

Estimating Network Effects in Mobile Telephony in Germany*

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Abstract

In this paper we analyze demand for mobile telecommunications services in Germany in the period from January 1998 to June 2003. During this time, there was an explosive growth in the subscriber base by about 700% and a rather moderate decrease in prices by about 41%. Our conjecture is, that prices alone cannot account for such rapid diffusion. We estimate a system of demand functions to measure the impact of network effects on the demand for mobile subscriptions. In this analysis, we use publicly available data on subscriptions and price indices, which are generated using public data on tariffs. We find that network effects played a significant role in the diffusion of mobile services in Germany.

Keywords: mobile telephony, discrete choice, network effects.

JEL Classification: L13, L96.

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1 Introduction

Since one decade mobile telephony has been the fastest growing segment in the telecommunications industry. In June 2003 in Germany, after a few years of exponential growth, there were above 60 million subscribers to mobile telephony. Between January 1998 and June 2003, a change in the total number of subscribers was about 700%. During the same period of time, the index of prices for mobile services calculated by the German statistical office came down by about 41%. Whether such a price decrease can fuel the exponential change in the market size is a question which awaits an answer. At a first glance, it is unlikely that prices alone can account for such a large increase in the user base. The introduction of prepaid cards and new services, such as the short message service (SMS) and wireless application protocol (WAP), together with rising attractiveness of handsets have played a very important role for the industry development. However, we believe that network effects are another force, which caused such tremendous growth rates. If any product exhibits network effects, it becomes more valuable when more people use it. In our opinion, the decision about subscription to mobile services is influenced by network effects, which we represent in this study by past mobile consumer base. Network effects in mobile telephony may have different origins. First, an increase in the number of mobile users raises communications possibilities. In particular, the usage of mobile phones is attributed to a single person and not to a household as in the case of fixed telephony. In addition to voice telephony, mobile firms can offer several other services, such as SMS, MMS, WAP and email, which may also be subject to network effects. Furthermore, the spread of mobile services within social circles puts the non-adopters, in particular young people, under social pressure. For instance, lack of mobile contact may lead to exclusion from spontaneous social events.

In this paper, we analyze whether network effects have impact on the decision of consumers about subscription to mobile telephony. We estimate a system of demand functions for mobile subscriptions in Germany in the period from January 1998 to June 2003. Apart from new consumers, there is also a number of mobile users in each period, which change network operator. Unfortunately, we lack information on monthly sales of mobile services, that is on the number of people, which make subscription decision each month. We compute sales using publicly available data on accumulated subscriptions and quarterly churn rates, that is the percentage of consumers leaving network operators. We would like to note that former studies estimating demand for subscriptions to telecommunications services ignored the presence of consumers, which change operators. Furthermore, we construct operator-specific price indices using information on tariffs from magazines and Internet sources. Our results suggest, that network effects played a significant role in the diffusion of mobile services in Germany. In the absence of network effects, if prices remained as observed, the penetration of mobiles could be lower by at least 50%. Furthermore, current penetration levels could be reached without network effects only if prices were drastically lower. The measurement of network effects may be important for forecasting the diffusion of future telecommunications technologies, such as the UMTS. Moreover, assuming that observed prices are the result of pure strategy Nash equilibrium, we compute marginal costs

and markups. The markups for all three network operators increased over time from about 13% in January 1998 up to above 30% in June 2003.

The next section provides a short overview of empirical literature on network effects and telecommunications industry. In section 3, we present a brief history and state of mobile industry in Germany. The model which we use for econometric analysis is presented in sections 4. Data description and estimation results follow in sections 5 and 6 respectively. Finally, we conclude our analyzes in section 7.

2 Literature

There is a growing number of studies, which try to provide measurements of indirect and direct network effects in a variety of network industries. For instance, Gandal, Kende and Rob (2000) study the diffusion of CD technology and find that the number of CD titles has an impact on the adoption of CD players. Park (2000) analyzes the role of network effects in the standard war between VHS and Betamax video recording systems. Similarly, Ohashi (2001) estimates a random utility model and measures the role of network externalities in the diffusion of VCR in the U.S. between 1978 and 1986. Goolsbee and Klenow (2000) estimate a reduced form diffusion model for home computers and find that people are more likely to adopt computer technology in areas with a higher fraction of computer users. Brynjolfsson and Kemerer (1996) use hedonic pricing model to determine the impact of network effects, defined as compatibility with the dominant standard, on the prices of microcomputer spreadsheets. Farrell and Klemperer (2004) provide an excellent review of theoretical and empirical literature on network effects and switching costs.

The number of empirical studies on network effects in telecommunications industry is scarce. In a recent study, directly related to ours, Grajek (2003) estimates the magnitude of network effects in Polish mobile telephone industry in the period 1996-2001 and finds that mobile subscriptions are explained by past network size. In another study, Birke and Swann (2004) use household survey data to identify price-mediated network effects in mobile telephony in the UK. Finally, Kim and Kwon (2003) use a consumer survey to analyze Korean mobile telephony and conclude that consumers prefer carriers, which have a larger consumer base. Our study estimates a system of demand functions for mobile subscriptions in Germany using discrete choice framework. Network effects are identified by estimating the impact of lagged consumer base on current demand.

3 Mobile Telephony in Germany

3.1 Development of the Industry

The GSM and UMTS mobile telecommunications systems were preceded by few technologically different analog networks – the first generation of mobile systems. The first commercially available mobile telecommunications network in Western Germany was provided in years 1958–1977

by the state-owned monopolist in postal and telecommunications services Deutsche Bundespost. The so called A-network covered about 70% of the country and amounted to about 11.000 users due to frequency limitations. In years 1972-1995, Deutsche Bundespost was providing mobile communications services through the B-network. For the first time, roaming services in a few neighboring countries were offered. The total amount of users accounted for approximately 27.000, which was again due to frequency limitations. The prices of mobile phones were very high and affordable only for well situated groups of the society.

The following C-network was fully automated and used a SIM card to access the network. Again, it was provided by the state-owned monopolist Deutsche Bundespost-Telekom. This network was in use in years 1986-2000 reaching the high point of about 812.000 users. It was switched off after the introduction and successful development of second generation digital networks. The C-network was the first one that allowed utilization of small sized mobile phones due to a large number of basis stations, which increased transmission efficiency and required low power consumption.

The analog networks were followed by digital D-networks (GSM 900), which started to provide services in 1992. There were only two licenses granted – the first one to the state-owned Deutsche Telekom Mobilnet, which was later privatized and transformed into T-Mobile, and the second to the first private mobile network operator Mannesmann Mobilfunk, which was later taken over by Vodafone. In 1993, E-plus was granted a licence and one year later started operating GSM standard at 1800 MHz frequency. The other licence was granted in 1997 to Viag Interkom (later called O2), which started providing services in November 1998. In 1999, the D-networks were granted transmission rights at 1800 MHz frequency as well.

In 2000 German government auctioned licenses for third generation of mobile networks (UMTS), which allows for data transfer at much higher rates to satisfy the needs for multimedia applications. Six companies received the rights to develop 3G networks paying for licences in total DM 99 billion: Marabu – Group 3G, T-Mobil, Mannesmann-Vodafone, Auditorium, Mobilcom Multimedia and O2. These companies were established by consortiums of large multinational telecommunications companies and actual GSM network operators. The network development and introduction of 3G communication standard on the German market was expected to take place in years 2002-2005. One of the license winners – Quam entered the market in November 2001 signing national roaming agreements, acquired 200 thousands consumers and went bankrupt one year later.¹

3.2 Market Structure

The network operators may sell services to consumers directly or indirectly through independent service providers (ISPs). In general, ISPs resell airtime on the third party's mobile network by providing billing and customer care services under own brand names. In Germany, network operators can commercially decide whether to sign an ISP agreement. The German Telecommu-

¹Source: "Connect" magazine, <http://www.t-d1.de> and <http://www.xonio.de>

nications Act obliges network operators to supply airtime in a way, that the ISPs "can market and provide to their customers the services in their own name and on their own account". The agreements between the network operators and ISPs have to be non-discriminatory and assure fair competition between retailers. Typically, tariffs offered by the ISPs reflect tariffs of the network carriers.

In 2003 in Germany there were four network operator: T-D1, D2 Vodafone, E-Plus and O2 and about twelve ISPs. Only O2 has not concluded any agreement with service providers. Out of these firms, only eight have significant market shares, that is the network operators: T-Mobil (29.9%), D2 Vodafone (27.7%), E-Plus (9.3%), O2 (6.3%) and service providers: Debitel (12.7%), Mobilcom (6.5%), Talkline (3.2%), Drillisch (2.4%). The remaining service providers account for about 2.0% of subscribers.² The market share of independent service providers has been decreasing over time. Because of the market structure and data limitation, in this study we assume that consumers choose only among network operators. Subscribers to service providers are included into consumer bases of respective network operators.

Since the introduction of 2G networks, the mobile industry experienced dramatic growth rates. At the end of 2003, the number of mobile subscribers reached 64.8 million, which amounts for a penetration rate of 78.3%. The distribution of market shares among four network operators remained stable in the last years with T-Mobile having about 40.6%, D2 Vodafone – 38.1%, E-Plus – 12.7% and O2 – 8.6% as of 3rd quarter 2003. New customers have been distributed among the competitors more or less according to their actual market shares (see Figure 2). Clearly, an early entry played a critical role for the size and growth of consumer base, which may be due to lock-in and network effects. Late entrants, E-plus and O2 applied innovative pricing policies but did not manage to enlarge their market shares substantially. For instance, since July 1999, O2 has been offering Genion tariff, which users pay fixed line rates within at least one hundred meters around their declared home location and a lowered city tariff within the city area. Since December 1998, E-Plus has been providing a range of Time & More tariffs with free minutes and prices independent on call destination.

4 Empirical Model

Demand for mobile subscriptions is described by a discrete-choice model, as discussed in Anderson, de Palma and Thisse (1992) and Berry (1994). We follow the estimation strategy proposed by Berry (1994) and invert market-share equations to find the implied mean levels of utility for each alternative. It is enough to observe market shares to estimate the utility coefficients. The econometric error term is interpreted as the mean value of consumers' valuations for unobserved product characteristics, such as product quality, for instance.

We assume that all consumers have access to fixed line. In the first stage they decide whether to continue using fixed telephone alone or buy, in addition, a mobile and in the second stage

²Source: www.RegTP.de

they choose the network operator for mobile services. This is a standard nested logit structure, where one branch is degenerated and no further choices are made. The utility of outside option for consumer i at time t is given by U_{i0t} and may not only vary in time but also depend on prices of fixed line services, etc. The utility derived by consumer i from using fixed-line together with mobile services of network operator j may be written as

$$U_{ijt} = U_{i0t} + r_j + \alpha p_{jt} + \beta x_{jt} + V(z_{jt}^e) + \zeta_{gt} + \xi_{jt} + (1 - \sigma)\epsilon_{ijt} \quad (1)$$

where r_j is the stand alone value, p_{jt} represents service price and x_{jt} other network attributes, $V(z_{jt}^e)$ is the expected network benefit. The variable ζ_{gt} is a common value of all products in group $g = \{0, 1\}$ and has a distribution dependent on σ . The nest $g = 0$ stands for fixed line alone and $g = 1$ represents choice of mobile telephony together with fixed line.³ Here, ξ_{jt} accounts for the population average unobserved utility of operator j and ϵ_{ijt} is the idiosyncratic taste variable, which has a double exponential distribution. In nested logit model the taste of consumer for products within the nest may be correlated. When the choice of alternatives in the nest is independent, which implies that $\sigma = 0$, nested logit reduces to a simple logit. The probability of consumer i to subscribe to mobile network operator m is equal to

$$P_{imt} = P_{it}(g = 1)P[U_{imt} \geq \max_{j \in \{1, \dots, N\}, j \neq m} U_{ijt}]$$

and the share of network operator m in the total number of consumers making subscription decision is given by $s_{mt} = m_t P_{imt}$, where m_t is market size. The system of nested logit demands is given by

$$\log(s_{jt}) - \log(1 - s_t) = r_j + \alpha p_{jt} + \beta x_{jt} + V(z_{jt}^e) + \sigma \log(\bar{s}_{jt|g=1}) + \xi_{jt} \quad (2)$$

where $\bar{s}_{j|g}$ represents the share of operator j in the total sales of mobile services, ξ_{jt} is the econometric error term and the total number of mobile subscribers is given by $s_t = \sum_j s_{jt}$.

The utility specification (1) is representative for consumers with sufficiently low (zero) switching costs and for new consumers. Otherwise, the utility function should be state dependent due to switching costs. Because we miss precise data on the number of switching consumers and their choices of network operators, we have to make simplifying assumptions. We assume that there are three types of consumers. Consumers with sufficiently low switching costs and new consumers make the choices in each period, while consumers with high switching costs are locked-in and continue using the same mobile services. We use data on accumulated subscriptions and churn rates to account for the presence of locked-in consumers and to construct a sales variable.⁴ Sales of operator j in period t are represented by a difference $y_{jt} = \tilde{y}_{jt} - (1 - \lambda_j)\tilde{y}_{jt-1}$, where \tilde{y}_{jt} stands for the number of subscribers to operator j in period t and λ_j represents the churn

³By normalizing with respect to the utility of outside option, the choice of alternatives becomes independent on the determinants of fixed line utility.

⁴We are very grateful to Jan Kranke for providing us with data on approximate quarterly churn rates for network operators in Germany. We calculate monthly data by linear approximation.

rate. The total number of consumers, which make subscription decision may be specified as $m_t = M_t - \sum_{j=1}^N (1 - \lambda_j) \tilde{y}_{jt-1}$, where M_t is the market size. As the market size we use the population in age over 16, which is 84% of total population.

4.1 Network Effects in Mobile Telephony

We have not specified so far how consumers form expectations about network size and how the network benefit function is formulated. We employ a very simple rule for the formation of expectations. Consumers naively think that the network size in the last period will be realized in current period. When market reaches steady state, such formation of expectations will be fulfilled. Networks are fully compatible and their users may freely communicate with each other. Thus, the size of the network is represented by the total number of subscribers to all four network operators. There may also be asymmetric network effects due to the differences in on-net and off-net prices, which make larger networks more attractive to subscribers. However, it is impossible to disentangle price-mediated network effects from industry-wide effects because of high correlation of subscriptions, as presented in Figure (1).

Most of the empirical and theoretical literature on network effects assumes linear network benefits. Swann (2002) examines the assumptions on communications needs, which are necessary for the utility function to be either linear or s-shaped in the network size. He argues that an s-shaped utility function in the network size is more realistic for an average consumer and that the shape may differ for pioneers, medium adopters and late adopters. In the time period considered in this study, the mobile telephony in Germany was in the phase of fastest growth. Thus, the network benefits should be well approximated by a simple linear function $V(z_{jt}^e) = \beta z_{t-1}$, that is, each new subscriber to any of the networks brings the same marginal utility. Clearly, consumers derive network benefits from fixed line network as well. However, in the last decade, changes in the number of subscribers to fixed line telephony were negligible. In the case of linear network benefit function, including fixed line network size is equivalent to adding a constant to all utilities together with the outside option.

4.2 Consumer Choice

The determinants of network operator choice may be found using consumer surveys. Since there are no publicly available surveys of German consumers, we refer to surveys conducted by the British regulator Ofcom (former Oftel). Due to similar economic and cultural background in both countries, the consumers of mobile services in the UK and Germany should not differ much in their preferences. Hence, we assume that survey results for British consumers are also relevant for Germany. The majority of consumers in the UK (59%) declared, that the cost of mobile services is the main choice factor, followed by the reception quality and geographic coverage (21%).⁵ Interestingly, the majority of consumers (79%) choose network operator without taking

⁵Oftel, Q8 February 2002 and Oftel, Q11 November 2002.

the last determinants into consideration at all, which may be due to their belief, that network operators do not differ much in these factors. Also in Germany, according to tests carried on by telecommunications magazine "Connect", the networks are hardly distinguishable in the coverage and reception quality.⁶ There were no significant changes in the coverage and reception quality over the time period in this analysis. In fact, right after the entry, O2 had small network coverage but almost immediately signed a roaming agreement with E-Plus and later with T-D1, which automatically extended the coverage to the size of these networks. Nevertheless, O2 is excluded from this analysis for the reason discussed in the next section. Thus, the price of mobile services is the only factor, which differentiates network operators in Germany.

5 The Data

The German statistical office computes four monthly price indices for mobile services. First, three consumer profiles are defined based on consumption intensities: infrequent, average and frequent users. Typically, network operators provide a set of tariffs for each profile. For each tariff of each profile an expected monthly bill is calculated. Consumers are assumed to be perfectly informed about the range of tariffs available each month on the market and choose the cheapest one. In this way three profile indices are created, which are further used to calculate aggregate weighted price index for mobile services. Because tariffs consists of many price factors, such as on-net, off-net, fixed-line, time zones, billing intervals and so on, the statistical office for a simplicity uses only the most important ones in the calculation.⁷

For the purpose of this study, we need firm-specific prices. We collected tariff information from the price listings published in telecommunications magazines and Internet in the time period January 1998 – June 2003 and applied the methodology used by the statistical office to compute firm-specific indices.⁸ First, we assume infrequent usage behavior and calculate expected monthly bills for all tariffs provided by network operators. Out of the set of tariffs offered by each network operator we pick the tariff, which delivers the lowest bill. The cheapest tariff for the infrequent user is the tariff, which determines subscription decision of the marginal consumer. In addition to what the statistical office does, we assume some randomness in calling behavior. Hence, we randomize the number and length of phone calls, and the distribution of calls among destination networks and time-zones. The distribution among destination networks is proportional to the market shares. Moreover, we account for price discrimination between on-net and off-net calls, which is omitted in the computation of official indices. We simulate 200 bills for each tariff and compute the mean values to compare tariffs.

The price indices computed in this way are correlated with the official price indices provided by the statistical office, as shown in Table (1). Figure (3) presents changes in the minimum tariffs for infrequent user in the time period of this study. Apart from prices, firms compete

⁶"Connect" magazine, 30.11.2000

⁷Source: Statistisches Bundesamt Wiesbaden, 1999.

⁸Source: magazine "Connect", <http://www.teltarif.de>

also in handset subsidies and often provide handsets for free. For instance, in June 2003, TD-1 offered six different handsets for the price of 1 Euro, D2 – ten handsets, E-Plus – eight handsets and O2 – seven handsets.⁹ Network operators try to recoup the initial investment in consumers through a stream of future payments.

The data on mobile subscriptions is collected from the Internet site of the German regulator – RegTP. The subscription data is available from June 1992, but we restrict this analysis to the period, for which we could collect prices, that is we have 66 monthly observations from January 1998 to June 2003. Because of late entry of the fourth network operator O2 in November 1998 and its small market share at the end of the analyzed period (8,6%), it may be difficult to estimate demand for this operator. Thus, in this study, we estimate only demands for three main network operators: T-D1, D2 and E-Plus, which in total cover about 91% of the market.

Furthermore, to account for endogeneity of prices and within group shares, we use instrumental variables. We have to find instruments, which are correlated with current period prices and within group shares, but uncorrelated with the unobservable demand and cost shocks. The error terms may be autocorrelated due to the character of data. Thus, the usage of lagged endogenous variables, such as lagged consumer base, could be problematic. This means you have to instrument for lagged installed base as well. Apart from lagged installed base, we use only one exogenous variable in the model – a dummy for Christmas sales, which may be a good instrument for prices. Firms tend to offer special Christmas deals and there is a peak in mobile subscriptions in December. Also, usually at the start of the year, firms make announcements of new tariffs, which are due to preparation for the main telecommunications fair CeBIT. This fair takes place around start of March in Hannover. Thus, the first quarter dummy may be used as an instrument for prices. Other candidates for instruments could be proxies for cost factors. For instance, Evans and Heckman (1983) estimate total cost function in fixed line using input prices and output quantities as cost determinants. Input prices include the price of materials, the price of capital and the wage rate. Here, we use only the cost of telecommunications equipment as instrument, which is provided by the German statistical office. The correlation coefficient of prices for mobile services with the index of hourly wages in telecommunications industry is almost zero. Also, the time trend may be a component of cost function, which accounts for the technological innovation in mobile telephony. It could be interpreted as a constant upgrade in the quality of services and handsets. Furthermore, the entry of Viag, which took place in November 1998, must have had some impact on the market by inducing price decrease, for instance. As instruments for within group shares we use the number of tariffs offered by network operators. Potentially, the variation in the number of tariffs should effect the within group share. Unfortunately, we miss any other firm-specific variables. Hence, we use a following set of instruments $Z_t = [1, christmast_t, quart1_t, capital_t, time_t, viag_t, tariffs_t]$. Our identifying assumption is mean independence of the demand shocks in (2) with the set of instruments, i.e. $E(\xi_{jt} | Z_t) = 0$. Table (2) presents the correlation matrix of mobile prices and demands with

⁹Source: "Connect" magazine, June 2003

the instrumental variables.

6 Estimation Results

Consumers choose between using mobile and fixed line services together, as specified by utility function (1), or fixed line services alone, that is the outside option. This makes the demand function (2) independent on factors, which determine the demand for fixed line, such as fixed line prices. Thus, the demand for mobile subscriptions is dependent only on service price, lagged installed base and a dummy for Christmas sales. Figure (4) presents the dependence of demands for mobile subscriptions and prices of TD-1, D2 and E-plus. All three demands seem to have the same slopes but differ in intercepts, in particular the demand for E-plus. The coefficients for price and network benefits are assumed to be the same for all three networks but the Wald test rejects the equality of intercepts (see Table 3).

First, demands are estimated using ordinary least squares (OLS) and two stage least squares (2SLS) with the set of instruments discussed in the previous section. The estimation results are presented in Table (3). According to Hausman specification test, the null hypothesis of exogeneity of prices may be rejected at a significance level of 10%, which suggests an instrumental variables estimation strategy is more appropriate. Furthermore, the Breusch-Godfrey test indicates autocorrelation of the error terms in all three demand equations. We account for the problem of autocorrelation and endogeneity by using generalized method of moments (GMM) estimators with a Newey-West weighting matrix.

The estimates of all parameters are significant, as presented in Table (3). In particular, σ is estimated to be 0.80, which implies relatively high correlation of choices within the nest. We calculate the elasticities of demand to interpret the estimates of price and network benefits. The own price elasticity of demand in nested logit model is specified as

$$E_{p_{mt}}^{s_{mt}} = -\frac{\alpha}{1-\sigma} p_{mt} [1 - \sigma \bar{s}_{mt|g=1} - (1-\sigma) S_{1t}]$$

where S_{1t} is the share of all subscribers to mobile services at time t and $\bar{s}_{jt|g=1}$ is the within group share. The cross price elasticity of demand is given by

$$E_{p_{jt}}^{s_{mt}} = \frac{\alpha}{1-\sigma} p_{jt} \bar{s}_{jt|g=1} [S_{1t} + \sigma(1 - S_{1t})]$$

The percentage changes in the quantity demanded caused by a percentage change in the past installed base, that is the measurement of network effects, may be specified in a similar way as

$$E_{z_{t-1}}^{s_{mt}} = \frac{\beta}{1-\sigma} z_{t-1} [1 - \sigma \bar{s}_{mt|g=1} - (1-\sigma) S_{1t}]$$

Table (4) presents average elasticities for GMM estimates for period January 1998 – June 2003.

We calculate also the elasticity of demand for mobile services in total, which are given by

$$E_{p_{jt}}^{S_{1t}} = -\alpha p_{jt} \bar{s}_{jt|g=1} (1 - S_{1t})$$

The values in Table (4) are interpreted as follows, an increase in T-D1 price by 1% causes on average in time period January 1998 – June 2003 a decrease in sales of mobiles by 0.50%. The respective values for D2 and E-plus are 0.52% and 0.20%. The elasticity of demand for mobile services in respect to past installed base is specified as

$$E_{z_{t-1}}^{S_{1t}} = \beta z_{t-1} (1 - S_{1t}) \sum_j \bar{s}_{jt|g=1}$$

There are strong network effects, due to which an increase in the last period installed base by 1% raises current period sales on average by 0.71% in the time period considered. If there were no network effects, the industry growth would be stimulated only by price changes. Thus, as presented in Figure (5), the penetration level in the absence of network effects could be lower by at least 50%, compared to the current case. This is due to the fact that prices remained almost constant in the second part of the period analyzed, as presented at Figure (3). Network effect have also impact on the equilibrium prices, which is ignored in projections. In the absence of network effects, current penetration level could be reached only if prices were significantly lower. Figure (6) suggests that prices would have to fall down to zero and even below. These projections indicate the importance of network effects for the industry growth. Apart from network effects there is also a significant Christmas effects due to which the demand for mobile service has increased in each November and December by about 35%, as calculated using the estimates from Table (3).

Furthermore, assuming that observed prices are the result of a pure strategy Nash equilibrium, we can make use of the first-order equations to retrieve information about marginal costs. This ignores effects of current prices on future profits. Thus it overestimates markup hence these measures are an upperbound. Following Berry (1994), using first-order conditions for the nested logit model, the marginal cost may be written as

$$c_{jt} = p_{jt} - \left[\frac{(1 - \sigma)}{\alpha} \right] / [1 - \sigma \bar{s}_{jt|g=1} - (1 - \sigma) s_{jt}] \quad (3)$$

Using the estimates of α and σ from the demand side we may calculate the changes in marginal cost and markup for each network operator over the time period analyzed. Figure (7) shows changes in the markup relative to the price level, which are calculated as $(p_{jt} - c_{jt})/p_{jt}$. The markups for all three network operators increased over time from about 13% in January 1998 up to above 30% in June 2003. The markups at the end of the period differed across network operators with E-plus having the lowest markup of about 28%, TD-1 of 31% and D2 of about 36%. This increase is due to the fact, that in absolute value the markups remained almost constant while the prices decreased.

7 Conclusion

In this paper, we analyze the role of network effects in the mobile telecommunications industry in Germany. In the empirical model we incorporate network effects by assuming that consumers

expect the current network size to be equal to the installed base in the previous period. We find that network effects have a significant impact on the decision of consumers about subscription to mobile telephony. We are able to disentangle the impact of price and network effects on the demand and estimate reasonable price elasticities of demand for mobiles. An increase in T-D1 price by 1% causes on average in time period January 1998 – June 2003 a decrease in total sales of mobiles by 0.50%. The respective values for D2 and E-plus are 0.52% and 0.20%. There are strong network effects, due to which an increase in the last period installed base by 1% rises current period sales on average in the time period considered by 0.71%. If there were no network effects, the penetration of mobiles at the end of the period analyzed could be lower by at least 50%. Current penetration level could be reached only if prices were drastically lower. Furthermore, by estimating price coefficient and assuming Nash equilibrium in prices we could provide measurements of marginal costs.

This study provides some information, which may be of interest for policy makers. The extremely high cost of licences in the UMTS auctions induced a debate on the ability of the firms to develop network and make further investments in consumer acquisition. As the widespread of the 3G technology is an important social objective, it is crucial to know, to what extent the diffusion of 3G technology could be stimulated by network effects. Thus, the estimates of network effects and price elasticities of demand in the 2G telephony could be some basis for projections onto 3G technology.

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8 Appendix

Figure 1:

Industry growth in years 1992–2003

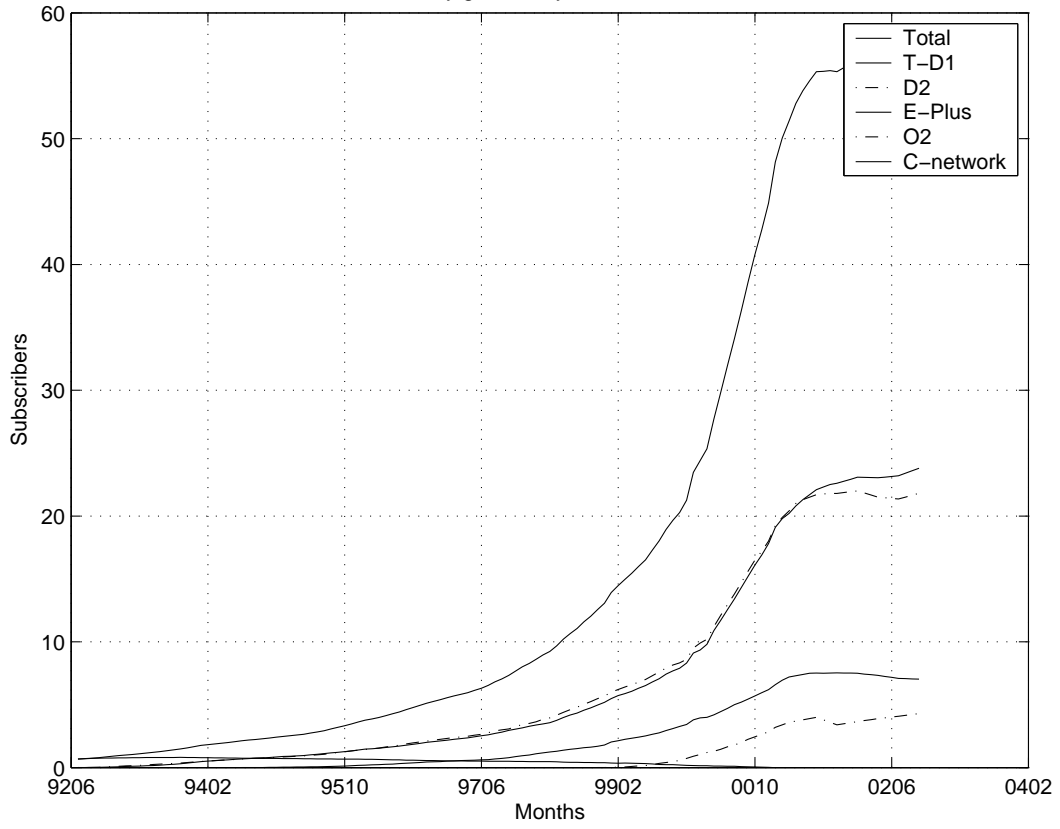


Figure 2:

Development of market shares in years 1992–2003

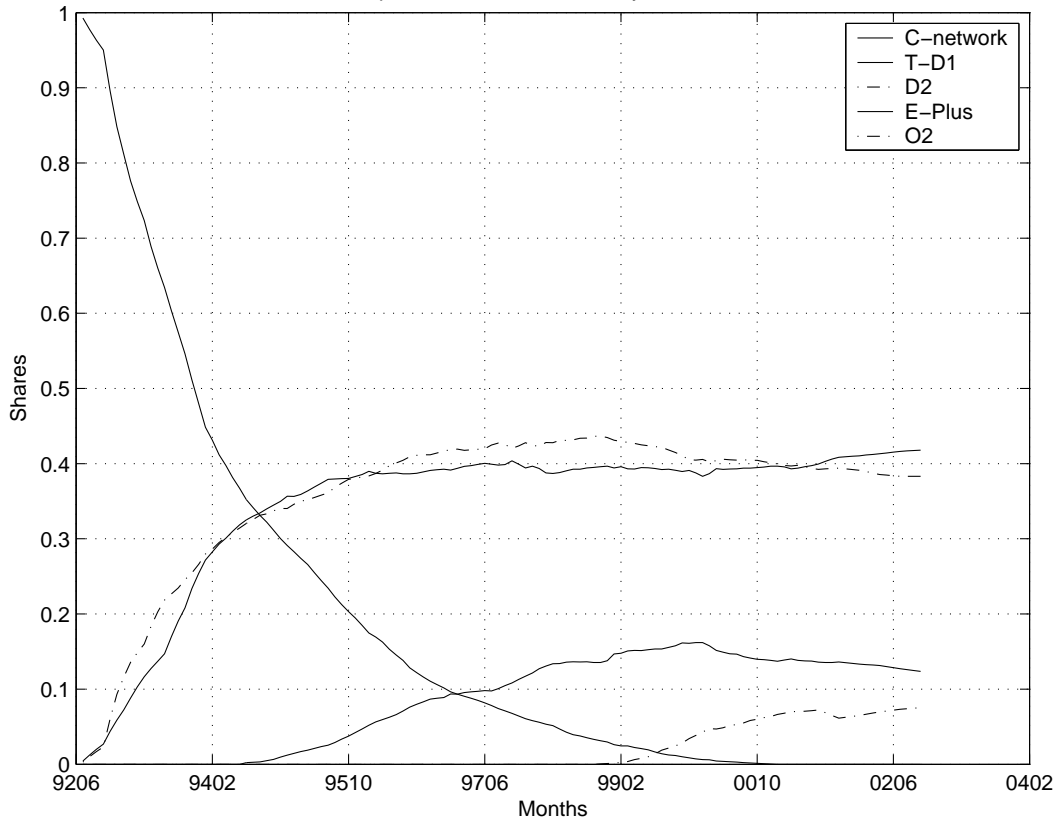


Table 1: Correlation of price indices

Index	Infreq.	Aver.	Freq.	TD1	D2	E-plus	O2
Infrequent	1.00						
Average	0.84	1.00					
Frequent	0.99	0.85	1.00				
TD1	0.79	0.91	0.78	1.00			
D2	0.77	0.88	0.78	0.92	1.00		
E-plus	0.50	0.61	0.47	0.70	0.55	1.00	
O2	0.22	0.00	0.24	-0.13	0.05	0.01	1.00

Table 2: Correlation of prices and instruments

	p_{d1}	p_{d1}	p_{d1}	time	viag	1stquart	christ	capital	tar_{d1}	tar_{d1}	tar_{d1}
p_{d1}	1.00										
p_{d2}	0.98	1.00									
p_{e1}	0.95	0.94	1.00								
time	-0.93	-0.92	-0.86	1.00							
viag	-0.75	-0.76	-0.86	0.59	1.00						
1stquart	0.02	0.03	0.02	-0.04	-0.05	1.00					
christ	-0.05	-0.09	-0.04	0.04	0.16	-0.25	1.00				
capital	0.88	0.87	0.84	-0.95	-0.57	0.05	0.02	1.00			
tar_{d1}	-0.72	-0.70	-0.59	0.78	0.41	-0.04	-0.02	-0.60	1.00		
tar_{d2}	-0.74	-0.73	-0.60	0.81	0.41	-0.11	0.03	-0.66	0.93	1.00	
tar_{e1}	-0.80	-0.81	-0.74	0.78	0.59	-0.11	0.05	-0.64	0.76	0.81	1.00

Figure 3:

Lowest monthly bill for an infrequent user

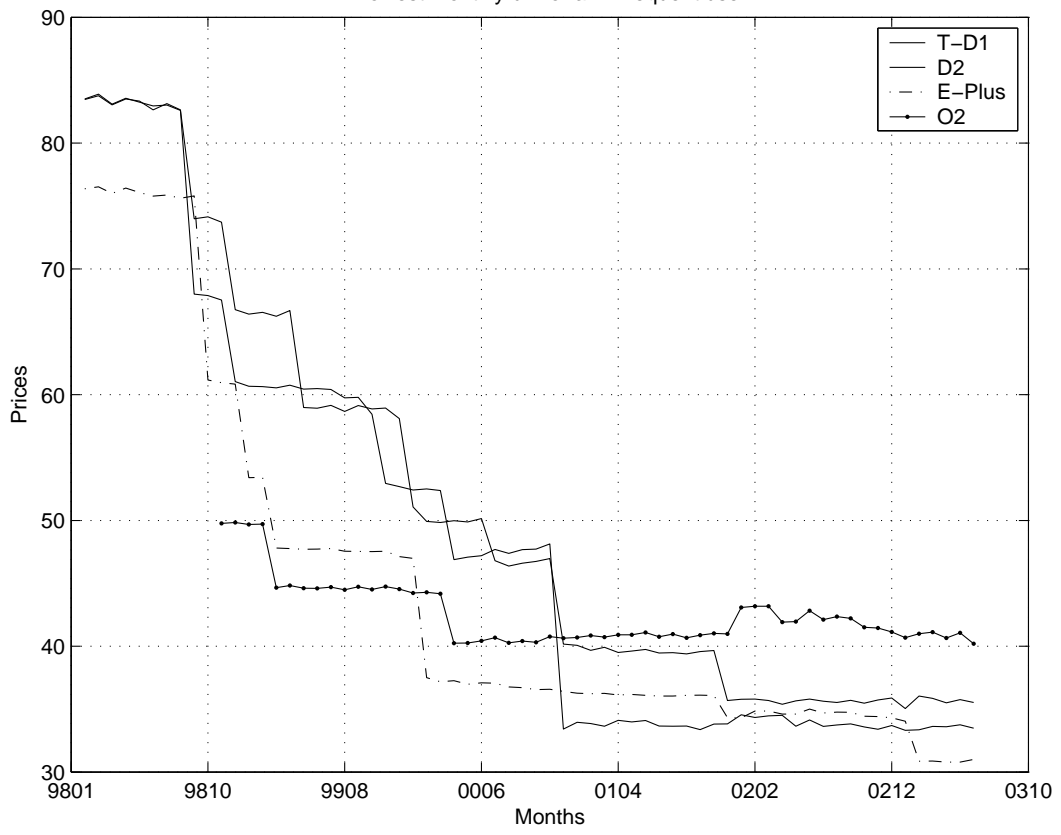


Figure 4:

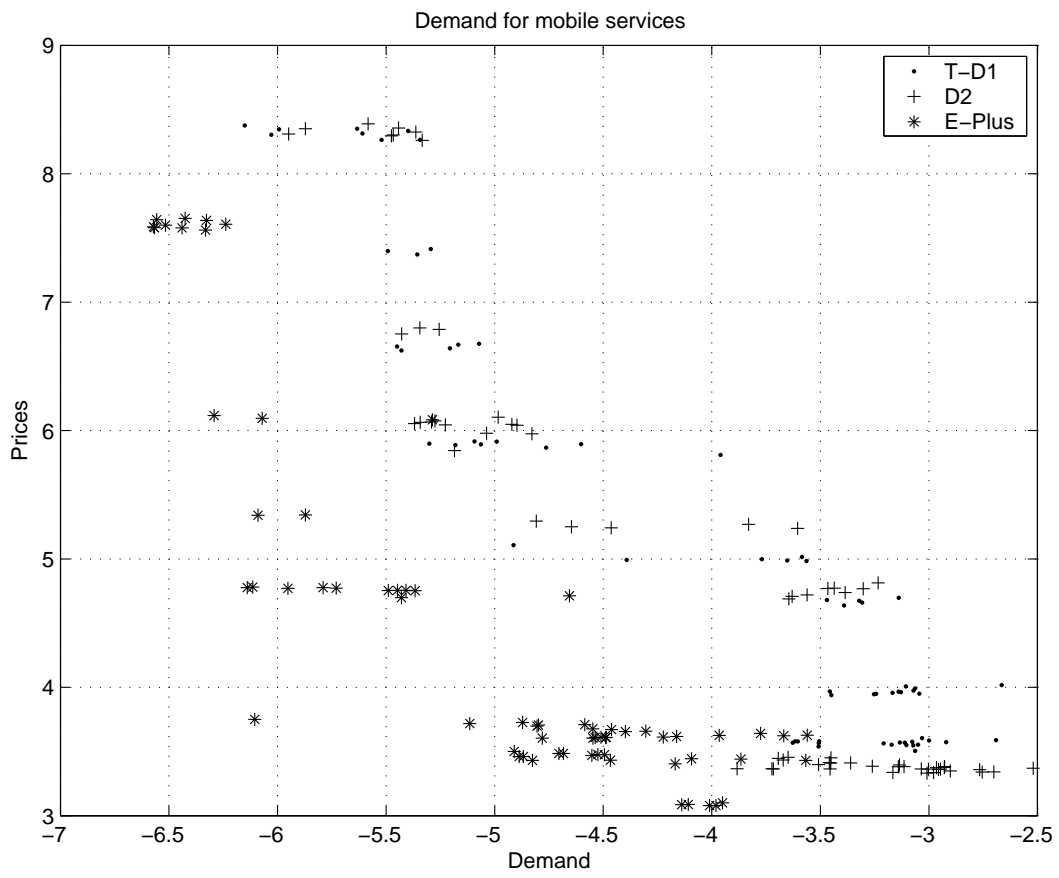


Table 3: Nested logit – TD1, D2 Vodafone, E-plus

Parameter Name	OLS Estimates (t)	2SLS Estimates (t)	GMM Estimates (t)
r_{d1}	-2.62 (-8.77)	-2.83 (-8.40)	-2.92 (-21.68)
r_{d2}	-2.69 (-9.24)	-2.89 (-8.81)	-2.98 (-22.46)
r_{e1}	-2.96 (-8.68)	-3.21 (-7.43)	-3.28 (-30.34)
β	1.34 (6.09)	1.40 (5.17)	1.47 (10.23)
α	-2.46 (-8.40)	-2.27 (-6.44)	-2.16 (-15.14)
Christmas	0.31 (4.78)	0.31 (4.85)	0.33 (4.84)
σ	0.85 (6.57)	0.79 (3.49)	0.80 (23.34)
LM test T-D1	35.86		
LM test D2	39.78		
LM test E-plus	33.39		
MSE T-D1	0.1073	0.1090	0.1098
MSE D2	0.1193	0.1196	0.1199
MSE E-Plus	0.1002	0.1000	0.1000
N*Objective	20.80	6.1479	12.2979
Hausman		12.55	
$Pr > \chi^2$		0.0840	
Wald	6.16		
$Pr > \chi^2$	0.046		

Table 4: Demand elasticities – prices and past consumer base

	T-D1	D2	E-Plus	Mobiles
T-D1	-4.45	2.25	2.25	-0.50
D2	2.21	-4.18	2.21	-0.52
E-Plus	0.80	0.80	-5.02	-0.20
Network	2.57	2.57	3.46	0.71

Figure 5:

Industry growth with and without network effects

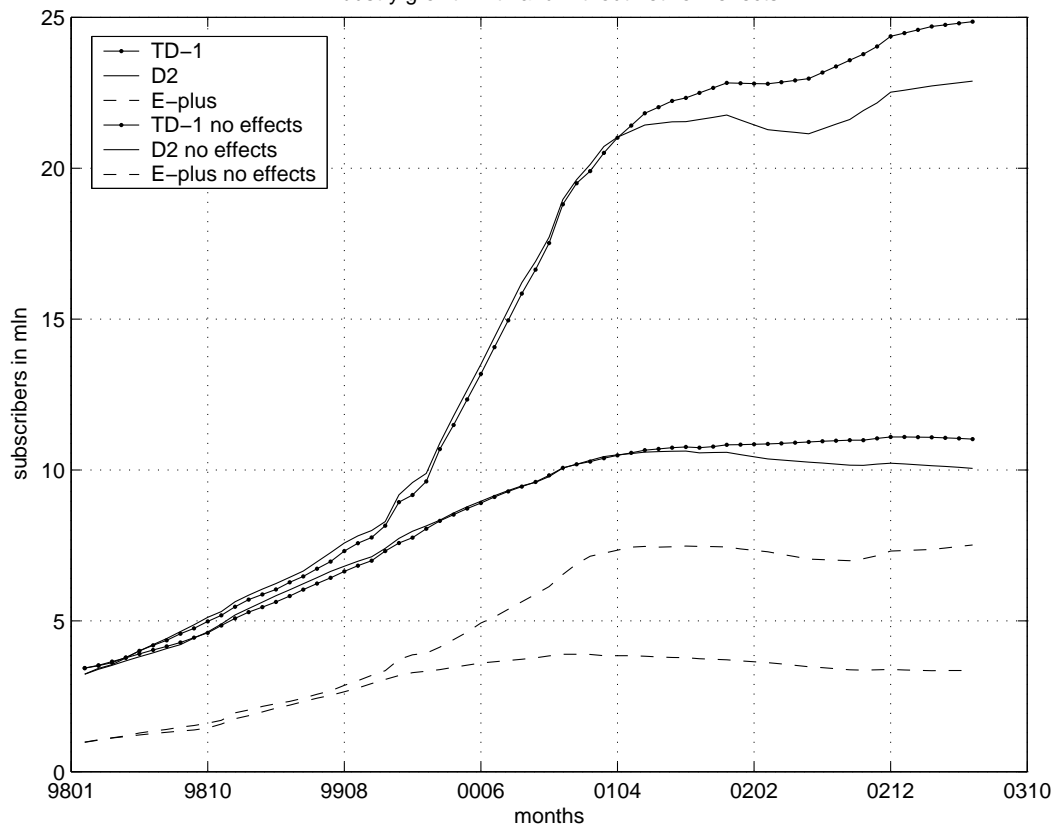


Figure 6:

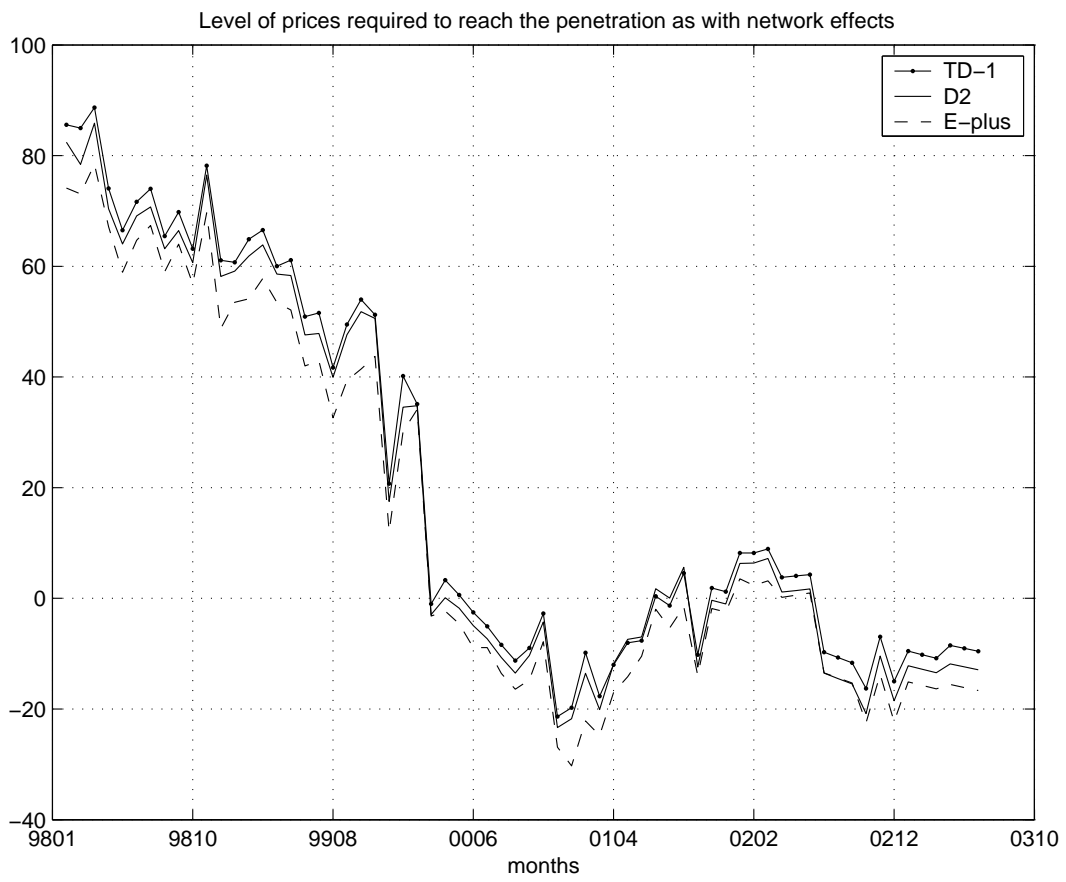


Figure 7:

