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Kjetil Andersson, Øystein Foros  
and Frode Steen

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# TEXT AND VOICE: COMPLEMENTS, SUBSTITUTES OR BOTH?

**Kjetil Andersson, Telenor R&D**

**Øystein Foros**, Norwegian School of Economics and Business Administration  
**Frode Steen**, Norwegian School of Economics and Business Administration and  
CEPR

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Centre for Economic Policy Research  
90–98 Goswell Rd, London EC1V 7RR, UK  
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999  
Email: [cepr@cepr.org](mailto:cepr@cepr.org), Website: [www.cepr.org](http://www.cepr.org)

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## ABSTRACT

### Text and Voice: Complements, Substitutes or Both?\*

Text messaging has become an important revenue component for European and Asian mobile operators. We develop a simple model of demand for mobile services incorporating the existence of call externalities and network effects. We show that when incoming messages and calls stimulate outgoing communications, services that are 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.

JEL Classification: C2, D12 and L1

Keywords: call externalities, demand structure, network effects, positive feedback effects and text messaging

Kjetil Andersson  
Telenor R&D  
Snarøyveien 30  
1331 Fornebu  
Norway  
Email: [kjetil.andersson@telenor.com](mailto:kjetil.andersson@telenor.com)

Øystein Foros  
Department of Economics  
Norwegian School of Economics and  
Business Administration  
Helleveien 30  
5045 Bergen  
NORWAY  
Email: [oystein.foros@nhh.no](mailto:oystein.foros@nhh.no)

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Frode Steen  
Department of Economics  
Norwegian School of Economics  
and Business Administration  
Helleveien 30  
5045 Bergen  
NORWAY  
Email: Frode.Steen@nhh.no

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## 1 Introduction

*“The mobile phone and text messaging have changed our lives more dramatically than any other technical device; you coordinate your day better, you start your love affairs on SMS, and you terminate them later”*

*Rich Ling, the Norwegian newspaper “Dagbladet”, June 27<sup>th</sup> 2004*

“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 usage per month per customer in several European countries exceeded sixty messages in 2004, the number for the United States was seven.<sup>1</sup> According to The Economist “The short answer is that, in America, talk is cheap.” The early adopters of text messaging in Europe and Asia seemed to be price sensitive teenagers who found text messaging a cheap alternative to mobile calls. However, since mobile voice calls are less expensive than in Europe, Americans prefer to make voice calls.<sup>2</sup> Revenues from text messaging (or SMS) are 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.<sup>3</sup> 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.<sup>4</sup> 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 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 fact that text messaging and voice are two communication channels available on the same platform suggests that consumers will

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<sup>1</sup> 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).

<sup>2</sup> 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. While text messaging is available to all GSM-subscribers in Europe, texting is often offered as an additional service in the United States. Accordingly, customers cannot be sure that a message gets through.

<sup>3</sup> Source: The Norwegian Post- and Telecommunication Authorities’ statistics.

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

consider the two services to be substitutes. This is 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.

Although it is likely that consumers in many situations consider text messaging and voice to be interchangeable channels for exchange of information, it is not possible to ascertain that consumers always consider the two services to be substitutes. Text messaging contains features that differentiate it from voice as communication medium. For instance, text messaging does not require instantaneous attention by the receiver. A text message can be sent even if the sender knows that the recipient will not read or respond immediately. This asynchronous feature may come in handy. When exchanging information with their ex-husbands, divorced women prefer text messaging to voice since texting is less synchronous and thus allows for strategic thinking (Ling, 2006). Furthermore, compared to voice it is 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 texting user interface may be considered much too slow and cumbersome compared to a phone call. In such situations text messaging and voice may be largely independent services. It is also possible to envisage situations where they can be complementary. The grandmother calling her grandson to tell him that she has sent him a text message is an immediate, though not very economically important, example.

We develop a simple structural demand model for communication services that combines the effect of *call externalities* and *network effects* in the estimating equation. A call externality is said to exist if the number of incoming calls affects the number of outgoing calls.<sup>5</sup> In reviewing the empirical literature that models point-to-point fixed line communication in the US and Canada, Taylor (2002) reports that the number of incoming calls strongly affects the number of outgoing calls. “A call in one direction stimulates something like one-half to two-thirds of a call in return” (Taylor, 2002, p. 129). In a recent theoretical model, Cambini and Valletti (2005) show that such positive feedback effects (call externalities) from incoming calls will reduce the incentives to use off-net price discrimination.<sup>6</sup> We are not aware of any empirical studies that report on the existence of call externalities for mobile services. However, it is highly likely that similar relationships exist for mobile services. In the

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<sup>5</sup> The term call externality is utilized e.g. by Taylor (2002) and adopted here.

<sup>6</sup> Cambini and Valletti (2005) denote this positive feedback effect “the propagation factor”.

theoretical model we assume that the same kind of relationship holds also for mobile services, i.e. we assume that the number of outgoing text messages (or calls) is positively affected by the number of incoming messages *and* calls. The existence of such relationships has significant implications for the demand specification. The number of incoming calls or messages is rarely available for the modeler. If positive network effects exist, i.e. if the number of messages (or calls) is increasing in the network size, the number of incoming messages (calls) will be proportional to the network size. We develop reduced form demand equations that incorporate this effect, 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 our 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 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 if the feedback effects are strong. 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.<sup>7</sup>

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.<sup>8</sup> Thus, the relationship between the two services remains untested on real market data.<sup>9</sup> Our paper is also related to the analyses of the relationship between fixed-line and mobile telephony. Using world data of mobile penetration rates, Gruber and Verboven (2001a) and Anh and Lee (1999) find that fixed and mobile telephony largely are

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<sup>7</sup> 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.

<sup>8</sup> Another reason for not including the text message price may be that there is no variation in the price in the sample.

<sup>9</sup> The Competition Commission (2003) also refers to a conjoint survey analysis by Holden Pearmain Research. This analysis finds that mobile calls and SMS are complements.

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.<sup>10</sup> 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<sup>11</sup>**

As mentioned in the Introduction, the combination of cheap text messages and high per minute prices on mobile phone calls is probably a key factor of the success of text messaging in several European countries. This structure was particularly important to 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 by making phone calls.

Another key explanation for the success of text messages in Europe and Asia as opposed to the US is compatibility and interconnection. In Europe and Asia the GSM standard dominates and everyone that has a mobile phone has the ability to use text messaging.<sup>12</sup> Competing mobile providers agreed on bilateral compatibility agreements (interconnection) that ensured

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<sup>10</sup> 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.

<sup>11</sup> A more comprehensive description of the evolution of text messaging with a focus on the Norwegian market, is given by Andersson, Fors and Steen (2006).

<sup>12</sup> 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 respect to typing messages, such as the option to store pre-defined message templates, dictionaries and predictive text, and special keyboards.



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 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. Hence customers cannot be sure that a message gets through even if the customer is on the same network. All this has hampered the possibility to fuel market growth by positive network effects.

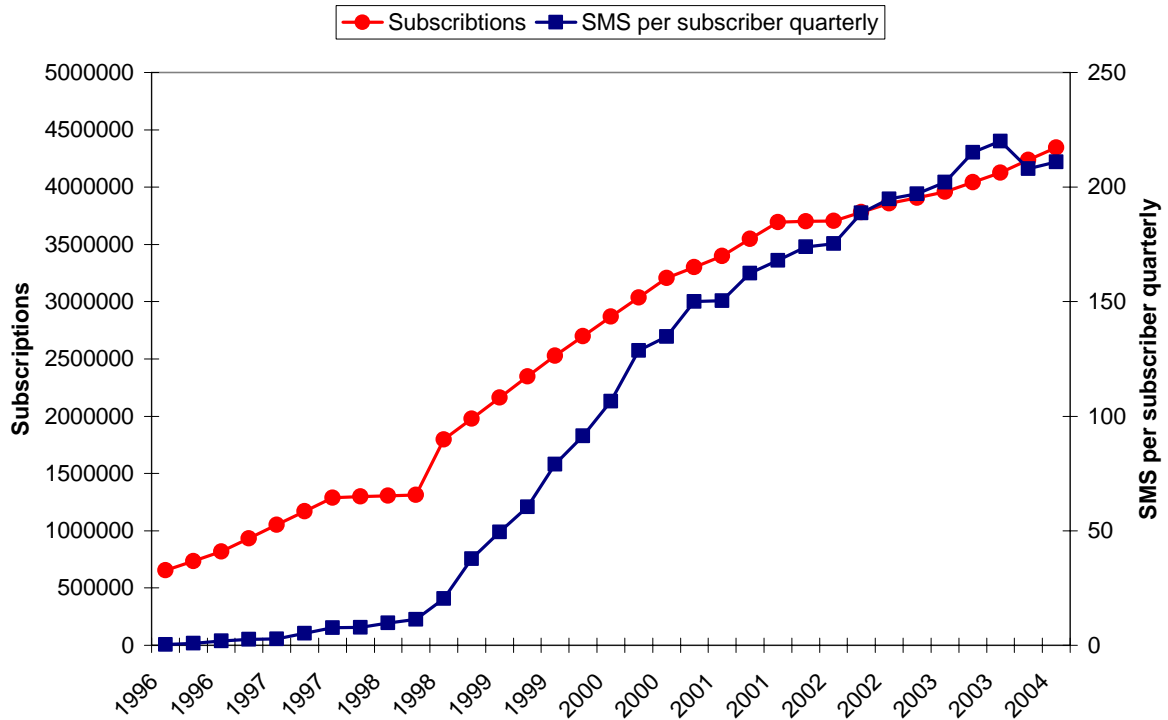
Scandinavia is among the areas where the take up and use of mobile phone services have been most intense.<sup>13</sup> By the second quarter in 2004 a Norwegian mobile customer sent approximately 70 SMS messages per month, and the growth seems to continue. The mobile penetration rate was only 0.15 in 1996 but has grown to 0.99 in the second quarter of 2004.<sup>14</sup> Thus, by mid 2004 there was basically *one* mobile phone subscription per capita in Norway, mirroring the fact that Norway was very early in the take up of both mobile voice and text messaging. This provides us with information on both an emerging and a mature market, allowing us to estimate the demand structure for both market phases. Since Norway was early in the diffusion process, this also implies that the Norwegian providers had no other markets to compare with when making their pricing strategies and other strategic decisions. The development of text-messaging and mobile subscriptions is shown in Figure 1.

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<sup>13</sup> 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.

<sup>14</sup> 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 A model of positive feedback in the demand for mobile services

The mobile phone may be considered as a platform that gives access to two communication services; text (t) and voice (v). Conceptually, mobile demand can be divided into two stages. The first stage is the demand for a mobile subscription to a network. The second stage is the demand for the offered mobile services, here text and voice, conditioned on being a subscriber to the network.

We concentrate on the second stage, and let  $x_t$  and  $x_v$  denote the number of originated text messages and voice minutes for a subscriber. Analogously, the number of incoming messages and voice minutes per subscriber are  $x_t^I$  and  $x_v^I$ . The unit prices are given by  $p_i$ , where  $i=t,v$ . The network size is given by  $n$ , where  $n \in [0,1]$ . We assume a linear structural demand function, and write the demand for a given consumer as

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

where  $i,j=t,v$  and  $i \neq j$ .

We expect the own-price effects to be negative, i.e.  $\beta_{i1} \leq 0$ . As discussed in the Introduction, we assume that each consumer considers text and voice to be substitutes at any given situation where they wish to exchange information, such that  $\beta_{i2} \geq 0$ .

The latter three terms reflect the fact that the services under consideration are *communication* services. The third and fourth terms capture the call externalities (the feedback effects). We expect that the more incoming calls or messages you receive, the more calls or messages you originate. In particular this seems reasonable for text messaging. When you receive a message, you need to originate a message or a call in order to continue to communicate. Hence, we expect that the feedback effects  $\beta_{i3}$  and  $\beta_{i4}$  are positive. As discussed in the Introduction, this assumption is consistent with empirical findings that incoming calls stimulate outgoing calls (Taylor, 2002).<sup>15</sup> We denote  $\beta_{i3}$  and  $\beta_{i4}$  for positive feedback effects, but the signs and size of these effects are ultimately empirical questions. The last term captures potential network effects, and we assume that  $\beta_{i5} \geq 0$ .

Data on incoming calls and messages are not available, and we cannot model the structural equations of  $x_t$  and  $x_v$  directly. Instead we have to model some form of a reduced form. Assume that all customers are equal and every customer has an equal probability of receiving a call or a message. The number of incoming calls and messages to any individual will then be  $x_i^I = \delta_i n x_i$  (where  $i=t,v$ ). We ignore the scaling parameters,  $\delta$ , and make the following assumption:

*Assumption 1:*  $x_i^I = n x_i$  where  $i=t,v$ .

Inserting Assumption 1 into (1), and solving the system for  $x_t$  and  $x_v$  we obtain the following demand functions:

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

where the marginal effects are given by,

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<sup>15</sup> Of course, the sign of the effects does not have to hold for all cases. For instance, if you receive a message from your wife saying she will be late for dinner, this may stop you from making the call asking when she will arrive. However, we believe that the aggregate effects will be positive because people usually expect a response to most forms of communication initiatives.

$$\pi_{i_0} + \pi_m = A^{-1} \left( (1 - n\beta_{j_3})(\beta_{i_0} + \beta_{i_5}n) + n\beta_{i_4}(\beta_{j_0} + \beta_{j_5}n) \right) \quad (3)$$

$$\frac{\partial x_i}{\partial p_i} = \pi_{ii}(n) = A^{-1} \left( (1 - n\beta_{j_3})\beta_{i1} + n\beta_{i4}\beta_{j2} \right) \leq 0 \quad (4)$$

$$\frac{\partial x_i}{\partial p_j} = \pi_{ij}(n) = A^{-1} \left( (1 - n\beta_{j_3})\beta_{i2} + n\beta_{j1}\beta_{i4} \right) \quad (5)$$

$$A = (1 - n\beta_{i_3})(1 - n\beta_{j_3}) - n^2\beta_{j_4}\beta_{i_4} > 0 \quad (6)$$

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

$$\left. \frac{\partial x_i}{\partial p_j} \right|_{n=0} = \beta_{i2} > 0 \quad (7)$$

Thus, when the network size is small, text and voice will be substitutes. From equation (5) we see that the term  $\left( (1 - n\beta_{j_3})\beta_{i2} + n\beta_{j1}\beta_{i4} \right)$  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 becomes negative when the network size becomes large. Thus, even if consumers consider text and voice to be substitutes when they wish to exchange information (originate a message or a call), as the network grows voice and text can evolve into complements in demand.

It is straightforward to show that the condition that ensures that  $n^* \in (0,1)$  is that:

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

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,  $\beta_{j_3}$  and  $\beta_{i_4}$ , and the lower the direct substitution effect,  $\beta_{i_2}$ , the more likely it is that voice and text become complements in demand in a mature market.

The intuition behind 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 that may even dominate the direct substitution effect from  $\beta_{12} \geq 0$ . The decrease in the call price may in this way cause an increase in text leaving voice as a complement to text in terms of the marginal cross-price effect.

#### 4 The econometric model

To be able to understand the development in the demand structure of the SMS market we formulate a simple demand model that incorporates positive network feedback. We have information on the SMS usage per subscriber ( $SMS_t^{SUB}$ ) for all Telenor customers, weighted Telenor price per SMS message ( $P_t^{SMS}$ ), weighted Telenor per minute prices on voice calls ( $P_t^{VOICE}$ ).<sup>16, 17</sup> To account for the network effects in the text messaging market, we use normalized market penetration rate of all Norwegian mobile users ( $SUBSCR$ ) (number of subscriptions for all providers, where we normalize such that 2004:4=1).<sup>18</sup> Premium SMS was introduced in the second quarter in 2000, and will be represented by a dummy ( $CPA$ ) that takes the value 1 from quarter 2, 2000.<sup>19</sup> To imbed the effects from the positive network feedback we also include two interaction terms where we interact prices with the network size ( $SUBSCR$ ).<sup>20</sup> The demand model estimated is thus given as;

$$(1) \quad \begin{aligned} SMS_t^{SUB} = & \alpha + \beta_{SMS} \cdot P_t^{SMS} + \beta_{SMS \times SUBSCR} \cdot SUBSCR_t \cdot P_t^{SMS} \\ & + \beta_{VOICE} \cdot P_t^{VOICE} + \beta_{VOICE \times SUBSCR} \cdot SUBSCR_t \cdot P_t^{VOICE} \\ & + \beta_{SUBSCR} \cdot SUBSCR_t + \beta_{CPA} \cdot CPA_t + \varepsilon_t, \end{aligned}$$

<sup>16</sup> We are grateful to Telenor for providing these data. A more comprehensive explanation is provided in the Appendix A.

<sup>17</sup> 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.

<sup>18</sup> These can be found on [www.npt.no](http://www.npt.no), the home page for the Norwegian Post and Telecommunication Authority.

<sup>19</sup> 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.

<sup>20</sup> The price parameters  $\beta_{SMS}$  and  $\beta_{VOICE}$  measure the direct price effects for  $n=0$ , or the effects that hold the number of incoming calls and messages constant. The two interaction terms  $\beta_{SMS \times SUBSCR}$  and  $\beta_{VOICE \times SUBSCR}$  measure the additional effects from positive feedback effects as the network size increases. The net effects depend on the combination of price and interaction parameters.

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  $\varepsilon_t \sim (0, \sigma^2)$ . The summary statistics of the variables are presented in Table 1.

**Table 1** Summary statistics of included variables

	Obs	Mean	Std. Dev.	Min	Max
<b>Continuous Variables</b>					
SMS per subscriber	33	102.30	82.95	0.38	220.03
Price SMS	33	1.17	0.32	0.71	1.58
Price Voice	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 (2004:4=1)	33	0.605	0.284	0.151	1
<b>Dummies</b>					
CPA	33	0.515	0.508	0	1
<b>Instruments</b>					
Income per subscriber	33	3623.60	356.01	553.04	3809.19
NetCom					
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

Given the market structure in the mobile phone market in Norway, with primarily two main competitors there are good reasons to believe that prices are predetermined sequentially for each period. If this is the case, ordinary least squares (OLS) will provide the most efficient estimates. However to embed potential simultaneity in prices we also estimate our demand model using Two Stage Least Squares (2SLS). To be able to compare these models and our hypothesis of predetermined prices we look at our 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,<sup>21</sup> and

<sup>21</sup> One might have argued that the fixed line prices are not fully exogenous since if e.g., fixed line prices decreases this reduces the need for sending SMSes because you rather made a fixed line phone call than answering with your mobile phone. However, we assume that you have a mobile phone available in our model, i.e., we are on a mobile platform in the first place when receiving the message (voice or text). When this is a case you would never choose to use your fixed line phone since it is always at least as expensive as using your mobile phone (which by definition is available). The rate from fixed line to mobile is either as expensive, but generally more expensive than using your mobile phone.

interactions of these with the network variable to instrument for the Telenor prices and the interaction terms.<sup>22</sup>

The results are summarized in Table 2. 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

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

	OLS		2SLS	
	Coefficient	Standard Error	Coefficient	Standard Error
$P^{SMS}$	-83.366 *	(41.768)	-251.192 ***	(106.536)
$P^{SMS} \cdot SUBSCR$	167.726 **	(75.827)	109.895 ***	(29.333)
$P^{VOICE}$	71.125 ***	(15.230)	488.936 ***	(210.838)
$P^{VOICE} \cdot SUBSCR$	-225.054 ***	(50.597)	-448.468 ***	(144.130)
$SUBSCR$	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.<sup>23</sup> 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

<sup>22</sup> 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).

<sup>23</sup> An alternative interpretation of the Dickey-Fuller results is that the estimated relations represent cointegrated steady state relations.

(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 accept our hypothesis on predetermined prices and 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.<sup>24</sup>

The CPA dummy suggests a significant and positive effect from the introduction of premium SMS and we find a clear and significant network effect. 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 (-251) and a positive marginal cross price effect suggesting substitutability with regard to voice (71). Both interaction terms are significant and change signs, suggesting that the marginal net price effects are dependent on network size and that feedback effects as predicted in our theoretical model are important. In particular when it comes to the cross-price effect this implies that when the network is small, voice is a substitute to text, but as the network size increases the net 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 0.316. To get a better understanding of the size of the economic effects we translate the point estimates into elasticities in Table 3.<sup>25</sup>

**Table 3** Estimated own- and cross-price elasticities from the OLS model

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

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

<sup>24</sup> 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.

<sup>25</sup> 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:

$$\eta_{ownprice} = [\beta_{SMS} + \beta_{SMS:SUBSCR} \cdot \overline{SUBSCR}] \cdot [P^{SMS} / \overline{SMS}^{SUB}]$$



For average prices, quantity and network size the own price effect is indistinguishable from zero, and voice is a complement to text with a significant cross-price elasticity of -1.5. The point estimate of the average network effect elasticity is 1.18, with a 95% confidence interval of [0.88,1.50]. This suggests that if the subscriptions increase by 10% the SMS usage increases by as much as 12%.<sup>26</sup>

We also find the emerging market to be more own price sensitive, suggesting that as the market has matured the own price effect has become neglectable. Note that the average network size is 0.6, well beyond the critical point of  $n=0.31$ .

The results imply that continued growth in the mobile phone market will stimulate growth also in the text messaging market, potentially increasing revenues from text even more. We have only been able to estimate the price effects from voice to text. To be able to say something about the effects from text to voice, a demand model for mobile voice calls is needed. If text generates the same feedback effects and is complimentary to voice usage in the same manner as voice is complimentary to text usage in a matured market, the text market growth will trigger continued growth in the mobile voice market.

## **5 Concluding remarks**

The mobile phone is a multi-service device that gives access to both voice calls and text messaging. The users may choose between text and voice whenever they wish to exchange information. This suggests that consumers will consider text and voice to be substitutes. However, in a simple theoretical model we show that if incoming calls stimulate outgoing text messaging, voice may evolve into a complement (in terms of the net cross price effect) when the network grows. Utilizing data for the Norwegian market we find that, consistent with the theoretical predictions, mobile voice calls were a net substitute to text messaging in the infancy of the mobile diffusion process and evolved into a complement as the network size became larger. This suggests that feedback effects are important elements in the demand function for text messages. An interesting future challenge is therefore to look for more detailed data on incoming communications, since this information would enable us to test the positive feedback explanation put forward here more directly.

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<sup>26</sup> 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.

In the case at hand, the pricing schemes in the infancy are crucial. Relatively high prices on the initial service (voice) compared to the emerging service (text messaging) may be necessary to ensure the take-up of the emerging service. If the customers did not value the idiosyncratic attributes of text messaging immediately, such that the majority of the customers initially considered text as inferior to voice, the low price of voice may explain the low adoption of text in the United States. Consequently, low prices for the current service (voice), due to strong competition or regulatory obligations, may then prevent the take-up of an inferior substitute (text) that later turns into a complement in demand to the current service. This potential demand side link between matured 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<sup>27</sup>. 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 one 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.

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<sup>27</sup> Telenor Mobil is the Norwegian mobile affiliate of Telenor ASA.