# *Text and Voice: Complements, Substitutes or Both?*[ψ]


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September 2006


*Abstract*

Text messaging has become an important revenue component for most mobile operators. We develop a simple model of demand for mobile services incorporating dynamics of information exchange. We show that when incoming communication stimulate outgoing communication, services that initially may be perceived as substitutes, such as mobile text and voice, may evolve into complements in terms of the price effect when the network size becomes large. We estimate the demand for text messaging in the Norwegian market and find that the cross-price effect of voice depends on the network size. Voice is a substitute for text messages for small network sizes, and a complement for large network sizes.



*Keywords*
Text messaging, cross-price elasticity, dynamics of information exchange



[ψ] We thank Gorm Grønnevet, Erik Ø. Sørensen and Lars Sørgard for valuable comments. Furthermore we thank seminar participants at EARIE 2006, Amsterdam, the Norwegian Competition Authority, the Norwegian School of Economics and Business Administration, the Norwegian University of Science and Technology and the Portuguese Competition Authority. Finally, Kjetil Andersson thanks Telenor R&D for financial support, Øystein Foros and Frode Steen are grateful for financial support from the Research Council of Norway through the research programs KIM 1303 and ISIP 154834, respectively.

## 1 Introduction

"No text please, we're American" is The Economist's headline when zooming on the striking discrepancy between Europe and the United States when it comes to the take-up of text messaging (The Economist, 2003). While the average monthly usage exceeded sixty messages in several European countries in 2004, the corresponding figure for the United States was seven.[1] According to The Economist "The short answer is that, in America, talk is cheap." The early adopters of text messaging in Europe seemed to be price sensitive teenagers who found text messaging a cheap alternative to mobile calls. In the United States mobile voice calls are less expensive than in Europe, hence Americans prefer to make voice calls.[2] Revenues from text messaging (SMS) are now significant in several European and Asian countries. In Norway, SMS revenues amounted to an overwhelming 20% of total mobile revenues in 2002, one third of the revenues from mobile voice traffic.[3] Text messaging has grown to become something much more than a niche product for the youth market.

The mobile phone is a platform that enables information exchange through several different channels.[4] In the following we focus on the two, at present, primary channels for person-to-person communication, namely voice calls and text messaging. A mobile subscriber that wants to exchange information with another mobile subscriber may choose text, voice or both. Which channel(s) that will be utilized in each particular situation obviously depends on a host of factors related to individual preferences, what kind of information is in question, and the context of both the sender and the receiver. The implicit assumption in the explanation of the text messaging take-up in Europe, and the differences in usage between Europeans and Americans stated previously, is that text and voice are substitutes.

Although it is likely that consumers in many situations consider text messaging and voice to be interchangeable channels for exchange of information, text messaging contains features that differentiate it from voice as communication medium. For instance, text messaging does

[1] The picture is not entirely homogeneous in Europe. The French seem to agree with the Americans in their view on text messaging. SMS is less popular in France and Sweden than in most other parts of Europe (The Economist, "Texting: Je ne texte rien", July 10th 2004).

[2] Other explanations may be that instant messaging services are more widely adopted in the United States than in Europe. Moreover, in the United States different wireless standards are in use, and these have until recently been incompatible with respect to text messaging. In addition, while text messaging is available to all GSM-subscribers in Europe, texting is often offered as an additional service in the United States.

[3] Source: The Norwegian Post- and Telecommunication Authorities' statistics.

[4] A typical GSM 2G mobile phone includes voice, text messaging (SMS), multimedia services (MMS) and Internet access through the WAP protocol.

not require instantaneous attention by the receiver. Thus, a text message can be sent even if the sender knows that the recipient will not read it or respond immediately. Furthermore, compared to voice, text messaging may be more discreet. Some people (but not all) find it inappropriate to talk on the mobile phone on the bus or at a meeting. Hence, text messaging can be utilized in situations where voice would not be considered as an alternative. Conversely, in other situations the text message user-interface may be considered too slow and cumbersome compared to a phone call. In such situations text messaging and voice may be weak substitutes. They may even be complementary services. A call center operator for instance, may send supplementary information by SMS to the caller.

In this paper we are not interested in the potential varying relationship between text and voice at the micro level *per se*. Rather, we want to investigate how the workings of what has been referred to as the *dynamics of information exchange* by Taylor (1994) may affect this relationship – regardless of whether customers treat the services as substitutes or complements. In particular, we want to see what dynamics of information exchange implies for the specification of a reduced form estimating equation on market data.

Dynamics of information exchange refer to a situation “in which an exchange of information creates the need for further exchanges of information”, (Taylor, 2002: p 103). Consider the case of a call from person A to B. This may cause B to return a call to A, *reverse* or *reciprocal calling*. But it can also induce B to make a new call to C which in turn makes a call to D and so forth. As pointed out by Taylor such “dynamics can operate whenever, by whatever means, a piece of information is injected into a group that forms a community of interest”, (Taylor 2002: p 103). This description fits the market for text messaging extraordinary well. Text messaging is a communication tool that is used to spread information quickly within a community, whether this is a group of friends, family or business colleagues.

Larson, Lehman and Weisman (1990) represent a pioneering effort in empirical modelling of telecommunications demand that takes account of reverse traffic. Utilizing a household production approach where the agent derives utility from both incoming and originated calls, they set up a model of fixed line point-to-point toll demand between 9 city pairs. The estimating equations of originated minutes from city *i* to city *j* includes the reverse traffic flow as an endogenous regressor. They find a strong and significant positive effect of reverse traffic.

We are not aware of any empirical studies that report on the dynamics of information exchange for mobile services, although models with call externalities have been studied in some theoretical works. Cambini and Valletti (2005) set up a theoretical model of competition between two mobile networks and show that positive reverse traffic effects from off-net calls will reduce the incentives to use off-net price discrimination.[5]

In this study we set up a model that allows for dynamics of information exchange when two services (text and voice) are offered on the same platforms. This means that in addition to within service dynamics we allow for cross-effects between the two communication services, i.e. we allow the number of incoming calls to affect outgoing text messages and vice versa. We develop reduced form demand equations that take account of not only the reverse communication effect, but also the induced effect in the dynamics of information exchange hypothesis, and investigate the properties of the price effects.

To our knowledge, this study represents the first attempt to estimate a demand function for text messages on market data. Our primary concern is to use the demand model to determine the relationship between voice and text messaging by estimating the cross-price elasticity of voice. We utilize a quarterly dataset of text messages for the Norwegian incumbent mobile operator in the period when text messaging became popular in Norway (1996:2-2004:2). In the regressions, the number of messages per subscriber is matched with price data for mobile voice, text messages and network size. We find that even if consumers initially consider voice to be a substitute to text messaging, as the network grows voice may turn into a complement in terms of the price effect. When this model is matched with data in section 4, we find that voice is a substitute for normalized network sizes below 0.3 and a complement above 0.3.[6]

The literature on mobile demand has for the most part been occupied with the diffusion of mobile subscriptions, see Gans, King and Wright (2005), and the studies referred to below. Few studies have examined the demand for mobile services. Econometric analysis of the demand for mobile calls includes Haucup and Dewenter (2004), and work by DotEcon and Frontier Economics referred to in the Competition Commission (2003). Neither of these includes the SMS price in their estimating equations, assuming that the two services are independent.[7] Thus, the relationship between the two services remains untested on real market data.[8] Our paper is also related to the analyses of the relationship between fixed-line and

[5] Cambini and Valletti (2005) denote this positive feedback effect "the propagation factor".
[6] The network variable is normalized to take the value 1 in the last quarter of 2004. A network size of 0.3 is reached already in the fourth quarter of 1998.
[7] Another reason for not including the text message price may be that there is no variation in the price in the sample.
[8] The Competition Commision (2003) also refers to a conjoint survey analysis by Holden Pearmain Research. This analysis finds that mobile calls and SMS are complements.

mobile telephony. Using world data of mobile penetration rates, Gruber and Verboven (2001a) and Ahn and Lee (1999) find that fixed and mobile telephony largely are complements. In contrast Gruber and Verboven (2001b) use penetration data from the European Union in the period 1991-1997, and they find a substitution effect between fixed and mobile phones. Cadima and Barros (2000) and Sung and Lee (2002) report analogous results by using data from Portugal and Korea, respectively.[9] Gans, King and Wright (2005) emphasize that the conflicting results may be due to the fact that fixed and mobile phones initially were complements, but as mobile penetration has increased mobile and fixed telephony have become substitutes.

The rest of the paper is organized as follows: In section 2 we give a brief overview of the evolution of text messaging. In section 3 we present a simple theoretical model that shows that communication services offered on the same platform may evolve from substitutes to complements as the network size increases. In section 4 we present the econometric model and results, while we in section 5 offer some concluding remarks.

## 2 The evolution of the market for text-messaging[10]

As mentioned in the introduction, the combination of cheap text messages and high minute prices on mobile calls may be a key factor for the success of text messaging in several European countries. This structure was particularly important for the new customer groups that entered the mobile markets in the late 1990s. A large part of these customers bought prepaid cards with very high prices for calls. Teenagers, for instance, quickly grasped that they could communicate much cheaper by text messages than calls.

Another key explanation for the differences between Europe and the United States is compatibility and interconnection. In Europe the GSM standard dominates and all mobile subscribers have the ability to use text messaging.[11] Competing mobile providers agreed on

[9] Other analyses of the diffusion of mobile phones are Koski and Kretschmer (2005), Gruber (2001), Liikanen, Stoneman and Toivanen (2004) and Jang et al. (2005). In addition to Gans et al. (2005), Gruber (2005) gives a comprehensive survey of the literature and the economics of mobile telecommunications.

[10] A more comprehensive description of the evolution of text messaging with a focus on the Norwegian market, is given by Andersson, Foros and Steen (2006).

[11] Text messaging or SMS is a non-proprietary standard that was developed in the early 1990s by the cross industry forum GSM Association, and SMS was part of the GSM standard. The initial application was to send voice mail notifications from the network operators to their subscribers. The initial purpose also explains the limited functionality and capacity of SMS. An SMS message can only contain up to 160 characters. To overcome these problems the handset producers have included new features to improve the user interface with

bilateral compatibility agreements (interconnection) that ensured that people could send messages regardless of which operator the recipient subscribed to. With respect to mobile-to-mobile text messaging, a complete degree of national compatibility has been agreed on in most European markets. In Norway the two providers, Telenor and Netcom, have had such agreements since the fourth quarter of 1996. The number of SMSs increased by about 30% in Telenor's network immediately after this agreement was enforced. In addition to the technological compatibilities between networks there has also been compatibility in the pricing with respect to text messaging. Whereas the voice price has differed largely between on-net and off-net calls, the SMS price has been independent of the network of the receiver.

In the United States, in contrast, different wireless standards are in use, and these have until recently been incompatible with respect to text messaging. In addition text messaging is often offered as an additional service in the United States. All this has hampered the possibility to fuel market growth by positive network effects.

Scandinavia is among the areas where the take up and use of mobile services have been most intense.[12] By the second quarter in 2004 a Norwegian mobile customer sent approximately 70 SMS messages per month, and the growth seems to continue. The mobile penetration rate was 0.15 in 1996 and has grown to 0.99 in the second quarter of 2004.[13] Thus, by mid 2004 there was basically one mobile subscription per capita in Norway, mirroring the fact that Norway was very early in the take up of both mobile voice and text messaging. The development of text-messaging and mobile subscriptions is shown in Figure 1.

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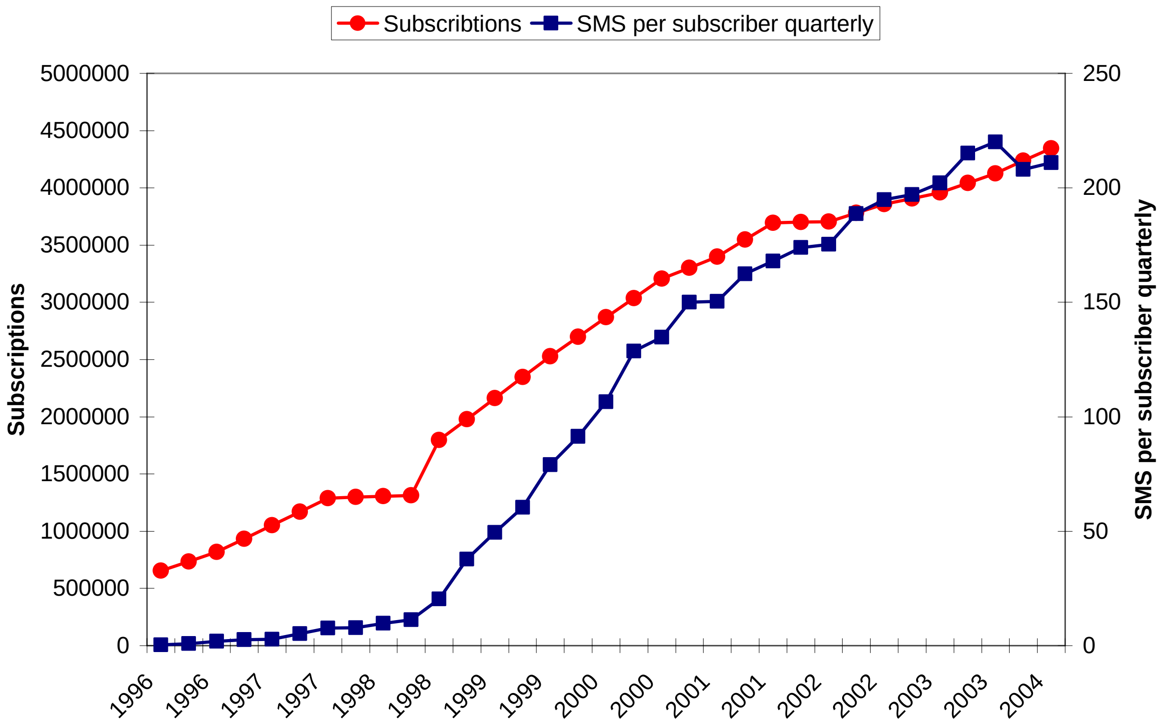
respect to typing messages, such as the option to store pre-defined message templates, dictionaries and predictive text, and special keyboards.

[12] Scandinavian people have also historically been early adopters of telecommunications services. Holcombe (1911) and Webb (1911) were the first who paid attention to the early and fast diffusion of fixed line telephones in Scandinavia.

[13] Note that this rate does not imply that all Norwegian inhabitants have a mobile phone subscription. A number of people have double subscriptions (work, home) and some have "sleeping" subscriptions in terms of prepaid cards that are not in use.

**Figure 1** Growth of SMS messaging and subscriptions in Norway for the period 1996 to 2004




## 3 Dynamics of information exchange for mobile services

Conceptually, the demand for mobile services can be divided into two stages: At the first stage is the demand for access and at the second stage is the demand for the offered mobile services, conditioned on being a subscriber to the network.

We concentrate on the second stage. Let $x_t$ and $x_v$ denote the number of originated text messages and voice minutes per subscriber per time period. As discussed in the introduction the dynamics of information exchange phenomenon refers to the situation where an exchange of information creates the need for further communication (Taylor, 1994, 2002). These dynamics can be of two kinds: Firstly, a communication session (call or message) from customer A to customer B may cause B to initiate a communication session to A. This is the reverse calling effect. In addition there may be an induced effect. This refers to the situation where the communication session from A to B causes B to initiate a session to C (and C to D and so on). We will in the following refer to the reverse calling effect and induced effect as *positive feedback*.

To capture the positive feedback effects we allow the number of originated communication sessions in *the network* to affect the number of originated communication sessions *per subscriber*. We assume a linear structural demand and write the demand per subscriber as

$$x_i = \beta_{i0} + \beta_{i1} p_i + \beta_{i2} p_j + \beta_{i3} n x_i + \beta_{i4} n x_j + \beta_{i5} n \qquad (1)$$

where $i,j=t,v$ and $i \neq j$, $n$ is network size normalised such that $n \in [0,1]$, and unit prices are given by $p_i$ and $p_j$. $\beta_{i1}$ and $\beta_{i2}$ are the marginal own- and cross-price effects holding the total communication constant. We denote these as the direct price effects. We assume a negative direct own price effect, i.e. $\beta_{i1} \leq 0$. Assume further, for the sake of comparison, that $\beta_{i2} \geq 0$. This is in line with the casual observations referred to previously, i.e. that early adopters considered text messaging and voice to be substitutes.

The third and fourth terms capture the positive feedback effects, i.e. the joint effects of reverse calling and induced effects: $\beta_{i3}$ captures within service feedback and $\beta_{i4}$ across service feedback. In line with the dynamics of information exchange hypothesis we assume that these feedback effects are positive. The last term capture the joint effect of potential network effects and composition effects and may take any sign.

Solving the system for $x_t$ and $x_v$ we obtain the following reduced form demand functions:

$$x_i = \pi_{i0} + \pi_{in}(n) + \pi_{ii}(n) p_i + \pi_{ij}(n) p_j \qquad (2)$$

where the marginal effects are given by,

$$\pi_{i0} + \pi_{in} = A^{-1}\Big((1 - n\beta_{j3})(\beta_{i0} + \beta_{i5} n) + n\beta_{i4}(\beta_{j0} + \beta_{j5} n)\Big) \qquad (3)$$

$$\frac{\partial x_i}{\partial p_i} = \pi_{ii}(n) = A^{-1}\Big((1 - n\beta_{j3})\beta_{i1} + n\beta_{i4}\beta_{j2}\Big) \leq 0 \qquad (4)$$

$$\frac{\partial x_i}{\partial p_j} = \pi_{ij}(n) = A^{-1}\Big((1 - n\beta_{j3})\beta_{i2} + n\beta_{j1}\beta_{i4}\Big) \qquad (5)$$

$$A = (1 - n\beta_{i3})(1 - n\beta_{j3}) - n^2 \beta_{j4}\beta_{i4} > 0 \qquad (6)$$

We assume that $A$ is always strictly positive (6), and that the marginal own-price-effects are always non-positive (4)[14]. The marginal cross-price effect is equal to the direct cross-price effect in the structural demand equation (1) when the network size is zero:

$$\left.\frac{\partial x_i}{\partial p_j}\right|_{n=0} = \beta_{i2} \geq 0 \tag{7}$$

Thus, when the network size is small, text and voice will be substitutes. From equation (5) we see that the term $\left((1-n\beta_{j3})\beta_{i2}+n\beta_{j1}\beta_{i4}\right)$ determines the sign of the cross-price effect. This term is decreasing in *n*. If it changes sign and becomes negative for some $n^* \in (0,1)$, the marginal cross-price effect will be negative when the network size is above $n^*$. It is straightforward to show that the condition that ensures that the marginal cross-price effect will change sign for a $n^* \in (0,1)$ is that:

$$-\beta_{j1}\beta_{i4} > \beta_{i2}(1-\beta_{j3}) \tag{8}$$

Thus, if the inequality in (8) holds, we have that $\partial x_i / \partial p_j < 0$ if $n > n^*$ and $\partial x_i / \partial p_j \geq 0$ if $n \leq n^* < 1$. Thus, the larger the feedback effects, $\beta_{j3}$ and $\beta_{i4}$, and the lower the direct substitution effect, $\beta_{i2}$, the more likely it is that voice and text become complements in a mature market.

The intuition for the result is as follows: Consider a decrease in the price of voice. This causes an increase in the demand for voice. This in turn increases the number of incoming calls for all subscribers. The larger the network, the higher the number of incoming calls. Some customers prefer to respond to these calls by text messages. If these feedback effects are strong they may dominate the direct substitution effect from $\beta_{i2} \geq 0$. Hence, the decrease in the voice price may cause an increase in text messaging leaving voice as a complement to text in terms of the marginal cross-price effect.

## 4 The econometric model

We want to estimate the own-price and cross-price effects in the demand for SMS, conditioned on being a subscriber to a network. The dependent variable is the number of

[14] The assumption in (6) puts restrictions on the size of the positive feedback effects. Put loosely, it secures that the feedback effects cannot jointly be too large.

SMS's per subscriber for the Norwegian incumbent operator Telenor, *SMS*, see figure 1 in section 2 and table 1 below. This variable is constructed by dividing the total number of originated SMS by Telenor subscribers by the number of Telenor subscriptions enabled for SMS.[15] The dependent variable is measured quarterly from the 2 quarter of 1996 to the second quarter of 2004 leaving 33 observations. In the estimating equation this variable is matched with a weighted average price per *SMS* message, $P^S$, a weighted average price per minute called, $P^V$, the number of subscribers in the Norwegian market, *N*, and a dummy, CPA, for the introduction of premium SMS.[16,17] The number of subscribers, *N*, is normalised such that 2004:4=1).[18] Premium SMS was introduced in the second quarter in 2000, hence the CPA dummy takes the value 1 from quarter 2, 2000.[19] The summary statistics of the variables are presented in Table 1.

**Table 1** Summary statistics

| | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| **Continuos Variables** | | | | | |
| SMS per subscriber (*SMS*) | 33 | 102.30 | 82.95 | 0.38 | 220.03 |
| Price SMS ($P^S$) | 33 | 1.17 | 0.32 | 0.71 | 1.58 |
| Price Voice ($P^V$) | 33 | 2.39 | 0.45 | 1.84 | 3.32 |
| Number of Subscriptions | 33 | 2 630 302 | 1 232 841 | 654 804 | 4 347 086 |
| Normalized Subscriptions (*N*) | 33 | 0.605 | 0.284 | 0.151 | 1 |
| **Dummies** | | | | | |
| CPA | 33 | 0.515 | 0.508 | 0 | 1 |
| **Instruments** | | | | | |
| Income per subscriber NetCom | 33 | 3623.60 | 356.01 | 553.04 | 3809.19 |
| Price fixed line telephone peak | 33 | 1.03 | 0.15 | 0.72 | 1.15 |
| Price fixed telephone off peak | 33 | 0.85 | 0.14 | 0.43 | 0.96 |

The point of departure for the estimating equation is the reduced form equation (2) given in the previous section. In this model the price effects depend on the network size. We assume a

[15] The number of subscriptions enabled for SMS corresponds to the number of GSM subscriptions except for a short period in 1998 when the prepaid subscribers were not enabled for SMS.
[16] We are grateful to Telenor for providing these data. A more comprehensive explanation is provided in the Appendix A.
[17] More recently we have seen several new contracts offering free SMS messages as part of the contracts. However, even in our last sample year 2004 these contracts were very rare to observe.
[18] These can be found on www.npt.no, the home page for the Norwegian Post and Telecommunication Authority.
[19] Premium SMS is information services where the messaging system is used for downloading of logos and ringtones, voting, interactive TV, quizzes and games, jokes, betting, pay per view web content and so on. In 2000 the mobile providers in Norway introduced Content Provider Agreements (CPAs) that allowed information providers to offer such services.

linear model, and to allow for network dependent price effects we include two terms were prices are interacted with the network size. The demand model estimated is thus given as

$$\begin{aligned} SMS_t &= \alpha + \beta_S \cdot P_t^S + \beta_{SN} \cdot N_t \cdot P_t^S + \beta_V \cdot P_t^V + \beta_{VN} \cdot N_t \cdot P_t^V \\ &\quad + \beta_N \cdot N_t + \beta_{CPA} \cdot CPA_t + \varepsilon_t , \end{aligned} \tag{9}$$

where the variables are defined as above and $\varepsilon_t$ is an error term assumed to have the standard statistical properties, i.e., $\varepsilon_t$ is *i.i.d.* and $\varepsilon_t \sim (0, \sigma^2)$.

In the estimation we treat the network size at the beginning of the period, $N_t$, and the dummy for introduction of premium SMS, $CPA_t$ as predetermined. The prices may, of course, be endogenous. Hence, we present estimation results using both Two Stage Least Squares (2SLS) and ordinary Least Squares (OLS). We look at the instruments' performance and compare the models using a Hausman tests. As instruments we use income per subscriber for the main competitor NetCom, the peak and off peak 3 minute prices for fixed-line voice calls, and interactions of these with the network variable to instrument for the Telenor prices and the interaction terms.[20]

The results are summarized in Table 2[21]. Both the OLS and the 2SLS model behave well, both in statistical terms and with regard to economic predictions. All the price parameters and the network parameters are significant in both models with corresponding signs but different magnitudes. In the OLS model also the CPA dummy and the constant term are significant. The explanation power is high, and the Box-Pierce tests (Q1 and Q4) show no or very little sign of autocorrelation. We have also tested the error term using Augmented Dickey Fuller

[20] The Netcom numbers are collected from Netcom's webpage and annual reports. We are grateful to Bente Johnsen in NetCom for help in collecting these. The fixed net prices are from the International Telecommunication Union (World Telecommunications Indicators); I153, Cost of a local 3 minutes call (peak rate), I153O, Cost of a local 3 minutes call (off-peak rate).

[21] We have also estimated a non-linear diffusion model where we can distinguish between different sources of subscription growth (Berndt, Pindyck and Azoulay, 2003). For a more general discussion of these models see Mahajan, Muller and Bass (1990). The problem with this approach is that we have a relatively short dataset when it comes to asymptotic estimators, resulting in very unstable results, and very often lack of convergence in our models. These results are therefore omitted here.

**Table 2** OLS and 2SLS results for the demand model

| | OLS | | | 2SLS | | |
|---|---|---|---|---|---|---|
| | **Coefficient** | | **Standard Error** | **Coefficient** | | **Standard Error** |
| $P^S$ | -83.366 | * | (41.768) | -251.192 | *** | (106.536) |
| $P^S \cdot N$ | 167.726 | ** | (75.827) | 109.895 | *** | (29.333) |
| $P^V$ | 71.125 | *** | (15.230) | 488.936 | *** | (210.838) |
| $P^V \cdot N$ | -225.054 | *** | (50.597) | -448.468 | *** | (144.130) |
| *N* | 540.863 | *** | (40.143) | 598.416 | *** | (60.993) |
| *CPA* | 18.427 | *** | (6.822) | 14.642 | | (9.403) |
| *Constant* | -112.880 | *** | (46.441) | 53.950 | | (110.739) |
| $R^2$ | 0.994 | | | 0.996 | | |
| *N* | 33 | | | 33 | | |
| *Q1* | 0.465 | *** | | 0.818 | *** | |
| *Q4* | 9.97 | ** | | 13.863 | | |
| *DF(0)* | -4.554 | *** | | -4.802 | *** | |
| *DF(2)* | -5.41 | *** | | -5.89 | *** | |
| *Hausman(6)* | | | | 3.09 | | |

*** Significant at a 2.5% level, ** Significant at a 5% level, * Significant at a 10% level,

tests and can reject non-stationarity in the error terms clearly for both the OLS and the 2SLS model.[22] When we look at the first stage regressions in the 2SLS model the instruments are clearly correlated with the potential endogenous variables. The six exogenous instruments (income Netcom, fixed telephone line prices and their interaction terms with subscriptions), are significant at a 5% level or better in 20 out of 24 cases (4 equations, 6 instrumental variables in each) and in the remaining four cases 3 show significance at a 10% level. The Hausman test however suggests no significant difference in the OLS and the 2SLS model results, suggesting that we can use the more efficient OLS model. The discussion of economic predictions will therefore be based on the OLS model. However, the 2SLS predictions differ only in magnitude and not in terms of qualitative predictions.[23]

The CPA dummy suggests a significant and positive effect from the introduction of premium SMS. The direct price effects are in line with the assumptions in the theoretical model in the previous section, i.e. a negative direct marginal own-price effect (-83) and a positive marginal

[22] An alternative interpretation of the Dickey-Fuller results is that the estimated relations represent cointegrated steady state relations.

[23] Both models and their predictions are robust towards inclusion of seasonal dummies and time trend. However, since these were not significant they are omitted from the models that are presented here.

cross-price effect (71) suggesting that voice is a substitute to text messaging for small network sizes. Both interaction terms are significant which implies that the marginal price effects are dependent on network size as predicted by the model in the previous section.

To get a better understanding of the size of the economic effects we translate the point estimates into elasticities evaluated at the mean of the involved variables.[24]

**Table 3** Estimated elasticities at means

| | Elasticity at mean | Standard Error | 95% confidence interval |
|---|---|---|---|
| *Own price elasticity* | 0.207 | (0.205) | [-0.214, 0.629] |
| *Cross price elasticity* | -1.517 *** | (0.508) | [-2.561, -0.473] |
| *Network elasticity* | 1.185 *** | (0.149) | [0.879, 1.491] |

*** Significant at a 2.5% level, ** Significant at a 5% level, * Significant at a 10% level.

For average prices, quantity and network size the own price elasticity is indistinguishable from zero. This suggests that once the customer has decided to become a subscriber, the unit price does not constrain the usage of text messaging. The SMS price may however affect the choice of subscription (which we have not modelled here). If so, this would restrict the provider's ability to raise the unit price indefinitely.

For the average network size of 0.6, the cross-price elasticity is -1.5. Thus, in terms of the price effect, voice is a complement to text messaging. The positive effect of $P^V$ and the negative effect from the interaction term, $P^V \cdot N$, implies that when the network is small voice is a substitute to text, but as the network size increases the cross price effect changes sign and we get a complementary relationship between voice and text. The cross price effect changes sign when the normalized subscription variable reaches 0.32. This pattern supports the existence of positive feedback as described in the previous section.

At means the network elasticity is 1.18 *i.e.*, when the network increases with 1%, the number of originated messages per subscriber increases with roughly 1%. The result suggests that positive network effects dominate a possible negative effect from decreasing activity from additional customers. This result is in contrast to Dewenter and Haucup (2004) who find a

[24] Note that both price elasticities and the network elasticity consist of a direct effect and an indirect effect from the interaction term, e.g., the own price elasticity evaluated at mean is $\left[\hat{\beta}_S + \hat{\beta}_{SN} \cdot \overline{N}\right] \cdot \left[\overline{P^S} / \overline{SMS}\right]$.

negative effect from network size in their estimation of mobile calls on Austrian data from 1998-2002.

## 5 Concluding remarks

In a simple model we show that if mobile calls stimulate text messaging, voice will be a weaker substitute to text the larger the network. If such positive feedback effects are strong voice may even turn into a complement when the network becomes large. Utilizing data from the Norwegian mobile incumbent we find that mobile voice calls were a substitute to text messaging in the infancy of the diffusion process and evolved into a complement as the network size became larger. This suggests that feedback effects are important in the demand for text messages. An interesting future challenge is to look for more detailed data on incoming communications, since this would enable a direct test of the positive feedback explanation.

The case analyzed points at a potentially changing relationship between two communication services offered at the same platform and bring about interesting challenges for pricing. If an eventually complementary relationship between the services is overlooked when considering the introduction of a new service, one risks pricing the emerging service too high relative to the existing service. This may prevent the take-up of a substitute that later turns into a complement to the current service. This potential demand side link between mature and emerging services has not been given much attention from policy makers and market players.

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**Appendix 1 - Data description**

**SMS per subscriber**: Number of originated SMSs by customers of Telenor Mobil divided by number of SMS-enabled subscribers of Telenor Mobil[25]. By SMS-enabled is meant the postpaid GSM subscribers and the prepaid GSM subscribers from the fourth quarter of 1998 (This was when SMS was enabled for the prepaid customers). Sources: The quarterly reports of Telenor Mobil and internal sources in Telenor

**Price SMS:** The average price of originating an SMS for Telenors customers. This is the weighted average of the prepaid SMS price and a postpaid SMS price index. The weights are the proportion of prepaid and postpaid customers measured each quarter. The postpaid SMS price index is a weighted average of the SMS prices in the two main postpaid call-plans “Privat” and “Privat+”. The weights are obtained from a time-invariant estimate of the share of customers on the two call plans. Sources: The quarterly reports of Telenor Mobil, the press archive of Telenor Mobil and internal sources in Telenor.

**Price Voice:** The average price of originating onr minute of mobile call. This is the weighted average of the prepaid per minute price index and the postpaid per minute price index. The weights are the proportion of prepaid and postpaid customers measured each quarter. The minute price indices are constructed from the call-plan specific on-net and off-net, peak and off-peak minute prices, weighted by a time-invariant estimate on the distribution of minutes on call-types. Source: The quarterly reports of Telenor Mobil, the press archive of Telenor Mobil and internal sources in Telenor.

[25] Telenor Mobil is the Norwegian mobile affiliate of Telenor ASA.