the inequality, $\theta_{D0} < \theta_{VD}$, holds given our assumption that the cannibalization effect from mVoIP on telephony revenues is significant, i.e. $\beta > 0$. The last part of the versioning constraint is (Appendix part B):

$$0 \leq \theta_{D0} \quad \rightarrow \quad p_D \geq k \quad \rightarrow \quad \frac{k}{s_D} \leq 1$$

With the previously stated assumption, $k < s_D$, the inequality above holds as a strict inequality, $\frac{k}{s_D} < 1$. So the solution does satisfy the versioning constraint, $0 < \theta_{D0}$, and we see that there are three consumer groups that can be distinguished by their θ-values:

$$Consumers\ buying\ the\ s_V\ version\ = 1 - \theta_{VD}$$

$$Consumers\ buying\ the\ s_D\ version\ = \theta_{VD} - \theta_{D0}$$

$$Cosumers\ buying\ nothing\ = \theta_{D0} - 0$$

Even though versioning is successful in segmenting the market, it is not necessarily more profitable than selling only one version. The next important step is to compare profits for the two cases: selling only one quality version and versioning.

4.1.3 Versioning vs. selling only one version

There are two distinct effects of versioning that Belleflamme (2005) described, which we look at here as well. One of them is the cannibalization effect between the different product versions when a degraded version is introduced. When the monopolist offers a degraded subscription, s_D, some consumers that otherwise bought the full subscription, s_V, when only that was on offer, will now switch to the s_D version. Keep in mind, this is a completely different cannibalization effect than the one represented by β. The cannibalization effect that the degraded version has on the full version is expressed as follows (Appendix part C):

$$d\pi_{ca} = [\theta_{VD}(\dot{p}_D, \dot{p}_V) - \theta_{V0}(\hat{p}_V)][\dot{p}_D - (\hat{p}_V - \beta)]$$

$$\rightarrow \quad d\pi_{ca} = -\frac{\big((s_V + n_V) - s_D - \beta\big)((s_V + n_V)k - s_D(k - \beta))}{4(s_V + n_V)(s_V + n_V - s_D)} < 0$$

As the expression above shows, the cannibalization effect between the product versions is negative, given the condition $\beta < s_V + n_V - s_D$. That is because the consumers who switch from the full version to the degraded version now pay a lower price than before. To put it another way, the consumers switch from buying a high margin product to buying a low margin product.

The second effect that we need to take into account is the market expansion that occurs when adding the degraded version, s_D. By putting the s_D version on the market, new customer will choose to buy this version. These consumers would not buy any subscription with a data plan before, when only the s_V version was available. The market expansion effect can be expressed the following way (Appendix part C):

$$d\pi_{me} = \big(\theta_{V0}(\hat{p}_V) - \theta_{D0}(\dot{p}_D)\big)\dot{p}_D$$

$$\rightarrow \ d\pi_{me} = \frac{\big((s_V + n_V)k - s_D(k - \beta)\big)(k + s_D)}{4s_D(s_V + n_V)} > 0$$

The market expansion effect is of course positive as new consumers enter the market that would otherwise choose to not buy any subscription with data plan.

Like Belleflamme (2005) illustrated, we can compare the profits made from versioning with the profits made from selling only the high-quality version by adding up the market expansion and cannibalization effects (Appendix part C):

$$\dot{\pi}_{2q}(\dot{p}_D, \dot{p}_V) - \hat{\pi}_{1q}(\hat{p}_V) = d\pi_{ca} + d\pi_{me} - F = \frac{[(s_V + n_V)k - s_D(k - \beta)]^2}{4s_D(s_V + n_V)(s_V + n_V - s_D)} - F$$

Let us start by examining the fraction term in the result above. The numerator is squared and therefore has to be positive, and the denominator is also positive given the previous assumptions that were made for the parameters:

$$\rightarrow \quad \frac{[(s_V + n_V)k - s_D(k - \beta)]^2}{4s_D(s_V + n_V)(s_V + n_V - s_D)} > 0$$

So whether or not versioning is the most profitable strategy in the Benchmark Monopolist model will depend on the size of the fixed costs of implementing versioning, F. If we assume that F is smaller than the sum of the cannibalization and market expansion effect, versioning will be most profitable. However, if F is greater than these two effects combined, selling only one version will be most profitable. The result is somewhat ambiguous, but at least the Benchmark Monopolist model does not discount the possibility of versioning being a worthwhile strategy. The model shows that versioning is profitable if it can be implemented at a reasonable cost, and if $\beta < s_V + n_V - s_D$. Now we will continue with a discussion on how changes in β and n_V could alter the results of the Benchmark Monopolist model, and summarize the model's most important points.

4.1.4 The results of the Benchmark Monopolist model

We can start by taking a look at prices. As we saw above, versioning had no effect on the price of the s_V version, similar to Belleflamme's (2005) result. Like Belleflamme (2005), the model recognizes that an increase in p_D makes the s_D version less attractive relative to the s_V version, allowing the monopolist to increase p_V as well. This link between the two prices causes the monopolist to set p_D such that p_V remains unchanged after versioning has been implemented.

Even though the price of the s_V version remains the same when versioning, the number of people who buy this subscription goes down, as some consumers switch to buying the s_D version instead. At the same time, the total number of customers increases when the degraded subscription is introduced, as some new customers choose to enter the market to buy the s_D version. Since the price of the s_V version remains the same, and the total number of customers increase, it seems clear that consumer welfare is improved through versioning in the Benchmark Monopolist model. The degraded subscription version brings new consumers with lower valuation of quality into the market, without punishing consumers with higher valuation of quality through increasing the price of the full subscription.

If the fixed cost of implementing versioning, F, is smaller than the net revenue increase from combined cannibalization and market expansion effects, $d\pi_{ca} + d\pi_{me}$, the monopolist is also better off with a versioning strategy. We can show that versioning becomes increasingly profitable compared to only selling the s_V version, with a marginal increase in β, assuming $\beta < s_V + n_V - s_D$. Differentiating the sum of the cannibalization and market expansion effects with respect to β gives us a mathematical illustration (Appendix part D):

$$\frac{\partial(d\pi_{ca} + d\pi_{me})}{\partial\beta} = \frac{2s_D[(s_V + n_V)k - s_D(k - \beta)]}{4s_D(s_V + n_V)(s_V + n_V - s_D)} > 0$$

Remember that β is a measure of the cannibalization effect on revenues from the telephony side, per consumer who buys the s_V version with mVoIP access. Therefore the result above is as expected, since a larger β reduces the magnitude of the negative cannibalization effect, and increases the positive market expansion effect.

The former can be explained by viewing β as a marginal cost associated with the s_V version. The larger β becomes, the smaller is the margin that Telenor earns on selling the s_V version, and therefore, the smaller is the loss per consumer who switches from the s_V version to the s_D version. On the other side, an increase in β will lead to an increase in the number of consumers who switch from buying the s_V version to buying the s_D version, when the monopolist starts selling the degraded subscription. The reason for this increase in consumer migration between the product versions is that a higher β pushes up the price for the s_V version, making the s_D version a more attractive alternative. However, the net result from an increasing β is that the negative cannibalization effect becomes smaller in absolute value (Appendix part D).

The latter effect that an increase in β has, is on the market expansion from versioning. This is explained by β's influence on the indifferent consumers. The θ-value for the indifferent consumer when the monopolist is only selling the s_V version, $\theta_{V0}(\hat{p}_V)$, will increase as β increases. The reason for this is that a higher β will push up the price, $\hat{p}_V$, reducing the number of consumers who choose to buy the s_V version. This leads to a greater gap relative to the consumer that is indifferent between buying the s_D version and not buying anything, when selling two versions, i.e. an increase in the size of this difference: $\theta_{V0}(\hat{p}_V) - \theta_{D0}(\dot{p}_D)$. An increasing β will therefore mean that a greater number of new customers enter the market when the monopolist implements the versioning strategy (Appendix part D):

$$\frac{\partial d\pi_{me}}{\partial \beta} = \frac{k + s_D}{4(s_V + n_V)} > 0$$

It should be emphasized again that, if the assumption: $\beta < s_V + n_V - s_D$, does not hold, then only selling the s_D version is the best option for the monopolist, and not versioning.

A marginal increase in the value of the network effect, n_V, will have two conflicting effects on the cannibalization effect from versioning. On the one hand, the number of consumers that would choose to switch from the s_V subscription to the s_D subscription, when it enters the market, goes down. The reason behind this is that an increase in n_V increases the utility of having the s_V version, making the s_D version a less attractive alternative. In a pure mathematical sense this implies that the difference: $\theta_{VD}(\dot{p}_D, \dot{p}_V) - \theta_{V0}(\hat{p}_V)$, is reduced. But there is also a negative another effect. When n_V increases, the price of the s_V version also increases. So for every consumer that does decide to switch to the s_D version, the loss is now greater as the difference in profit margins between the two subscriptions have increased. The net result on the cannibalization effect from a marginal increase in n_V is positive, $\frac{\partial d\pi_{ca}}{\partial n_V} > 0$, if (Appendix part D):

$$k(s_D + \beta) + \frac{\beta^2(2s_D(s_V + n_V) - s_D^2)}{((s_V + n_V) - s_D)^2} < s_D\beta$$

However, the net result is negative , $\frac{\partial d\pi_{ca}}{\partial n_V} < 0$, if (Appendix part D):

$$k(s_D + \beta) + \frac{\beta^2(2s_D(s_V + n_V) - s_D^2)}{((s_V + n_V) - s_D)^2} > s_D\beta$$

A marginal increase in n_V would also have two contradictory effects on the market expansion from versioning. First a higher n_V makes the s_V version more valuable in the eye of consumers, which means that more consumers will chose to buy it when the monopolist is only selling this version. Therefore the difference: $\theta_{V0}(\hat{p}_V) - \theta_{D0}(\dot{p}_D)$, will become smaller, thereby reducing the market expansion effect. On the other side, a higher n_V will also lead to a higher price for the s_V version. This will have a diminishing effect on the number of people who buy the s_V version, and increase the difference, $\theta_{V0}(\hat{p}_V) - \theta_{D0}(\dot{p}_D)$. A marginal increase in n_V therefore also has an increasing marginal effect on the market expansion from versioning. If $k > \beta$, the net effect of a marginal increase of n_V is an increase in the positive market expansion effect. The opposite is true if $\beta > k$ (Appendix part D).

The overall effect of a marginal increase in n_V on the change in profit from versioning is also dependent on the size of β. If $\beta < \frac{k((s_V+n_V)-s_D)}{2(s_V+n_V)-s_D}$, then the net effect of an increasing n_V is positive on the change in profit from versioning, i.e. $\frac{\partial(d\pi_{ca}+d\pi_{me})}{\partial n_V} > 0$. The opposite is the case if $\beta > \frac{k((s_V+n_V)-s_D)}{2(s_V+n_V)-s_D}$, (Appendix part D). If we assume that $k > \beta$, a marginal increase in n_V will cause an increase of the market expansion effect and a decrease in the cannibalization effect from versioning. This assumption is also equivalent to saying that the consumer with the lowest willingness to pay for quality, $\theta = 0$, is willing to buy the s_V

version, if it is priced at the marginal cannibalization cost, β, between mVoIP subscriptions and telephony revenues. After now having constructed and calculated the results of the Benchmark Monopolist model, it is time to apply these results to the Telenor case.

5. Application of analysis to the Telenor case

We start applying the insight of the analysis with the assumption that Telenor is a monopolist, which is a fundamental assumption in the Benchmark Monopolist model. Later on, the perspective is also broadened to a competitive setting to see how this will influence the results. This chapter ends with an honest assessment of the strengths and weaknesses of the Benchmark model, as it relates to the Telenor case.

5.1 Telenor as a monopolist

The Benchmark Monopolist model indicates that it will be profitable for Telenor, as a monopolist, to implement versioning, assuming that the fixed cost of doing so, F, is not too high:

$$\frac{[(s_V + n_V)k - s_D(k - \beta)]^2}{4s_D(s_V + n_V)(s_V + n_V - s_D)} > F$$

and that:

$$\text{(A)} \qquad \beta < s_V + n_V - s_D$$

If the inequality (A) does not hold, then blocking mVoIP completely and only selling the s_D subscription is the most profitable option for Telenor. However, we assume for now that the inequality does hold. Versioning would allow Telenor to expand its market for mobile phone subscriptions with data plans, by offering a degraded subscription for consumers with less willingness to pay for quality. The degraded subscription might also help slow the growth of mVoIP services, and thereby limit the cannibalization of telephony revenues, as some consumers switch from the mVoIP subscription to the degraded version. Even though this consumer migration does imply a cannibalization effect between the product versions themselves, this specific cannibalization cost is outweighed by the gains of market expansion. The price of the s_V subscription also remains the same after the s_D subscription is introduced. Therefore, this versioning strategy does not force the customers who buy the full subscription to pay more for mVoIP access, but it allows those who do not value mVoIP access so highly to pay less for internet access on mobile phones without mVoIP.

This result deviates somewhat from the intention that Telenor and other telecom companies seem to have, by limiting mVoIP. Based on some of the statements made by telecom companies in the media, their hope is to be able to charge a higher price for subscriptions with mVoIP access (E24 and Picard). However, the benchmark model indicates that the price should stay the same for mVoIP subscriptions, while new customers brought into the market by the degraded subscription will give Telenor as a monopolist increased profits overall, from versioning.

With time as all forms of VoIP services evolve, improve and grow their user base, the size of β might change. Better mVoIP services and applications in the future will pose an even greater threat to revenues from regular telephony services, as consumers will be more inclined to switch to this alternative technology. When we differentiated the change in profit from implementing versioning with respect to β, we saw that an increase in β will make versioning a more profitable option. This result is conditioned on assumption (A) being satisfied. So it seems that if mVoIP, or VoIP services in general, continue to take over for traditional telephony services, i.e. β grows, it will become more and more likely that the gains Telenor receive from versioning will outweigh any fixed costs of versioning. Since Telenor and other telecom companies are expressing concern regarding mVoIP (E24 and Picard), we might view this as a signal that β is in fact growing.

In the Benchmark Monopolist model also analyzed how a change in the value of the network effect associated with mVoIP access, n_V, would change the prospects of versioning. The results are dependent on the size of β. If $\beta < \frac{k((s_V+n_V)-s_D)}{2(s_V+n_V)-s_D}$, then the net effect of an increase in n_V is an increase in the change of profit from versioning, and vice versa. Since: $0 < \frac{k((s_V+n_V)-s_D)}{2(s_V+n_V)-s_D} < s_V + n_V - s_D$, the condition (A) does not give us enough information to accurately judge the impact of an increase in n_V. All we know about the size of β by the given assumptions, is that: $0 < \beta < s_V + n_V - s_D$. However, we know that an increase in n_V will make the full subscription more valuable in the eye of consumers, allowing Telenor to increase the price, p_V, on the s_V subscription. If we assume:

(B) $$\beta < k,$$

a marginal increase in n_V will lead to an increase in the market expansion effect Telenor receives from versioning, and a decrease of the cannibalization effect between the product versions. The reason for the latter is that a higher margin on the full subscription means a higher loss for Telenor on every consumer that switches to the degraded version.

Overall, the Benchmark Monopolist model indicates that versioning, if not already a profitable strategy, might become an increasingly profitable option for Telenor over time. Assuming β will grow within the bounds of condition (A), whatever fixed costs that are associated with implementing versioning, F, will become less and less significant. The impact a change in n_V will have on the incentive to implement versioning is more unclear. Moving on, it is now time to look at how the element of competition could influence the results of the benchmark model.

5.2 The effects of competition

In the benchmark model a fundamental assumption is that Telenor is a monopolist. This assumption gave the company market power which allowed them to manipulate prices. However, in the industry characteristics section earlier we saw clearly that Telenor is not a monopolist. NetCom with its own network is a serious competitor to Telenor. There are also many other smaller competitors, without their own networks, that Telenor has to take into account. Comparing the telecommunications sector in Norway with other OECD countries, we also see that prices for telecom services are low in Norway relative to other industrialized economies. This would seem to indicate that the telecom market in Norway is highly competitive on prices. So in a context of intense competition, what would the consequences be for Telenor if they attempt the strategy of versioning?

We can view this as a game resembling the Prisoners' Dilemma. To simplify we limit the players to Telenor and NetCom. They can each choose between either only selling one high-quality subscription, s_V, with mVoIP access, or they can choose versioning, by adding a new degraded subscription, s_D, without mVoIP. What happens if Telenor goes ahead with a versioning strategy while Netcom does not? Originally, both companies only sell the s_V version. Assuming both companies have the same price for this high-quality subscription, they share the market evenly, with a $\frac{1-\theta_{V0}}{2}$ market share each. When Telenor introduces the

s_D version at a lower price, both companies lose customers for the s_V subscription, as some will choose to switch to buying the s_D version instead. However, since Telenor is the only company selling the s_D version, they get all these migrating customers, as well as new customers that now enter the market. NetCom's response to Telenor taking their customers is to cut the price on the s_V version, winning over all the high-WTP consumers in the market who buy the s_V version, and also winning back some of the consumers who migrated to the s_D version.

Since it is very easy for customers to switch telecom providers, Telenor, by versioning alone, endures a heavy loss due to an exodus of customers. The versioning company might also be hurt by the fact that some customers are angry about them trying to block a popular service, mVoIP, and these customers might choose to go to the competitor in protest. The non-versioning company gains a significant increase in customers and profits, despite having cut prices. In short, the versioning company incurs a significant loss in profits, as the company that did not go ahead with versioning gains a significant increase in profits.

The game can be illustrated in a payoff matrix:

Versioning and competition		**Netcom**	
		Not versioning	Versioning
Telenor	Not versioning	1, 1	10, -10
	Versioning	-10, 10	5, 5

Figure 11: This figure illustrates a payoff matrix of a game, where Telenor and Netcom in a duopoly have to choose whether or not versioning will be profitable. The game is assumed to resemble a classic Prisoners' Dilemma.

In the payoff matrix above, each of the four cells in the bottom right corner shows the payoffs from each of the four possible outcomes. The numbers represents profits, so the higher the number, the higher the profits are for the company. Telenor's payoffs are to the left in each cell, and NetCom's payoffs to the right. We see that there is an incentive for both players to not pursue versioning in this game, regardless of what the competitor is doing. Therefore, keeping the status quo of selling only one version, s_V, is the dominant strategy for both players. The Nash equilibrium is the top left cell in the payoff matrix. In this equilibrium, both companies earn a profit of 1. They could potentially be better off if they decided to pursue a versioning strategy together, which would give both a profit of 5. So the next question we should ask is: how can the companies reach an equilibrium where they both are versioning?

It is possible to reach a solution where both Telenor and Netcom are versioning. To reach this goal Telenor needs some form of assurance that their competitor will follow their lead if they implement a versioning strategy. In a recent article Telenor's Chief Information Officer said in relation to blocking mVoIP (Appendix part E for English translation):

"Vi følger utviklingen i nabolandene nøye, men i Norge har Telenor ikke planlagt å innføre mekanismer som legger slike begrensninger på kundenes bruk. Men vi må vurdere ulike scenearier fremover, og det kan for eksempel være aktuelt å se på samarbeid med andre aktører om denne type løsninger" (E24 2012).

This statement could be seen as a step forward in creating a common understanding in the Norwegian telecom market that versioning is beneficial for all. Netcom has also made similar statements in the media. Communications Consultant at NetCom, Charlotte Erikstad, said on the topic of limiting mVoIP access (Picard 2011):

"Vi følger utviklingen nøye, og på sikt vil det nok skje noen endringer på dette området. NetComs kunder vil alltid ha muligheten til å bruke MVoIP og vi vil legge til rette for dette ved å sikre god tjenestekvalitet, men i fremtiden vil det ikke være gratis" (Appendix part E for English translation).

It is important to send the signal that it would be in the interest of all the telecom companies to move in the direction of versioning, and that this should become the new industry standard. In addition, Telenor needs to make clear that if any competitor would rather try and undercut them to steal customers in the short term, this will only spark an even more intense competitive environment over the long term, hurting every telecom provider. If the Prisoners' Dilemma style game described above is stretched out over a longer time horizon, undercutting your competitor might look more like this:

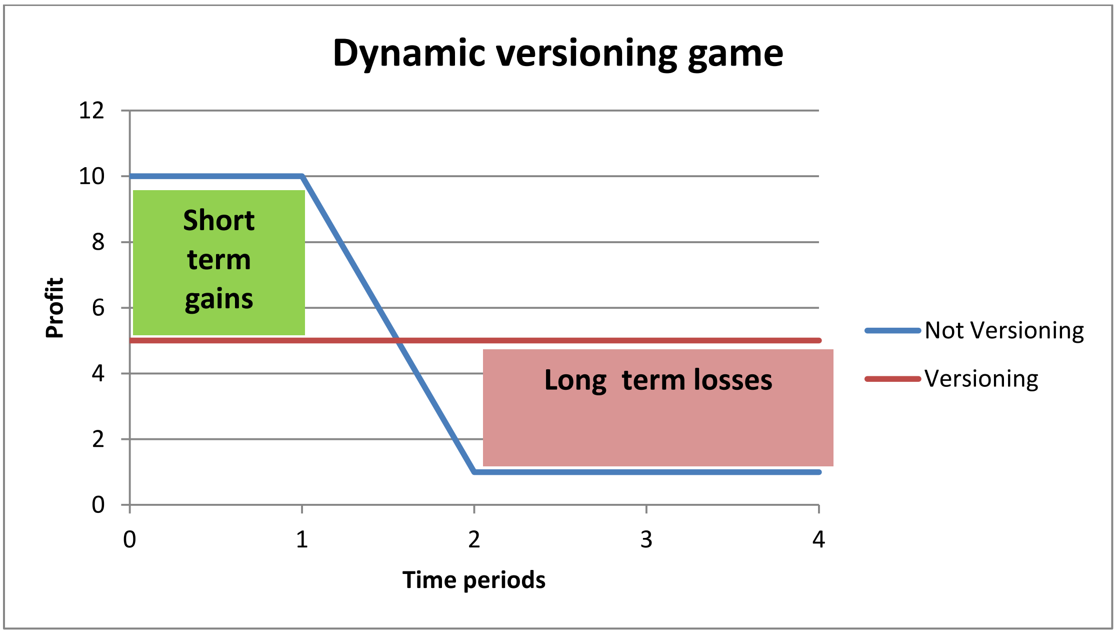

Figure 12: This figure shows that even if the competitor tries to increase profits by undercutting the versioning company, the gain is only short term. In the long term, the undercutting company could lose all it initially gained on a lengthy price war.

The graph above illustrates how the threat of a price war could be an incentive for competitors to collude instead of undercutting each other. The blue line represents profits over an extended period of time for a company that undercuts its competitor who is going ahead with versioning. The red line represents profits over an extended time horizon for a company that is colluding with its competitor in implementing a versioning strategy. Even though the short term gains of undercutting your competitor might be tempting, the long term sustained losses of a price war works as a deterrent against escalating price competition. This is not a static game, so Telenor will have the opportunity to respond to their competitor's response, should NetCom choose to undercut them.

The size of the cannibalization parameter, β, is a key factor. If the cannibalization effect that mVoIP subscriptions have on the telephony side is growing, as the use of programs like Skype becomes more widespread, Telenor could forcefully make the argument that the industry needs to adapt sooner rather than later. If they hesitate and stick their head in the sand, they could risk that revenues from time charge calls, the largest source of revenue in mobile services, declines significantly, without having any clear strategy to offset these losses or slow this trend. Telecom companies could increase the protection of their revenue stream from the telephony side by versioning, which will make some consumers give up access to mVoIP in exchange for a cheaper degraded subscription. Revenue from subscriptions is already increasing its share of mobile services revenue, and could in the future be a significant compensating factor for lost time-charged calls and SMS revenues.

If we now assume that the telecom companies all agree to move to versioning, how does this competitive versioning equilibrium compare to a monopolist versioning equilibrium for Telenor? With the increased competition, it would seem reasonable to assume that prices for both the full subscription and the degraded subscription will be lower in a competitive setting than in a monopoly. Without the market power that a monopoly position can offer, Telenor is forced to accept lower prices to avoid losing too many customers to its competitors. But there is now the possibility of sharing the fixed cost, F, associated with implementing versioning in practice. For example, if F involves the development of a new technology, a joint venture among industry actors could help share the research costs between them. Overall one would expect Telenor to make less profit when versioning in a competitive setting than in a monopolist setting, but as a strategy it would still be preferable if competitors can be convinced to come along as well. As the biggest company in the Norwegian telecom market, Telenor is most likely in the best position to take a leadership role on versioning and move the other industry actors with them into a new equilibrium that is more beneficial for everyone.

After having applied the analysis to the Telenor case, it is now time to assess how well the model fits reality. In the next section we take a critical look at strengths and weaknesses of the benchmark model.

5.3 Weaknesses and strengths of the model

Before accepting the results of the analysis it is important to question the assumption upon which it is based. Are the assumptions reasonable, and what real world complexities does the model fail to reflect?

In the case of only selling one quality version, it was assumed the monopolist would choose to sell the high-quality subscription, s_V, with mVoIP access. This is of course similar to what is happening today, as Telenor has not yet blocked mVoIP services, although they are differentiated their subscriptions along other dimensions. As mVoIP access is free and open today, the assumption of the monopolist only selling the high quality subscriptions seems acceptable as a benchmark.

It is also reasonable to assume that consumers are heterogeneous in their valuation of quality of internet access. Some call abroad more than others, and therefore have more to gain from using mVoIP, which is a lot cheaper for international calls than regular time-charged calls. Business professionals may have different needs from a mobile phone subscription than residential customers, and so on. A uniform distribution of θ-values is perhaps a simplification, but it does reflect some form of variation in consumers' valuation of quality in the subscription data plan.

However, the model does not capture any other variation in consumers' valuation of quality, beyond the data plan dimension. We know that telecom companies offer subscriptions with varying amounts of free SMS and call minutes, or cheaper service fees when calling or texting family and friends. Clearly there are also other dimensions along which it is possible to differentiate mobile phone subscriptions. Therefore, it does not seem obvious that all consumers would have the same valuation of telephony services, k. Allowing for k to vary among consumers would perhaps make the model more realistic, and might also influence the results of the Benchmark Monopolist model.

Since Telenor and other Norwegian telecom companies are not blocking mVoIP today, one could argue that the condition (A): $\beta < s_V + n_V - s_D$, is satisfied. If (A) did not hold, it would be more profitable to block mVoIP from mobile phones altogether, and only sell the degraded subscription. On the other hand, there may be factors like competitive pressure, legal issues and lack of technological solutions, that are stopping Telenor from blocking mVoIP completely. As was stated in the introduction, Telenor and other telecom companies have expressed concern regarding this cannibalization effect, β. Also, according to the Body of European Regulators for Electronic Communications (BEREC), there is evidence of VoIP services being blocked in Europe, for the most part on mobile networks (BEREC 2012). So some European telecom companies have already taken the step of limiting access to VoIP services, although the nature and extent of this practice is unclear.

I do not attempt to estimate the value of the β parameter in any empirical way in this thesis. As Swedish telecom companies are in the process of implementing some form of versioning with respect to mVoIP, and Norwegian telecom companies are assessing this option seriously (E24), it seems reasonable to assume that β is at least significant, $\beta > 0$, and perhaps even pushing the bounds of condition (A). In the review of the market characteristics for the Norwegian telecom industry, we saw that traditionally big revenue groups in mobile services, SMS and time-charged calls, are declining. Further increase in the use of mVoIP services should only exacerbate this trend. In other words, there is most likely a positive correlation between n_V and β. The more people use mVoIP programs, the less useful regular telephony services become, and as these services lose value in the eyes of consumers, they will also lose revenue potential. However, the benchmark model does not include the possible relationship between the n_V and β parameters.

The prices in the model are fixed prices for mobile phone subscriptions, including a free data amount. It is assumed that consumers will self ration data usage, thereby not exceeding the free amount included in the subscription. This assumption may not hold in real life. Consumer who buy the high-quality subscription with mVoIP access might use more data on average than other consumers, and therefore tend to exceed any free data amount. If this is the case, the cannibalization effect that mVoIP subscriptions have on telephony revenues would be somewhat offset by increased data revenues. So if the self rationing assumption does not hold it could for instance mean a smaller effective β than the benchmark model implies.

Furthermore, limiting the market to mobile phone subscriptions with data plans is also somewhat problematic. How would dedicated mobile data subscriptions, or regular mobile subscriptions affect the results, if included in the model? An introduction of a degraded subscription could perhaps cause some consumers who use regular mobile phone subscriptions with no data plan, to switch to the degraded subscription with a data plan. With access to a free data amount, these consumers might start sending more messages via data, further impacting the revenues from regular SMS messages. In other words, adding a degraded version could potentially cannibalize other Telenor products, and not just the s_V subscription. Dedicated mobile broadband subscriptions are also open to mVoIP programs. Would it be necessary to version this market segment as well, if the goal is to limit the cannibalization of telephony revenues in a significant way? The Benchmark Monopolist model does not include these possible substitute products, and how they may affect the result. It is important to keep this in mind.

The model treats mobile phone subscriptions with data plans as information goods. An argument for this assumptions is that the cost of building the telephone network may be seen as a fixed sunk cost. So the capacity already exists, and one extra consumer using the network will not cause any significant increase in costs for the telecom provider. Therefore, I think the assumption of equating subscriptions with data plans to information goods is tenable, which is why the marginal costs of the product versions are zero. However, the negative cannibalization effect that mVoIP subscriptions have on telephony revenues may be viewed similarly to a marginal cost for the s_V version.

The value of the network effect associated with using mVoIP, n_V, is treated as an exogenous parameter, and the monopolist maximizes profit by setting prices. However, the prices will determine the number of consumers who buy the mVoIP subscription, which will in turn affect the value of n_V, which affects the utility consumers receive from having access to mVoIP, and therefore the price consumers are willing to pay for mVoIP subscriptions. Treating n_V as an exogenously determined variable does not sufficiently account for the network effect when maximizing profit. As we saw in Belleflamme's (2005) Specific case of Functional Degradation, when maximizing profit with respect to network effects there might be more than one equilibrium. Given the possibility of coordination problems among consumers, it is difficult to figure out which equilibrium state the market will reach. For instance, if suddenly mVoIP subscriptions become more expensive relative to a degraded subscription, one cannot rule out that the market eventually ends up in an equilibrium where almost no one buys the s_V version.

Finally, I should reiterate what was mentioned briefly in the introduction. The model and analysis does not look deeply into legal or technical issues related to the implementation of versioning. The model assumes some fixed cost, F, of versioning, but it is unclear what size this fixed cost might take. Does the technology or mechanisms exist that would allow the telecom companies to block programs like Skype from certain mobile phone subscriptions? If there is a huge backlash from consumers who are angry at telecom operators trying to introduce a degraded subscription with limited internet access, the whole process could become very unpredictable, especially in a highly competitive setting. And what about companies like Skype? They might take legal action against telecom companies trying to limit their market. It is important to acknowledge such complications in light of the analysis results.

6. Conclusion

It is time to summarize the main points of the analysis and to answer the thesis question:

Is it profitable for Telenor to pursue a strategy of versioning by creating two types of mobile phone subscriptions: one with access to mVoIP services, and one without access to mVoIP services?

The Benchmark Monopolist model showed that versioning may be profitable, depending on the size of the fixed cost of implementing this strategy, F. As the cannibalization factor β marginally increases, versioning will become a more profitable strategy. However, if $\beta > s_V + n_V - s_D$, then selling only the degraded subscription, s_D, and blocking mVoIP altogether would be the most profitable option. But it is not certain that blocking mVoIP completely is a viable option given possible legal constraints and the fear of consumer uproar. The effects of a marginal increase in n_V is somewhat ambiguous, but it should increase the price and demand of the mVoIP subscription. How it affects the prospects for versioning is dependent on the size of β.

Moving on from the results in the Benchmark model, we took a look at how versioning in a competitive setting will affect the outcome. Based on dynamic game theory, there is an argument to be made for how Telenor could achieve an equilibrium where all telecom providers in Norway chose to implement versioning. To reach this equilibrium, Telenor must be successful in sending a clear signal that versioning will benefit all actors. At the same time, the threat of a lengthy price war will serve as a deterrent to anyone who are tempted to undercut the implementation of versioning. In an already highly competitive Norwegian telecom market, more intense price competition is probably something most telecom providers would like to avoid.

As a result, the analysis indicates that there is a path forward for Telenor to pursue the strategy of versioning. It could potentially increase profits through market expansion and limit the damage that mVoIP services inflict on revenue from telephony services. The latter effect of versioning would be especially important if: $\beta > s_V + n_V - s_D$, and blocking mVoIP altogether is not a realistic option. For a versioning pricing strategy to succeed, however, Telenor will need to persuade competitors to follow its lead for the optimized financial benefit of all. Finally, we must also acknowledge that this conclusion is bounded to the assumptions of the Benchmark model. As we discussed in the previous chapter, there are weaknesses to the model and they could affect these results.

7. Appendix

7.1 Part A

Below are the complete calculations for equilibriums price and profit for selling only one quality version.

Equilibrium price:

$$1 - \frac{p_V - k}{s_V + n_V} - (p_V - \beta)\frac{1}{s_V + n_V} = 0$$

$$s_V + n_V - p_V + k - p_V + \beta = 0$$

$$\hat{p}_V = \frac{k + s_V + n_V + \beta}{2}$$

Equilibrium profit:

$$\hat{\pi}_{1q} = (\hat{p}_V - \beta)(1 - \theta_{V0})$$

$$\hat{\pi}_{1q} = \left(\frac{k + s_V + n_V + \beta}{2} - \beta\right)\left(1 - \frac{\frac{k + s_V + n_V + \beta}{2} - k}{s_V + n_V}\right)$$

$$\hat{\pi}_{1q} = \left(\frac{k + s_V + n_V - \beta}{2}\right)\left(1 - \frac{s_V + n_V + \beta - k}{2(s_V + n_V)}\right)$$

$$\hat{\pi}_{1q} = \left(\frac{k + s_V + n_V - \beta}{2}\right)\left(\frac{2s_V + 2n_V - s_V - n_V - \beta + k}{2(s_V + n_V)}\right)$$

$$\hat{\pi}_{1q} = \left(\frac{k + s_V + n_V - \beta}{2}\right)\left(\frac{k + s_V + n_V - \beta)}{2(s_V + n_V)}\right)$$

$$\hat{\pi}_{1q} = \frac{(k + s_V + n_V - \beta)^2}{4(s_V + n_V)}$$

7.2 Part B

Below are the calculations for indifferent consumers, FOCs , equilibrium prices, and the parameter conditions under the versioning constraint, for the case of selling two quality versions.

Indifferent consumer expressions:

$$k + \theta_{VD}(s_V + n_V) - p_V = k + \theta_{VD}s_D - p_D$$

$$\theta_{VD}(s_V + n_V - s_D) = p_V - p_D$$

$$\theta_{VD} = \frac{p_V - p_D}{s_V + n_V - s_D} = \frac{\Delta}{s_V + n_V - s_D}$$

$$\Delta = price\ premium\ paid\ for\ access\ to\ mVoIP$$

$$k + \theta_{D0}s_D - p_D = 0$$

$$\theta_{D0} = \frac{p_D - k}{s_D}$$

Profit maximization problem with versioning constraint:

$$\max_{p_D,\Delta} \pi_{2q} = p_D\big(\theta_{VD}(\Delta) - \theta_{D0}(p_D)\big) + (p_D + \Delta - \beta)\big(1 - \theta_{VD}(\Delta)\big) - F$$

$$s.t.\ \ 0 \leq \theta_{D0} < \theta_{VD} < 1$$

FOCs:

$$\frac{\partial \pi_{2q}}{\partial p_D} = \big(\theta_{VD}(\Delta) - \theta_{D0}(p_D)\big) - p_D\frac{\partial \theta_{D0}(p_D)}{\partial p_D} + \big(1 - \theta_{VD}(\Delta)\big) = 0$$

(I) $$\frac{\partial \pi_{2q}}{\partial p_D} = \big(1 - \theta_{D0}(p_D)\big) - p_D\frac{\partial \theta_{D0}(p_D)}{\partial p_D} = 0$$

$$\frac{\partial \pi_{2q}}{\partial \Delta} = p_D\frac{\partial \theta_{VD}(\Delta)}{\partial \Delta} + \big(1 - \theta_{VD}(\Delta)\big) - (p_D + \Delta - \beta)\frac{\partial \theta_{VD}(\Delta)}{\partial \Delta} = 0$$

(II) $$\frac{\partial \pi_{2q}}{\partial \Delta} = \big(1 - \theta_{VD}(\Delta)\big) - (\Delta - \beta)\frac{\partial \theta_{VD}(\Delta)}{\partial \Delta} = 0$$

Finding equilibrium prices:

(I) $$\left(1 - \frac{p_D - k}{s_D}\right) - p_D \frac{1}{s_D} = 0$$

$$s_D - p_D + k - p_D = 0$$

$$\dot{p}_D = \frac{k + s_D}{2}$$

(II) $$\left(1 - \frac{\Delta}{s_V + n_V - s_D}\right) - (\Delta - \beta)\frac{1}{s_V + n_V - s_D} = 0$$

$$s_V + n_V - s_D - \Delta - \Delta + \beta = 0$$

$$\dot{\Delta} = \frac{s_V + n_V - s_D + \beta}{2}$$

$$\dot{p}_V = \dot{p}_D + \dot{\Delta}$$

$$\dot{p}_V = \frac{k + s_V + n_V + \beta}{2}$$

Checking what parameter conditions satisfy the versioning constraint:

$$\theta_{D0} = \frac{\dot{p}_D - k}{s_D} = \frac{\frac{k + s_D}{2} - k}{s_D} = \frac{s_D - k}{2s_D}$$

$$\theta_{D0} = \frac{1}{2} - \frac{k}{2s_D}$$

$$\theta_{VD} = \frac{\dot{\Delta}}{s_V + n_V - s_D} = \frac{\frac{s_V + n_V - s_D + \beta}{2}}{s_V + n_V - s_D} = \frac{s_V + n_V - s_D + \beta}{2(s_V + n_V - s_D)}$$

$$\theta_{VD} = \frac{1}{2} + \frac{\beta}{2(s_V + n_V - s_D)}$$

$$versioning\ constraint = \ 0 \leq \theta_{D0} < \theta_{VD} < 1$$

$$\theta_{VD} < 1 \rightarrow \ \frac{p_V - p_D}{s_V + n_V - s_D} \ < 1 \rightarrow \ p_V < p_D + (s_V + n_V - s_D)$$

$$\rightarrow \frac{1}{2} + \frac{\beta}{2(s_V + \ n_V - \ s_D)} < 1 \quad \rightarrow \quad \frac{\beta}{2(s_V + \ n_V - \ s_D)} < \frac{1}{2}$$

$$we\ know\ that: s_D < s_V\ and\ n_V > 0 \quad \rightarrow \quad (s_V + \ n_V - \ s_D) > 0$$

$\theta_{VD} < 1 \quad \rightarrow \quad p_V < p_D + (s_V + n_V - s_D) \quad \rightarrow \quad \beta < s_V + \ n_V - \ s_D$

$$\theta_{D0} < \theta_{VD} \quad \rightarrow \quad \frac{s_V + n_V - s_D}{p_V - p_D} < \frac{s_D}{p_D - k}$$

$$\rightarrow \ \frac{1}{2} - \frac{k}{2s_D} < \frac{1}{2} + \frac{\beta}{2(s_V + \ n_V - \ s_D)} \quad \rightarrow \ -\frac{k}{2s_D} < \frac{\beta}{2(s_V + \ n_V - \ s_D)}$$

$$\beta > -\frac{k(s_V + \ n_V - \ s_D)}{s_D} \rightarrow \beta > k - \frac{k(s_V + \ n_V)}{s_D}$$

$\theta_{D0} < \theta_{VD} \quad \rightarrow \quad \frac{s_V + n_V - s_D}{p_V - p_D} < \frac{s_D}{p_D - k} \quad \rightarrow \quad \beta > k(1 - \frac{s_V + \ n_V}{s_D})$

$$0 \leq \theta_{D0} \quad \rightarrow \quad 0 \leq \frac{p_D - k}{s_D} \quad \rightarrow \quad p_D \geq k$$

$$\rightarrow \ 0 \leq \ \frac{1}{2} - \ \frac{k}{2s_D} \quad \rightarrow \quad 0 \leq 1 - \ \frac{k}{s_D}$$

$0 \leq \theta_{D0} \quad \rightarrow \quad p_D \geq k \quad \rightarrow \quad \frac{k}{s_D} \leq 1$

7.3 Part C

Below are the calculations of the cannibalization effect, market expansion effect and both effects added together. These expressions are discussed in the Versioning vs. selling only one version section.

First we need to find another expression for the indifferent consumer when selling only one quality version:

$$\theta_{V0}(\hat{p}_V) = \frac{\hat{p}_V - k}{s_V + n_V} = \frac{s_V + n_V + \beta - k}{2(s_V + n_V)} = \frac{1}{2} + \frac{\beta - k}{2(s_V + n_V)}$$

Cannibalization effect:

$$d\pi_{ca} = [\theta_{VD}(\dot{p}_D, \dot{p}_V) - \theta_{V0}(\hat{p}_V)][\dot{p}_D - (\hat{p}_V - \beta)]$$

$$\rightarrow \quad d\pi_{ca} = \left(\frac{1}{2} + \frac{\beta}{2(s_V + n_V - s_D)} - \left(\frac{1}{2} + \frac{\beta - k}{2(s_V + n_V)}\right)\right)\left(\frac{k + s_D}{2} - \frac{k + s_V + n_V - \beta}{2}\right)$$

$$\rightarrow \quad d\pi_{ca} = -\frac{\big((s_V + n_V) - s_D - \beta\big)\big((s_V + n_V)k - s_D(k - \beta)\big)}{4(s_V + n_V)(s_V + n_V - s_D)} < 0$$

Market expansion effect:

$$d\pi_{me} = \big(\theta_{V0}(\hat{p}_V) - \theta_{D0}(\dot{p}_D)\big)\dot{p}_D$$

$$= \left(\frac{1}{2} + \frac{\beta - k}{2(s_V + n_V)} - \left(\frac{1}{2} - \frac{k}{2s_D}\right)\right)\left(\frac{k + s_D}{2}\right)$$

$$\rightarrow d\pi_{me} = \frac{\big((s_V + n_V)k - s_D(k - \beta)\big)(k + s_D)}{4s_D(s_V + n_V)} > 0$$

Adding up the cannibalization and the market effects:

$$d\pi_{ca} + d\pi_{me} =$$

$$-\frac{\big((s_V + n_V) - s_D - \beta\big)\big((s_V + n_V)k - s_D(k - \beta)\big)}{4(s_V + n_V)(s_V + n_V - s_D)}$$

$$+\frac{\big((s_V + n_V)k - s_D(k - \beta)\big)(k + s_D)}{4s_D(s_V + n_V)}$$

$$= \frac{2s_D(s_V + n_V)k\beta - 2s_D(s_V + n_V)k^2 - 2s_D^2k\beta + s_D^2\beta^2 + (s_V + n_V)^2k^2 + s_D^2k^2}{4s_D(s_V + n_V)(s_V + n_V - s_D)}$$

$$\dot{\pi}_{2q}(\dot{p}_D, \dot{p}_V) - \hat{\pi}_{1q}(\hat{p}_V) = d\pi_{ca} + d\pi_{me} - F = \frac{[(s_V + n_V)k - s_D(k - \beta)]^2}{4s_D(s_V + n_V)(s_V + n_V - s_D)} - F$$

7.4 Part D

Below are the differentiations with respect to β and n_V, of the change in profit, and the cannibalization and market expansion effect from versioning.

Differentiating change in profit when versioning with respect to β:

$$d\pi_{ca} + d\pi_{me} = \frac{[(s_V + n_V)k - s_D(k - \beta)]^2}{4s_D(s_V + n_V)(s_V + n_V - s_D)}$$

$$\frac{\partial(d\pi_{ca} + d\pi_{me})}{\partial\beta} = \frac{2s_D[(s_V + n_V)k - s_D(k - \beta)]}{4s_D(s_V + n_V)(s_V + n_V - s_D)} > 0$$

Given the assumption made about the parameter in the model we know that the fraction about is positive, proving that $\frac{\partial(d\pi_{ca}+d\pi_{me})}{\partial\beta} > 0$.

Differentiating change in profit when versioning with respect to n_V:

$$\textit{To shorten the calculation set}: x = 4s_D(s_V + n_V)(s_V + n_V - s_D)$$

$$y = [(s_V + n_V)k - s_D(k - \beta)]^2$$

$$\frac{\partial(d\pi_{ca} + d\pi_{me})}{\partial n_V} = \frac{2k[(s_V + n_V)k - s_D(k - \beta)]x - y4s_D(2(s_V + n_V) - s_D)}{x^2}$$

$$\frac{\partial(d\pi_{ca} + d\pi_{me})}{\partial n_V} > 0$$

$$\rightarrow \quad 2k[(s_V + n_V)k - s_D(k - \beta)]x > y4s_D(2(s_V + n_V) - s_D)$$

$$\rightarrow 2kx > [(s_V + n_V)k - s_D(k - \beta)]4s_D(2(s_V + n_V) - s_D)$$

$$\rightarrow 2k(s_V + n_V)(s_V + n_V - s_D) > [(s_V + n_V)k - s_D(k - \beta)](2(s_V + n_V) - s_D)$$

$$\rightarrow \quad \beta(2(s_V + n_V) - s_D) + k\big(s_D - (s_V + n_V)\big) < 0$$

$$\rightarrow \quad \beta < -\frac{k\big(s_D - (s_V + n_V)\big)}{2(s_V + n_V) - s_D} = \frac{k\big((s_V + n_V) - s_D\big)}{2(s_V + n_V) - s_D}$$

If the inequality above holds, a marginal increase in n_V will lead to an increase in the change in profit from versioning. The opposite is true if the inequality is reversed.

Differentiating the cannibalization effect from versioning with respect to β:

$$d\pi_{ca} = [\theta_{VD}(\dot{p}_D, \dot{p}_V) - \theta_{V0}(\hat{p}_V)][\dot{p}_D - (\hat{p}_V - \beta)]$$

$$\frac{\partial d\pi_{ca}}{\partial \beta} = \left(\frac{1}{2(s_V + n_V - s_D)} - \frac{1}{2(s_V + n_V)}\right)\left(\frac{s_D - s_V - n_V + \beta}{2}\right) + \frac{1}{2}\left(\frac{\beta}{2(s_V + n_V - s_D)} - \frac{\beta - k}{2(s_V + n_V)}\right)$$

The first product in the equation above is negative and the second product is positive. Next step is to check the condition:

$$\frac{\partial d\pi_{ca}}{\partial \beta} > 0$$

$$\rightarrow \frac{1}{2}\left(\frac{\beta}{2(s_V + n_V - s_D)} - \frac{\beta - k}{2(s_V + n_V)}\right) > \left(\frac{1}{2(s_V + n_V - s_D)} - \frac{1}{2(s_V + n_V)}\right)\left(\frac{s_D - s_V - n_V + \beta}{2}\right)$$

$$\rightarrow (s_V + n_V)(s_D - s_V - n_V + \beta) - (s_V + n_V - s_D)(s_D - s_V - n_V + \beta) < \beta(s_V + n_V) - (\beta - k)(s_V + n_V - s_D)$$

$$\rightarrow s_D(s_D - s_V - n_V + \beta) < \beta s_D + k(s_V + n_V - s_D)$$

$$\rightarrow s_D(s_D - s_V - n_V) < k(s_V + n_V - s_D)$$

$$\rightarrow s_D(s_D - s_V - n_V) - k(s_V + n_V - s_D) < 0$$

$$\rightarrow (s_D + k)(s_D - s_V - n_V) < 0$$

On the left side in the expression above, the first term in the product, $s_D + k$, is positive and the second term, $s_D - s_V - n_V$, is negative given the assumption made about the parameter values. This proves that the inequality holds, and that the cannibalization effect is dampened by an increase in β, i.e. $\frac{\partial d\pi_{ca}}{\partial \beta} > 0$.

Differentiating the cannibalization effect from versioning with respect to n_V:

$$d\pi_{ca} = -\frac{\big((s_V + n_V) - s_D - \beta\big)((s_V + n_V)k - s_D(k - \beta))}{4(s_V + n_V)(s_V + n_V - s_D)}$$

$$To\ shorten\ the\ calculations\ set:$$

$$x = 4(s_V + n_V)(s_V + n_V - s_D)$$

$$y = \big((s_V + n_V) - s_D - \beta\big)((s_V + n_V)k - s_D(k - \beta))$$

$$\frac{\partial d\pi_{ca}}{\partial n_V} = -\frac{\Big(\big((s_V + n_V)k - s_D(k - \beta)\big) + k\big((s_V + n_V) - s_D - \beta\big)\Big)x - 4\big((s_V + n_V - s_D) + (s_V + n_V)\big)y}{x^2}$$

$$\frac{\partial d\pi_{ca}}{\partial n_V} = -\frac{s_D k((s_V + n_V) - s_D)^2 - s_D\beta((s_V + n_V) - s_D)^2 + k\beta((s_V + n_V) - s_D)^2 + \beta^2(2s_D(s_V + n_V) - s_D^2)}{4\big((s_V + n_V)(s_V + n_V - s_D)\big)^2}$$

$$If: (s_D + \beta)k + \frac{\beta^2(2s_D(s_V + n_V) - s_D^2)}{((s_V + n_V) - s_D)^2} > s_D\beta$$

$$\rightarrow \frac{\partial d\pi_{ca}}{\partial n_V} < 0$$

$$If: (s_D + \beta)k + \frac{\beta^2(2s_D(s_V + n_V) - s_D^2)}{((s_V + n_V) - s_D)^2} < s_D\beta$$

$$\rightarrow \frac{\partial d\pi_{ca}}{\partial n_V} > 0$$

Differentiating the market expansion effect from versioning with respect to β:

$$d\pi_{me} = \frac{\big((s_V + n_V)k - s_D(k - \beta)\big)(k + s_D)}{4s_D(s_V + n_V)}$$

$$\frac{\partial d\pi_{me}}{\partial \beta} = \frac{k + s_D}{4(s_V + n_V)} > 0$$

Since we know from our assumptions about the parameters that the fraction above is positive we can say that a marginal increase in β will increase the market expansion effect, i.e. $\frac{\partial d\pi_{me}}{\partial \beta} > 0$.

Differentiating market expansion when versioning with respect to n_V:

$$\frac{\partial d\pi_{me}}{\partial n_V} = \frac{k(k + s_D)4s_D(s_V + n_V) - 4s_D\big((s_V + n_V)k - s_D(k - \beta)\big)(k + s_D)}{\big(4s_D(s_V + n_V)\big)^2}$$

$$\frac{\partial d\pi_{me}}{\partial n_V} > 0$$

$$\rightarrow \quad k(k + s_D)4s_D(s_V + n_V) > 4s_D\big((s_V + n_V)k - s_D(k - \beta)\big)(k + s_D)$$

$$\rightarrow k(s_V + n_V) > (s_V + n_V)k - s_D(k - \beta)$$

$$\rightarrow \quad 0 > s_D(\beta - k) \quad \rightarrow \quad k > \beta \quad \rightarrow \quad \frac{\partial d\pi_{me}}{\partial n_V} > 0$$

$$If\ \beta > k \quad \rightarrow \quad \frac{\partial d\pi_{me}}{\partial n_V} < 0$$

7.5 Part E

Below are the Norwegian quotes from the section: The effects of competition, followed by the English translations:

In a recent article Telenor's Chief Information Officer said in relation to blocking mVoIP:

"Vi følger utviklingen i nabolandene nøye, men i Norge har Telenor ikke planlagt å innføre mekanismer som legger slike begrensninger på kundenes bruk. Men vi må vurdere ulike scenearier fremover, og det kan for eksempel være aktuelt å se på samarbeid med andre aktører om denne type løsninger" (E24 2012).

English:

"We are following the developments in our neighbouring countries closely, but Telenor has no plans of implementing mechanisms that put such limitations on the consumers use in Norway. But we have to review various scenarios for the future, and it may for instance be of interest to cooperate with other actors with regards to these types of solutions" (E24 2012)

Communications Consultant to Netcom, Charlotte Erikstad, said on the topic of limiting mVoIP access (Picard 2011):

"Vi følger utviklingen nøye, og på sikt vil det nok skje noen endringer på dette området. NetComs kunder vil alltid ha muligheten til å bruke MVoIP og vi vil legge til rette for dette ved å sikre god tjenestekvalitet, men i fremtiden vil det ikke være gratis" (Appendix part E for English translation).

English:

"We are following developments closely, and in the future some changes are likely to be made in this area. NetCom's customers will always have the option of using MVoIP and we will make sure of that by guaranteeing good service quality, but in the future it will not be free."

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