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Cable vs. DSL – Competing IT Innovations and Lock-in from the customer's standpoint

Abstract:

Based on the question of technology choice between two competing IT innovations, research suggests bandwagon effects to explain adoption and diffusion of a single dominant technology (Leibenstein 1950). However, when neither direct nor indirect network effects exert an infrastructure-specific influence on the diffusion process – as in the case of German broadband competition between DSL and Cable infrastructures – bandwagon effects cannot explain the emergence of a single technology standard. Due to digital convergence and non-proprietary IP-infrastructures network effects work comprehensively for both technologies. Hence adoption patters should converge, when the two competing technologies are relatively similar in terms of performance and pricing. The quest is therefore to identify and measure consumer adoption mechanisms responsible for the continuous asymmetries in DSL and Cable adoption patterns. We show that information externalities may arise from high uncertainty involved in the purchase of IT services such as broadband. As a result a stable lock-in emerges and prevents significant competition between the alternatives by creating implicit switching costs.

1 Research Question

When considering German broadband penetration it becomes clearly visible that German broadband diffusion falls far short of international penetration rates within and outside the EU (OECD 2004). Even worse, current growth rates in adopters do not make up for below average penetration rates, continuously widening the existing gap. From an economic perspective higher broadband penetration rates are associated with positive effects on economic growth, innovative ability and GDP by stimulating investments and fostering the diffusion and use of new applications and services (DIW 2004). Hence, addressing a critical issue when considering sources for an insufficient economic development, the question arises why German broadband diffusion rates continuously remain on a below average level. Research on the influencing factors on the level of broadband penetration abounds. For the most part, existing studies agree that the driving force behind fast diffusion lies in intermodal, i.e. infrastructure competition (e.g. OECD 2001, 2002, 2003, Aron and Burnstein 2003, Newman 2003, Flamm 2004, Garcia-Murillo 2005, Distaso et al. 2006, Elixmann et al. 2007). Although several initiatives have been undertaken in Germany, relevant infrastructure competition has not emerged yet. The German broadband market exemplifies an unparalleled case of persevering dominance of a mono-technology broadband internet access structure. Roughly 97% of all existing broadband connections are built up by using the DSL technology. While Cable internet access plays a significant and sometimes even dominant role in several countries, German performance of Cable broadband remains poor. This result is even more surprising when considering its extraordinary well basic setting – with more than 22 Mio existing Cable connections, representing a 56% penetration quota and a potential of far more than 80%, Germany's Cable infrastructure is the 2nd largest worldwide behind the US' (Beckert et al. 2005, Gries 2003).

Research on the evolution of the Cable market in Germany does not go beyond tracing back current problems of Cable providers to the idiosyncratic division of the Cable distribution network levels, the split up of the last levels' owner structure and finally the difficult privatization process (Büllingen and Stamm 2001, Gries 2003, Kurth 2003, DIW 2004, Heng 2005, Beckert et al. 2005, BMWi 2005, Fornefeld et al. 2006, Büllingen et al. 2007). In this sense these works merely illuminate supply side aspects and therefore outline challenging developmental conditions for the establishment of competition from the perspective of a Cable provider (Beckert et al. 2005). Alas, these studies almost entirely neglect the consumer side. At the same time it becomes clear that privatization has been successfully completed by

2003 and the incumbent Deutsche Telekom is no longer in possession of the Cable infrastructure (Büllingen and Stamm 2006). This in turn means that the continuous lack of significant competition among broadband infrastructures can be no longer be exclusively attributed to the historically grown supply side structures. Rather, it appears that some mechanisms must be at work preventing a rapid establishment of competition. A study conducted by the WIK comes to similar conclusions by denoting that possibly path dependencies might constrict Cable technology from rapid diffusion, remains unclear about the source, mechanisms and nature of such path dependency, though (Gries 2003). The aim of this paper is to take a closer look at demand side dynamics evolving from buying behavior of innovative services such as broadband. Such dynamics would be generally attributed to the wide array of direct or indirect network effects (Katz and Shapiro 1985, 1986, 1994) increasing with availability of the dominant technology standard. However, considering the two perfectly compatible internet–access technologies DSL and Cable, it becomes obvious that no technology-specific network effects may foster the diffusion of one alternative against the other. Communication between users of the two different technologies is problem-free as well as any internet application or service is accessible and usable by any of the two infrastructure platforms. Hence, traditional notions of emerging path dependent patterns as in the case of VHS, QWERTY or Windows are not applicable in the present case due to the lack of traditional network effects. We will demonstrate though that a different type of externalities may explain the continuous adoption asymmetries and the perseverance of a technology standard even in the absence of classic network effects.

2 Theoretical Framework

2.1 Micro level broadband adoption behavior

In order to demonstrate the mechanisms at work an approach purely based on information economics is employed. The starting point is the conceptual division of individual buying processes into three distinctive ideal type phases (Adler 1998):

1) **Initial situation**, which is characterized by the existence of uncertainty as a result of asymmetric information. By employing the SEC paradigm, goods and services can be distinguished by their relative proportion of search, experience and credence qualities (Nelson 1970, Darby and Karni 1973). Broadband internet access represents an innovative standardized service in the realm of ICT. Services are generally assumed to have high levels of experience (and credence qualities) and low levels of search qualities (Zeithaml 1981, Parasuraman

et al. 1985, Murray 1991). Related buying processes are therefore associated with high levels of quality uncertainty prior to the buying decision.

2) **Phase of information gathering** in order to reduce existing uncertainties. When facing asymmetrically distributed information and individuals acting boundedly rational, strategies to reduce quality related uncertainty arise. They can be summarized under the terms of screening and signaling. Quality uncertainty stemming from a predominant proportion of experience qualities can be effectively reduced by recurring on experience. Prior Experience serves as an information substitute for ex ante not assessable qualities. Relying on experience therefore represents an efficient strategy of information gathering (Nelson 1970, Weiber and Adler 1995). Taking into account that broadband is treated as an innovation the overriding importance of experience of others becomes obvious. When no personal experience exists, adopters have to rely on information gathered by prior adopters. Communication of this information type between adopters can generally take two forms: First, product oriented information substitutes through personal communication, such as quality assessments and evaluations, e.g. word-of-mouth (Grewal et al. 2003). Second, market-process related data, such as market share (Hellofs and Jacobson 1999, Tolle 1991), number of previous adopters (Vahrenkamp 1991), market concentration (Hauser 1979) or standards (Kleinaltenkamp 1992) that represent market related (not product) related information substitutes and serve as quality signals.

3) **Phase of the buying decision**, which describes the selection and decision of an offer from a multitude of comparable options against a payment. For that purpose information obtained from the preceding information gathering phase is evaluated. This process takes place up until the consumer reaches an individual aspiration level, which enables him to reach a buying decision at still existing levels of uncertainty (Weiber and Adler 1995). Orientation on aforementioned demand side signals can result in macro market movements that are well captured by the model of information cascades (Banerjee 1992, Bikhchandani et al. 1998). The notion of information cascades (or herd behavior) offers the possibility to integrate demand side screening and signaling mechanisms in an information economics framework and to dynamize them as information externalities. In addition, herd behavior has been explicitly discussed within the context of a choice between two competing technology standards. It leads to a market-wide consideration of adoption decisions.

2.2 *Macro level adoption dynamics*

The common notion of all models dealing with the phenomenon of information cascades and herd behavior is that rational individuals ignore their personal information and rather mimic decisions of their predecessors. Theoretically assuming a sequential decision process in which every individual must decide between two alternatives, each decision is made under optimization of Bayes' probabilities. For that purpose individuals explicitly resort to prior decisions made within their social system. Decisions are accessible in the form of publicly observable signals. Taking into account that individuals face identical problems and wish to access identical information, experience offers a cost-saving access to information (Schotter 2003). „People prefer to do what other people do, particularly in areas where quality is uncertain." (Kretschmer et al. 1999 p.63) Information gathering processes of such a kind can be understood as a form of learning behavior, e.g. "observational learning", "social learning" (Bikhchandani et al. 1998 p.153, Vicente 2003 p.5) as well as a special case of free-riding behavior (Choi 1997), respectively, initiated by the observation of past decisions.

Each decision taken by an adopter produces publicly observable information when entering the market. Hence, becoming informative, it produces positive externalities, i.e. information externalities (Zhang 1997, Moscarini and Ottaviani 1997, Li 2004). Although actions do not reflect actual cost-benefit analyses made by the adopters they suffice to serve as signals of product quality. For subsequent adopters it is rational to assume, that the predecessor has not acted against his private signal but rather followed it (Bikhchandani et al. 1998). Although showing striking resemblance to Leibenstein's bandwagon effects (Leibenstein 1950), the information cascades approach is neither bounded by the trivial assumption of compliant or mimetic behavior nor reliant on concepts such as network effects or complementarities in consumption (Karni and Schmeidler 1989, Narduzzo and Warglien 1996). Rather it employs an economic rationale behind the underlying mechanisms purely based on information considerations. As the herd produces an externality in which personal information remains veiled (Banerjee 1992, Shiller 1995), information cascades are always prone to potential efficiency losses. The course of actions and thus the winning alternative is merely determined by the decisions of the very first adopters (Banerjee 1992). Misconduct at the beginning propagates in successive decisions. Choices of later adopters do no longer depend on payoff considerations between the two alternatives obtained by personal judgments. Rather, they are predetermined by the decisions of the first decision makers, hence "with virtual certainty, all but the first few individuals end up doing the same thing." (Bikhchandani et al. 1998 p.154). The massive impact of initial conditions on the course of subsequent adoption decisions easily enables inferior alternatives to emerge as the dominant standard. This holds true for any case when the superior alternative gets initially discarded and the subsequent herd imitating initial actions. Although every adopter is acting rationally from the individual standpoint and the majority would collectively opt for the better alternative, each single decision leads to the adoption of the dominant standard and therefore prolongs the cascade. Because of the positive feedback nature of the herd externality the cascade becomes stabilized and reinforced with every ensuing decision (Banerjee 1992). The formation and progression of an information cascade is therefore essentially path dependent in its nature.

2.3 A macro level model of broadband adoption behaviour

In general, the fragile character of information cascades is stressed (Bikhchandani et al. 1998, Shiller 1995, Watts 2002, Golder and Tellis 2004). As soon as two individuals deviate from herd behavior and follow their private signal an opposite cascade can easily be triggered (Anderson and Holt 1997). This may happen because of small changes in public information or marginal deviations from Bayesian behavior. However, the fragility of information cascades crucially depends on two assumptions: First, individuals observe the exact sequence of preceding decisions and second, all signals are of equal quality. Loosening both of these rather restrictive assumptions, a more realistic model obtains and leads to following insights:

i. Market-process Related Data

It is rather unlikely that individuals have detailed knowledge about the sequence and course of single actions within the diffusion process (Orléan 1995, Çelen and Kariv 2005). Fully transparent chains of decisions must be rather understood as conceptual abstractions for theoretic modeling and can only be simulated under laboratory conditions. So far, models of deviations from the full decision sequence have been undertaken by endogenizing the time of decision taking while not assuming sequential decision chains (Gul and Lundholm 1995, Sgroi 2003). In reality, information about past actions does not take the form of a history of sequential decisions but rather appears as aggregated market-process related data. It thus takes the form of market averages such as market share, degree of diffusion, level of awareness or industry-wide standards (Hauser 1979, Shiller 1995). Preceding individual decisions can be therefore conceptualized as a function of the relative number of individuals that have opted for an alternative against another one (Orléan 1995, Dosi et al. 1995). Precisely when orientation is on averages rather then on sequences, it can be assumed that not all individuals will be conscious of being part of a herd. Assuming that individuals are unclear, i.e. unconscious about being part of a cascade, both the probability of the advantageousness of the dominating alternative as well as the certainty with which the signal will be assessed as being accurate will be systematically overestimated (Orléan 1995) leading to a higher information value of the cascade.

To empirically test the model, categories must be identified that allow for visibility of former decisions by successive individuals as well as presentability of aggregated market data. Market-process related data satisfies both of these conditions. Considering the presence of a new technology, the degree of diffusion is used as an appropriate measure. Degree of diffusion levels resemble the relative market share of a technology. However, while the term market share is usually associated with a company-based measure, the term degree of diffusion rather hints towards an industry-wide measure of the aggregated number of participants or users of a technology. It therefore better suites the intuition of a cumulated amount of previous public adoption decisions, while abstracting from uncertainties as regards particular suppliers.

ii. Heterogeneous Signal Qualities

Attempts to distinguish the quality of signals can be summarized into those that focus on information costs (Burguet and Vives 2000, Feltovich 2002, Kraemer et al 2006) and those who focus on heterogeneous preferences (Zhang 1997, Grenadier 1999, Smith and Sørensen 2000, Goeree et al. 2007). Based on the latter approach this paper aims to make a two-fold distinction in private preferences. On the one hand, it can be assumed that individuals are generally prone to attach more value to their own personal private signals than to alien private signals, hence raising the issue of heterogeneous signal qualities (Goeree et al. 2007). Confidence in one's own ability to judge further expands the gaps between signal qualities (Dassiou 2000). On the other hand, an adequate modeling of the decision process at hand requires acknowledging that individuals may experience different magnitudes of uncertainty ex ante as well as they may come to different evaluations and therefore face signals of different intensity. This leads to a distinction of two separate dimensions of signal quality: Signal intensity and signal precision. Signal intensity relates to the power of the signal and delineates the expected level of payment when choosing one of the options against the other. Signal intensity is therefore appropriate for modeling heterogeneous consumer preferences. Signal precision in turn relates to the probability of facing a correct and accurate signal, respectively. It is therefore closely associated with the former conception of signal quality. However, in opposition to the classic model, signal precision is assumed to vary across individuals, too.

Including signal intensity and thus heterogeneous signal qualities results in further deviations from Baysian optimization behavior. However, in opposition to the consideration of aggregated adoption decisions, here the deviation translates into a systematic overvaluation of one's own private signals. As soon as adopters are aware of the fact that decisions are motivated by different preferences, the value of public signals decreases in relation to one's own private signal. Consequently, different preferences may produce different utility ratios between the two alternatives and therefore have different preference outcomes. These may bring counter-cascade decisions into life as an appropriate reaction to individual utility optimization processes (Nelson 2002). Accounting for this relation, the model is now able to explain cascade deviating behavior without invoking exogenous shocks. Rather, fragility becomes a possible and model endogenous feature of the cascade.

From an information economics perspective the individual level of search utility can be interpreted as an appropriate measure for signal intensity. Since the utility of a product is defined as the value of the combination of its search, experience and credence qualities and search qualities are the only ones ex ante assessable, search utility is the assessment's result. Search utility is initially the sole ground for individually formulating a preference for one of the existing alternatives based on the evaluation of their quality. Taking into account the existence of two alternatives, signal intensity for one alternative can be expressed as the perceived utility ratio of the two alternatives. As perceived utility purely stems from evaluation of search qualities, signal intensity can also be labeled as the ratio of search utility. By measuring individual cost-benefit analyses of search qualities one can renounce presenting abstract pre determined signal qualities in a given empirical design.

Decreasing levels of signal precision on the other hand can be expected to go in hand with undervaluing one's own private signals, assuming that former adopters had more precise signals (Huang and Zang 2003). The propensity for imitation is therefore assumed to rise with decreasing levels of signal precision and increasing levels of public information quality (Hirshleifer and Teoh 2003).

Signal precision in turn can be interpreted as the individual proportion of search qualities of a product or a service. As broadband is generally characterized by relatively high proportions of experience and credence qualities, the level of uncertainty is ex ante expected to be rather high. Hence, private information only indicates with some probability significantly lower than 1 the accurateness of one's own utility considerations and therefore the predominance of one technology over the other. The probability directly depends on the level of uncertainty which results from the perceived proportion of experience and credence qualities.

The higher the proportion of search qualities, the more likely signal intensity will be accurately assessed. This probability can therefore easily be translated into the relative proportion of search qualities and thus represents a measure for signal precision. It shows with which certainty the adopter can rely on his evaluation and the resulting search utility ratio. Consider the case when broadband is conceived of being a 100% search purchase – signal precision in this case becomes 1 and is at its maximum. In this situation no uncertainty remains after the evaluation of the two alternatives. The decision is purely geared to the alternative offering a higher utility level. Again, information economics foundation allow for individual measures of signal precision without requiring the use of predetermined stimuli in a given empirical design.

iii. Consequences for the Buying Decision

Given the two opposing effects on cascade fragility resulting from the model extension, the question arises which implications ensue for the individual decision. Now, the private signal quality is contrasted with the subjectively assessed value of the public information from the cascade. Basically, decisions in such a model are reached by considerations of expected utility values. In other words, utility ratios stemming from the two alternatives are evaluated under the prevalence of uncertainty. Herd behavior arises when individuals adopt an alternative in opposition to their private signal, thus implying expected utility derived from the cumulated public adoption signals is higher than expected utility derived from the private signal. Hence, endogenous change in adoption behavior is only feasible when the ratio of expected utility turns around. In this case, the private signal of an individual must be capable to overcompensate the cumulated public signals.

The fact that two opposing effects are considered leads to the supposition of a trade-off relationship between those two variables. Consequently, intervals are expected to be identifiable in which the quality of the private signal recompenses for the quality of the public information leading to cascade deviating behavior. On the other hand, intervals will exist, where the value of the public signals is associated with levels of private information quality leading to decisions perpetuating the herd. However, identifying such relationships can never take place without considering the specific market and the related market participants. In the present case the task is to find such relationships for the binary decision problem between the choice of DSL and Cable technology. Therefore the subsequent empirical study aimed at identifying transient probabilities for the adoption decision between DSL and Cable while taking into account the quality of private and public information. Individual threshold levels were measured at which a switching behavior could be projected and was likely to be observable. Based on the above thoughts, following research hypotheses can be stated:

H1: *Broadband buying processes are associated with higher levels of experience qualities than credence qualities.*

H2: *Broadband buying processes are associated with higher levels of experience qualities than search qualities.*

H3: *Broadband buying processes are associated with higher levels of credence qualities than search qualities.*

H4: *The adoption probability increases with increasing degree of diffusion levels.*

H5: *The influence of the degree of diffusion level on the adoption probability is lower with existing experience of broadband purchasing.*

H6: *Signal precision is higher for adopters with existing experience of broadband purchasing.*

H7: *Levels of uncertainty associated with purchasing processes of broadband decrease with rising levels of signal precision and are lower for adopters with experience of broadband purchasing.*

H8: *The adoption probability increases with the level of private signal quality.*

- *H8.1:* *The adoption probability increases with rising levels of signal intensity.*

- *H8.2:* *The influence of signal intensity on the adoption probability increases with rising levels of signal precision.*

H9: *Individual threshold levels of signal quality and degree of diffusion combinations can be identified that lock-in the market on one of the two technology alternatives.*

3 Research Design, Sample and Methods

The aim of the empirical study was to find evidence for the existence of herding mechanisms in the adoption of broadband technologies in Germany and to analyze their stability and persistence. The study has been conducted with the help of a web-based tool with 424 students and associates from the FU Berlin, TU Chemnitz, LMU München and the Universität Zürich. It can be separated into three distinct parts:

1. Questionnaire

The survey part consisted of 7 items in total. Most of the item formulations were based on Weiber and Adler (1995) and Adler (1998). However, original formulations were converted to suit the domain of broadband purchases. They aimed at measuring the following concepts:

i. The magnitude of individually perceived proportions of search, experience and credence qualities with broadband buying processes.
ii. The magnitude of individually perceived uncertainty with broadband buying processes.
iii. Existing personal experience with broadband buying processes.

iv. Broadband technology temporarily used by the participant.

2. Simulation of Broadband Buying Decisions

In the center of the study the influence of the degree of diffusion on the buying decision was investigated against varying levels of cost-benefit ratios of broadband offers, while simultaneously accounting for a high uncertainty environment. For that reason each participant was successively confronted with five buying decisions between two alternative product offerings of DSL and Cable technology, respectively. Each offering varied as regards its degree of diffusion and cost-benefit ratio. By using a projective design, the participant was asked to assist a friend in his product choice by indicating the better product from his/her individual standpoint. For this purpose, both DSL and Cable product cards were displayed, indicating varying levels of speed, price and contract duration with three distinct parameter values for each product feature. Selection of these features was based on pretests from over 50 broadband qualities potentially associated with broadband. However, introducing uncertainty, question marks were indicating no available information on values for interference liability and customer service, as information on these features was ex ante not available. Left-right positioning between the DSL and Cable product card was randomly alternated as well as the order of the presented product features on the cards to avoid systematic biases. Based on pretest conjoint analyses two five-pair card combinations were chosen from a total number of 729 potential card pairs to be individually presented. To increasing variance in the perceived utility ratios of the presented product cards, two groups were differentiated based on former experience with broadband purchases. The goal was to approximate ex ante defined variance producing ratio levels of 0.75, 1, 1.25 and 1.5. The last pair represented identical parameter values except for technology. The sequence of the individual pair's presentation was kept random for each participant.

In addition, both product offerings varied in terms of their degree of diffusion, represented by written figures as well as in graphical form (as a pie chart colored in blue and green). Note that both figures summed up to 100% and DSL diffusion degrees ranged from 50% to 97% with corresponding Cable diffusion degrees from 50% to 3%. The figures were randomly assigned within 5 groups of 50%-59%, 60%-70%, 70%-80% and 80%-97%, so that each participant faced one decision within each of the intervals in a randomized interval order.

3. Conjoint Analysis

In order to obtain individual measures of the presented cost-benefit ratios, a classic conjoint analysis with a partial profile approach was conducted following the buying simulation. The conjoint measurement only served as a tool for estimating individual utility ratios within the buying simulation and did not aim at identifying optimal product designs for marketing broadband services. In order to avoid survey drop-outs due to time length, hierarchical, choice-based or adaptive conjoint procedures were disapproved. In order to keep desired validity and reliability high, the number of presented stimuli must be kept low (Green and Srinivasan 1990). Thus, considering a 3x3x3x2 design with 54 potential stimuli, an asymmetrical reduced design with nine stimuli to evaluate obtained. Based on approximations of real broadband offers, following values were selected to represent values of product features:

1. price (29,90 €; 34,90 €; 39,90 €)
2. speed (1 Mbit, 4 Mbit, 8 Mbit)
3. contract duration (1 month, 12 months, 24 months)
4. technology (DSL, Cable)

Ranking of stimuli was chosen as an appropriate evaluation method of the preference order. The reason was mainly to gain a better manageability by the participants and higher validity (Green and Srinivasan 1978). Ranks were assigned to fields numbered from 1 to 9 and representing the preference order, leaving the participants to assign each field with the respective product cards of desire. This further enables a metric interpretation of the assigned values. In order to reach a higher goodness of fit in measurement, participants were asked to do an exercise work in conjoint analysis before undertaking the actual task. After successfully finishing, the main task was to order nine different broadband offers in accordance with personal preferences. The order of the stimuli displayed as well as the order of the cards' product features were randomized. Eventually, after successfully finishing the preference ordering, participants were asked to accomplish a hold-out task based on choosing first-best and second-best alternatives from a set of four stimuli (Huber and Hansen 1986).

4. Empirical Results

Results were achieved by employing quantitative statistical methods including ANOVA, MANOVA, conjoint analysis and logistic regression analysis.

To evaluate H1, H2 and H3 29 participants were sorted out from the final analysis for showing inconsistent answers relating to the measurement of search, experience and credence qualities. Overall, 365 valid observations obtained. Results show no significant differences (t - statistics = - .417, p= .677) between the average magnitude of perceived experience (31.35%, sd = 15,05%) and credence qualities (31.96%, sd = 19,77%). The relative proportion of search qualities (36.69%, sd = 21,39%) lies significantly above the proportions for experience and credence qualities (at the 2% level) leading to rejection of H1, H2 and H3. However, H2 and H3 can be found be confirmed for female subjects (significant at the 1% level). The same holds true for subjects with purchasing experience (significant differences at the 5% level and 1% level, respectively). Thus, H6 can be found to be confirmed as well.

Pearson's correlation coefficient between uncertainty and signal precision of 0.612 at the 1% level shows strong support for the first statement of hypothesis H7. Furthermore, subjects with prior purchasing experience show significantly lower levels of uncertainty of approximately one third than subjects without (significant at the 1% level) leading to confirmation of the second statement of H7 as well.

To test hypotheses H4, H5 and H8, aggregated data analysis was carried out treating each individual decision as a separate case generating 1,196 observations in total after data cleansing. Hierarchically well formulated binary logistic regression models were estimated (Jaccard 2001 p. 15ff) with stepwise inclusion of additional explanatory variables. The models aimed at measuring the effect of signal intensity and degree of diffusion as first-order independent variables as well as moderating effects (Baron and Kenny 1986 p.1174) by signal precision and prior purchasing experience on the adoption probabilities for DSL and Cable, respectively, as the dependent variables. Age, gender and field of study were used as control variables. Log-Likelihood-Ratios based on Chi^2 distributions served to compare successive nested models (McCullagh and Nelder 1989). As adoption decisions stemming from one participant cannot be treated as independent, robust estimators were employed by clustering individual decisions (Hosmer and Lemeshow 2000 p. 308ff).

Results show strong support for the final model specification accounting for all postulated first-order effects as well as the moderating effects. Nagelkerkes-R^2 of .403 indicates good model fit. 41% of formerly not explained variance can be elucidated by the model signifying good prognostic efficiency as well (Menard 2001 p. 28). Coefficients' estimates confirm H4, H5 and H8.1 and H8.2 as can be seen in Chart1. An increase in signal intensity (which translates into an increase of the Cable offering utility relative to the DSL offering utility) reduced the adoption probability, whereas an increase in the degree of diffusion of DSL increases the adoption probability of DSL. Both coefficients are highly significant. However, the effects of signal intensity and degree of diffusion are both dependent on the moderator variables signal precision and prior experience. The first interaction term indicates that higher signal precision is associated with stronger effects of signal intensity on the adoption decision. The second interaction term indicates that the effect of the degree of diffusion on the adoption decision is intensified when no prior purchasing experience exists.

Chart1 : Regression results of final model (fully specified)

Gender	Age	Field of Study	Signal intensity	Degree of diffusion	Signal precision	Experience	Signal intensity* Signal precision	Degree of diffusion* Experience	Constant
-0,14234	0,00364	0,39741	-0,01279	0,0542	0,03131	2,23021	-0,00034	-0,03174	-1,91602
(-0,19692)	(-0,02417)	(0,16982)*	(0,00474)**	(0,01014)***	(0,01245)*	(0,85304)**	(0,00011)**	(0,01178)**	(0,97601)*
* p<0.05, ** p<0.01, *** p<0.001; robust standard errors in paenthesis									

To test hypothesis H9, conjoint analysis results were utilized to examine decisions on an individual level. The basis idea was to estimate individual levels of compensating utility of the Cable technology for given degree of diffusion levels of the DSL technology. After data cleansing 211 remaining cases were analyzed by making use of the following procedure: To calculate individual threshold levels, the value of each decision's signal intensity – as an expression of the relative utility advantage of the Cable technology to the DSL technology – was divided by the value of the degree of diffusion level of DSL in the respective decision. Division generates an expression of the relative advantage of Cable vs. DSL accounting for both, signal intensity and degree of diffusion level in each decision. Summing up all individual decisions for DSL and Cable and dividing by the number of decisions in favor of DSL and Cable, respectively, RA_{Cable} and RA_{DSL} for each individual j obtain as follows:

1. $$RA_{Cable;j} = \sum_{i=1}^{n_j - m_j} \frac{\dfrac{\dfrac{SearchUtility_{Cable;i;j}}{SearchUtility_{DSL;i;j}}}{DegreeofDiffusionLevel_{DSL;i;j}}}{n_j}$$

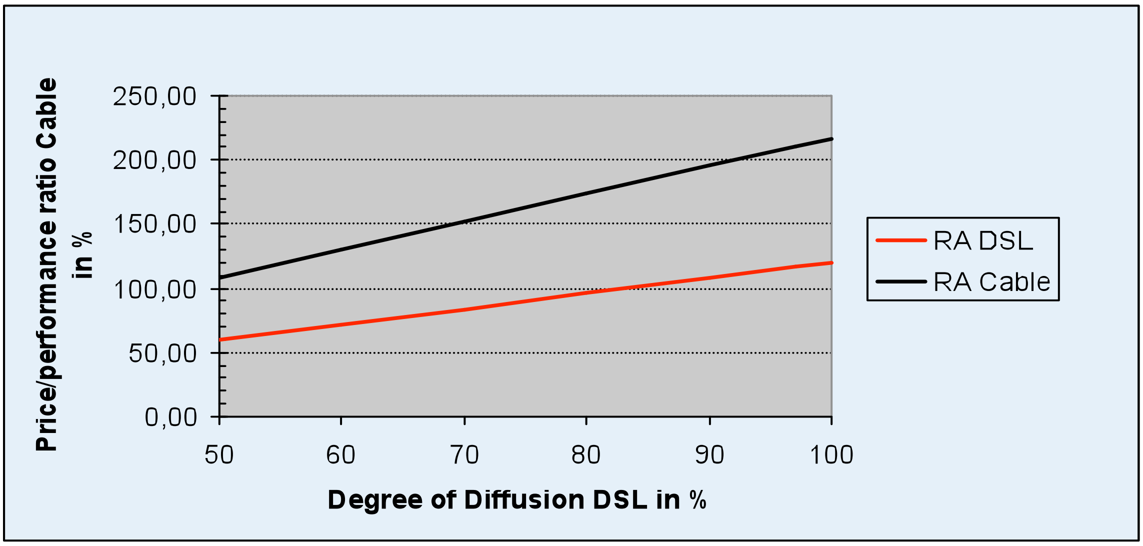
2. $$RA_{DSL;j} = \sum_{i=1}^{n_j} \frac{\dfrac{\dfrac{SearchUtility_{Cable;i;j}}{SearchUtility_{DSL;i;j}}}{DegreeofDiffusionLevel_{DSL;i;j}}}{n_j}$$

with n_j = the total number of decisions of individual j m_j = the number of decisions in favor of the Cable technology

The estimation of individual relative advantages for both technologies is based on mean formulation. Though desirable, no linear relations can be considered as the maximum of decisions in favor of one of the two technology alternatives does not exceed the number of four, turning attempts to estimate non-linear relationships futile. As linear relationships are estimated, the resulting values for RA_{Cable} and RA_{DSL} can easily be interpreted as the slope of a compensating line leading to the following interpretations: On the one hand, any point above the RA_{Cable} line represents combinations of search utility ratios and degree of diffusion levels at which the participant would opt for the Cable offering on average. On the other hand, any point below the RA_{DSL} line represents combinations of search utility ratios and degree of diffusion levels at which the participant would opt for the DSL offering on average. The range between the two lines contains combinations which represent stochastic uncertainty. It can therefore be considered an interval in which the individual's behavior cannot be predicted by the estimates obtained from the survey.

Accounting for cases with five decisions only which split up into four groups of 4:1, 3:2, 2:3 und 1:4 decisions of Cable vs. DSL, ANOVA testing does not display significant group differences (F = 1.055, p = .370 and F = 1.694, p = .170), hence allowing for aggregation of the individual data of the remaining 193 participants as depicted in Chart 2.

Chart 2: Utility compensation levels



5 Discussion and Conclusion

From information cascades theory it follows that private signals for technology choice can be neglected in favor of information stemming from predecessors' adoption decisions – this information can be obtained by communication and observation behavior. Based on that, the contribution of this paper is to show that such behavior can trigger path dependent processes leading to stable lock-in patterns. Later adopters are more likely to obtain information about the previously more intensely used technology. Hence reduction in uncertainty and therefore an increase in expected utility for this alternative augments the probability of opting for the formerly more frequented alternative. At the same time adoption decisions form an informational feedback in the sense that an adoption decision increases a) the publicly observable relative market share of this technology and b) the number of potential providers of experience information for subsequent adopters. This in turns raises the probability of the dominant technology to be chosen by the subsequent adopter, leading to a self-stabilizing increasing returns mechanism at which one technology comes to dominate the market – as it is the case of the German Broadband Market. A crucial assumption for such path dependent processes is the initial advantage of one alternative over the other.

The empirical model reveals broadband buying processes being associated with high levels of uncertainty, thus making the market vulnerable to informational feedback generated by initial advantages. Although H1, H2 and H3 were globally not confirmed, the average relative proportion of broadband qualities ex ante not assessable makes up for roughly two thirds (65.5%) of overall product qualities, thus substantially preserving the nature of a high uncertainty good. Degree of diffusion levels and signal quality were shown to have an effect on the adoption probabilities. Applying the empirical results to the actual degree of diffusion level of DSL on the German broadband market of 97%, a minimum of roughly 16% more utility for a Cable offering vs. any DSL offering is required to be taken into consideration by the adopters. This figure represents the minimum lock-in level. At the same time, Cable offerings providing a 117% benefit will certainly be chosen on average. This figure in turn would represent the maximum lock-in level of the DSL technology. Any benefit beyond that would trigger significant Cable adoptions. In this respect the model offers an approach of measuring lock-in levels by simultaneously offering implications of how to overcome existing technological paths.

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