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Information externalities and search behaviour in a dual technology choice model – the case of German Broadband

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. 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 are expected to converge, when the two competing technologies are relatively similar in terms of performance and pricing. In order to explain asymmetric consumer adoption behaviour an information cascades model is employed accounting for initial movements during the diffusion process. In order to test the model an empirical web-based buying decision simulation is conducted to evaluate the impact of former experience on the individual buying decision. The results offer some insights into the formation of informational self-reinforcing mechanisms leading to path dependency dynamics and potential lock-in on technology markets.

1. Introduction

In comparison to leading and economically powerful countries within and outside the EU, the diffusion of German broadband falls far short of international penetration rates (Bitkom 2005, OECD 2004). Furthermore, current growth rates in adopters do not make up for below average penetration rates, widening the existing gap continuously. From an economic perspective higher broadband penetration rates are associated with positive effects on economic growth, innovative ability and GDP by stimulating investments and the diffusion and use of new applications and services (DIW 2004, DTAG 2006). Hence, addressing a critical issue when considering causes for 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). Such statements may serve political actors as a guidance to shape the regulatory framework in order to enable the emergence of a friendly environment fostering infrastructure competition. Although several initiatives have been undertaken in Germany, relevant infrastructure competition has not emerged yet (Bitkom 2005). The German broadband market exemplifies an unparalleled case of persevering dominance of a mono-technology broadband internet access structure. Almost 96% of all existing broadband connections are built up by using the DSL technology (BNetzA 2007a). While the Cable technology 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 comes 2nd largest worldwide behind the US (Beckert et al. 2005, Gries 2003). However, in order to enable internet traffic the infrastructure must be technically upgraded to allow for bi-directional data transfer. Cable companies continuously invest in their infrastructure to offer not only internet access but also digital and interactive television. Estimates amount to 13.8 Mio households being ready for Cable internet traffic by the end of the third quarter in 2006 (BMWI 2007). Figures can be expected to have significantly increased by now. Especially large cities are almost entirely covered by potential broadband access via Cable.

The aforementioned studies give insight into relevant factors influencing the diffusion of broadband but do not succeed in answering the question why the implementation of diversified infrastructure competition in Germany has failed up until today. Specific research dealing with the evolution of the Cable market in Germany offer some approaches for explanation (e.g. Büllingen and Stamm 2001, Gries 2003, DIW 2004, Heng 2005, Beckert et al. 2005, Büllingen et al. 2007). However, summing up their results, all of these works do 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 problematic process of privatisation (Kurth 2003, Fornefeld et al. 2006, BMWI 2005). In this sense they 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). At the same time it becomes clear that privatisation 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 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).

Within the framework of existing studies the consumer side has been almost entirely neglected. The aim of this paper is to take a closer look at demand side dynamics evolving from buying behaviour of innovative services such as broadband. In order to demonstrate the mechanisms at work section 2 presents an approach purely based on information economics. Thus, the first contribution of the paper is to demonstrate the underlying mechanism of the information related aspects when considering the buying decision of innovative services such as broadband and the related information gathering strategies by employing the SEC paradigm. Section 3 deals with the theory of information cascades. By taking into account the time sequence of adoption decisions in order to account for the dynamic effects of sequential adoption decisions, macro level buying behaviour resulting from adoption patterns described in section 2 is outlined. Section 4 offers an extension of the traditional model of information cascades and discusses the implications for empirical testing in the context of the SEC paradigm. The section closes with a brief literature review of related approaches and finally presents the hypotheses that have been tested in the empirical study. Section 5 describes the computer-based simulative experiment that has been conducted in order to simulate adoption behaviour of broadband consumers and test the hypotheses developed in section 4. Section 6 presents the results obtained from the empirical study. Section 7 discusses the results and offers some conclusions.

2. Micro level adoption behaviour of broadband

Based on marketing science related insights, from an information economics perspective individual buying processes can be divided into 3 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. Such services are generally assumed to have high levels of experience (and credence qualities) and low levels of search qualities (Schade and Schott 1993, Kürble 1995, Ahlert and Evanschitzky 2003). 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 uncertainty arise. They can be summarized under the terms of screening and signaling (Kaas 1991). Quality uncertainty stemming from a predominant proportion of experience qualities can be effectively reduced by recurring on experience – hence experience serves as an information substitute for ex

ante not assessable qualities and relying on experience represents an efficient strategy of information gathering (Nelson 1970, Klinkers 2001, 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 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 buying decision,** which describes the selection and decision of an offer from a multitude of comparable options against a payment (Kuß 1991). 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. The particular relevance of the information cascades (or herd behaviour) approach for the question at hand results from the following aspects:

a) Existence of uncertainty stemming from low levels of search qualities
b) Lack of own personal experience to effectively reduce uncertainty
c) Existence of two equivalent technologies without technology-specific network effects
d) Examination of the diffusion of a telecommunication innovation

3. Macro level adoption dynamics

From the theoretical standpoint as well as regards context related the concept of information cascades is perfectly suited to serve as an operational framework to analyze the underlying mechanisms involved in this buying behaviour situation, i.e. a binary technology choice between two competing ICT innovations. On the one hand it offers the possibility to integrate demand side screening and signaling mechanisms in an information economics framework and to dynamize them as information externalities. On the other hand herd behaviour has been explicitly discussed within the context of a choice between two competing technology standards. Although prediction of herd behaviour may be quite difficult, the working mechanisms on an individual level can be clearly outlined. Typically triggered by external shocks which are - in terms of size - relatively small compared to the whole system, it is a priori almost impossible to identify those shocks that may eventually prompt the cascade (Watts 2002).

The common notion of all models dealing with the phenomenon of information cascades and herd behaviour 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 available 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 behaviour, e.g. "observational learning" and "social learning" respectively (Bikhchandani et al. 1998 p.153, Vicente 2003 p.5), initiated by the observation of past decisions. It can also be conceived of as being a type of free-rider behaviour which consists at its core of taking advantages from information already gathered by prior adopters (Choi 1997).

In the Information Cascades approach, each decision taken by adopters produces publicly observable information when entering the market. Hence, becoming informative, it produces positive externalities, i.e. information externalities (Kaas 1991, Zhang 1997, Moscarini and Ottaviani 1997, Li 2004). Information cascades are therefore a special case of decision models with externalities; they characterize the impact of information externalities in binary choice situations. Although actions do not reflect actual cost-benefit analyses made by the adopters they suffice to serve as signals of product quality. Consequently they are able to initiate sustained movements of following adopters towards the established standard. The reason is, 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). Imitation of such a kind shows striking resemblance to Leibenstein's bandwagon effects (Leibenstein 1950). However, the concept of bandwagon effects does not go beyond a simple presumption of mimetic behaviour. The information cascades approach in turn is not bounded by the trivial assumption of compliant behaviour. It rather employs an economic rationale behind the underlying mechanisms without having to rely on concepts such as network effects or complementarities in consumption (Karni and Schmeidler 1989, Narduzzo and Warglien 1996).

Considering the phase of information gathering, two forms of demand side signals have been identified: Personal communication and market process related data. However, for the concept of information cascades, personal communication between individuals is negligible. Schotter (2003) shows that identical or even stronger results in the same direction, respectively, obtain when providing for interpersonal communication in the form of advice or recommendation. Cao and Hirshleifer (2002) find strong evidence that knowledge of payoff arguments only affects the duration of herd behaviour. In addition, Duan et al. (2005, 2006) were able to demonstrate that potential opposite effects of qualitative assessments are dominated if not entirely suspended by quantitative market-process related signals. It is market structure related data which inherently evokes cascading effects. Interpersonal information exchange is explicitly considered within the class of related information contagion models (Arthur and Lane 1994, Lane and Vescovini 1996, Narduzzo and Warglien 1996).

As soon as imitative behaviour establishes no further information is accumulated on the market. The reason for this is that optimal decisions of individuals are no longer based on private signals but rather based on inferences about the predecessors' uninformative signals. Due to the information loss inherent, an information cascade is always associated with a potential efficiency loss. The herd produces an externality in which personal information remains veiled (Banerjee 1992, Shiller 1995). The consequence is that 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 not depend on payoff considerations between the two alternatives obtained by personal judgements but are rather 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 dominating 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 adoption of the dominating 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.

4. A macro level model of broadband adoption behavior

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 behaviour and follow their private signal an opposite cascade can be easily triggered (Anderson and Holt 1997). This may easily happen because of small changes in public information or marginal deviations from Bayesian behaviour. 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:

1. 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 translucent chains of decisions must be rather understood as conceptual abstractions for theoretic modelling and can only be simulated under laboratory conditions. 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). Assuming a significant number of previous decisions, relative measures of this kind are not modifiable in the short run, resulting in increased stability of the cascade. 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). In other words, if the sequence is not observable, the value of the cascade information is going to be overrated as conclusions that are drawn about private signals go beyond the first two adopters of the diffusion process. Thus, subsequent information becomes informative, too. The resulting individual decisions therefore do not rely on Bayes' rule of considering only the first two decisions as informative signals, as it is the case in the simple cascades model. Rather it can be expected that the information value of the cascade is considered higher, hence exerting additional stabilizing influence on the adoption 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, prevalence rate 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.

2. Heterogeneous Signal Qualities

On the one hand, it can be assumed that individuals generally attach more value to 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 modelling of the decision process at hand requires acknowledging that individuals may experience different magnitudes of uncertainty ex ante as well as individuals 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 modelling 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 behaviour. However, in opposition to the consideration of aggregated adoption decisions, the deviation here 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 behaviour without invoking exogenous shocks. Rather, fragility becomes a possible and model endogenous feature of the cascade.

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).

From an information economics perspective the individual level of search utility can be interpreted as an appropriate measure for signal intensity. As 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, the result of this assessment is the search utility. 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 labelled 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.

Signal precision in turn can be interpreted as the individual proportion of search qualities of a product or 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 level of utility. Again, information economics foundation allow for individual measures of signal precision without requiring the use of predetermined stimuli in a given empirical design.

3. 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 behaviour 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 behaviour is only feasible when the ratio of expected utility turns around. In this case, the private signal of an individual must be capable of overcompensating for 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 compensates for the quality of the public information leading to cascade deviating behaviour. 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 consideration of 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. The empirical study aims at identifying transient probabilities for the adoption decision between DSL and Cable taking into account the quality of private and public information. Hence, it will be assumed that individual threshold levels can be found, at which a switching behaviour will be observable and probable, respectively. However, it remains open to what extent the numerical results may be transferred into other markets.

4. Hypotheses

Based on the above thoughts, following research hypotheses can be stated:

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

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

H3: Signal precision is higher for adopters with existing experience of broadband purchasing than for people without.

H4: Signal precision decreases with increasing levels of uncertainty associated with buying processes of broadband.

H5: 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.

5. Brief Literature Review

Existing works in information cascades lack a profound analysis of the effects, when allowing for deviations from sequential decision taking as well as confronting individuals with heterogeneous preferences and signal qualities. However, some works offer starting points. Considering the first aspect, some research can be found that tries to endogenize the time of decision taking while still assuming sequential decision processes (Gul and Lundholm 1995, Sgroi 2003). Studies conducted outside the area of information cascades examine the influence of variables such as market share on the decision and quality perception, respectively (Katz/Shapiro 1985, 1986, 1994, Arthur 1989). However, these studies are mainly conducted in the framework of oligopoly models when network effects are apparent. In this context the role of switching costs has been extensively studied (Klemperer 1987, 1995, Beggs and Klemperer 1992). At the same time the role of market share for the buying decision has been studied in models explicitly assuming non-rational behaviour, such as Smallwood and Conlisk (1979) who ground their results on socio-psychological assumptions on adaptive behaviour and explain the effects of market share by employing the concept of heuristics.

On the other hand, an approach to integrate the second aspect is exemplified by the work of Kraemer et al. (2006). They introduce information gathering costs in order to discriminate between private signals. The results of their experimental study suggest increased fragility of cascading behaviour. Dependence of signal quality on costs is also modelled by Burguet and Vives (2000) as well as Feltovich (2002). Both studies come to the conclusion that information cascades still emerge. An additional approach to introduce divergent signal qualities can be found in Smith and Sörensen (2000), who explicitly model heterogeneous preferences. They reason that information cascades can still be hold up. In contrast Goerre et al (2007) find evidence in laboratory experiments that introducing heterogeneous signal quality is associated with augmented fragility of the cascade. In this experiment the influence of an interpersonal variation of the probability with which the private signal is correct ("signal informativeness") on the adoption decision is examined. The modelling of distinct signal precisions can also be found in Zhang (1997) and Grenadier (1999), whereas the focus of these studies lies in an endogenization of the decision sequence and the determination of the beginning of cascade formation.

Research simultaneously studying the effect of orientation on market-process related data as well as the modelling of heterogeneous signal qualities does not exist. Furthermore, while e.g. Goeree et al. (2007) modify occurring probabilities by using stochastic term, the empirical study employed to the above model employs a method to measure these probabilities on an individual level. In this respect the study represents a pilot project from the conceptual as well as from the methodological standpoint. Neither has the effect of both variables been studied in common, nor has signal quality been distinguished in two dimensions, nor have any of these dimensions been actually measured instead of offering predefined stimuli. Therefore a distinct empirical design has to be developed, in order to test for the hypotheses.

5. Empirical Design

The aim of the empirical study is 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
2. Simulation of broadband buying decisions
3. Conjoint Analysis

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 converted to suit the purchase of broadband services. They aimed at measuring the following concepts.

i. <u>The magnitude of individually perceived proportions of search, experience and credence qualities with broadband buying processes</u>

Pretests served as the foundation to identify combinations of several items with high Cronbach's alpha. The goal was to reduce survey size and avoid participant's personal impressions of repetitive questions. First items aimed at rating assessment possibilities before and after purchase on a six-point scale from "not at all" to "very good". The reason to use a 6 point scale was to force participants to decide for either better or worse judgements and thus avoiding uninformative mean ratings. Afterwards ratings were transformed into per cent measures. Next item to measure search, experience and credence qualities aimed at directly asking for percentage assessments of the possibilities to judge product quality of broadband services. Measures from all both construct measurements were combined by generating mean percentages. The result represents a measure for signal precision.

i. <u>The magnitude of individually perceived uncertainty with broadband buying processes</u>

Measurement of uncertainty involved several items, too. First, participants were asked to assess their familiarity with broadband purchases on a six-point scale from "not at all familiar" to "very familiar". Familiarity is an inverse measure for uncertainty. Second, another item asked again on a six-point scale from "not at all uncertain" to "very uncertain" to which extent the participant ex ante believes that the broadband service will comply with his expectations. The ratings directly reflect levels of uncertainty. Again, both item scorings were aggregated by mean building.

ii. Existing personal experience with broadband buying processes

One item served to measure with binary "yes" or "no" responses whether or not the participant has experience with buying broadband access services by asking whether he has bought some broadband products in the past for himself or someone else.

iii. Broadband Technology temporarily used by the participant

The use of the present broadband technology was asked for by one item offering „DSL", "Cabel", "WiMAX", "Satellite" as well as "Don't know", "Other " and "None" as possible answers. .

2. Simulation of Broadband Buying Decisions

The core of the study was to analyze the influence of the degree of diffusion on the buying decision against varying levels of cost-benefit ratios of broadband offers, considering the prevalence of uncertainty in that situation. Therefore each participant was successively confronted with five buying decisions between two alternative product offerings of DSL and Cable technology, each of which varied as regards degree of diffusion and cost-benefit ratio. By using a projective design, the participant was asked to make a choice for a friend by selecting the better product from his individual standpoint. A situation was presented in which a friend is moving to a new town and willing to get a broadband internet access. The participant was asked to help his friend with the choice between existing alternatives of which he could only obtain information of speed, price and contract duration. No data concerning susceptibility to damage and customer service was available.

The product choice was then asked for by presenting product cards of one DSL vs. one Cable product respectively providing information on explicit levels of the above mentioned product features. Selection of these features was done by pretests from over 50 broadband qualities potentially associated with broadband. However, introducing uncertainty, question marks were indicating no information on values for susceptibility to damage 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. Only technology remained as the heading information on each card. 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. Differentiation of these two groups was based on item responses on existing experience with broadband purchases and aimed at increasing variance in utility ratios of the presented product cards with ex ante desired ratio levels of 0.75, 1, 1.25, 1.5. The last pair represented identical product characteristics except for technology. The presentation sequence of the pairs was kept random.

In addition, the degree of diffusion of both technologies in the town was presented in written figures as well as in graphical form (as a pie chart coloured in blue and green) varying with each presented card pair. 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 every participant faced one decision within each of the intervals, with 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 (Backhaus et al. 2003) 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 obtains. Based on approximations of real broadband offers, following values have been selected to represent values of product features:

1. price (29,90€; 34,90€; 39,90€)
2. speed (1Mbit, 4Mbit, 8Mbit)
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 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 (Schmidt 1996). 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 stimuli presented as well as the order of the product features on the card was randomized.

Eventually, after successfully finishing the preference ordering, participants were asked to accomplish a hold-out task, in order to check for validity of the conjoint measurement. For this, following Huber and Hansen (1986), a procedure was chosen in which the participant was faced with four stimuli, of which he was asked to make his preferred choice. From the remaining three stimuli he was again asked to make his preferred choice. The procedure was repeated with a second set of four stimuli. The stimuli were randomly selected, and within each of the two groups (experience in broadband purchases) identical with randomized order of presentation.

6. Results

H1-H2

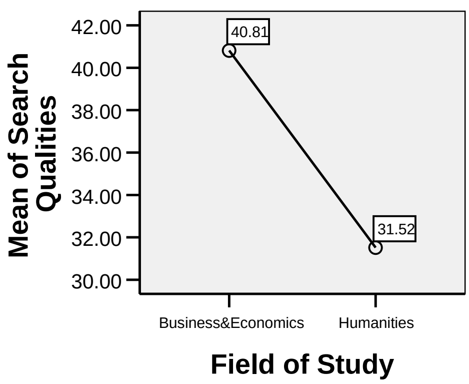
29 participants were sorted out from the final analysis for showing inconsistent answers relating to the measurement of search, experience and credence qualities. Overall, 365 valid observations obtain. Results show little differences between the average magnitude of perceived credence (36.83%) and search qualities (34.49%), statistically not significant ($t = -1.219$, $p=0.224$). Furthermore, the relative proportion of experience qualities (28.68%) lies below proportions for search and credence qualities leading to rejection of both H1 and H2. However, given the average relative magnitude of search qualities, the average relative proportion of broadband qualities ex ante not assessable makes up for roughly two thirds (65.5%), thus substantially preserving the nature of a high uncertainty good.

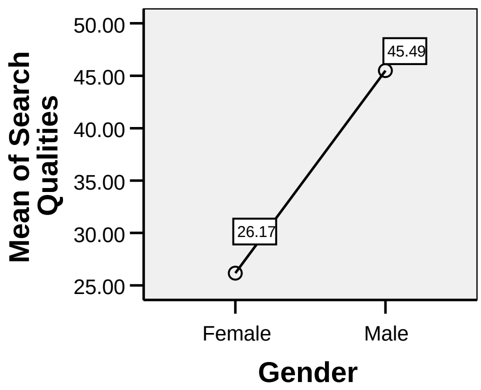
		Search	Experience	Credence
N	Valid	365	365	365
	Missing	59	59	59
Mean		34.4948	28.6761	36.8291
Std. Deviation		20.75294	12.80077	17.90211

H3

ANOVA demonstrates perceived proportions of search qualities being more than 50% higher for participants with existing experience (F = 42.681; p<0.000), thus leading to acceptance of H3.

In addition, ANOVA reveals significant group differences between males and females (F = 80.262; p<0.000), as well as between students of business and economics and students of the humanities (F-value = 16.625; p<0.000), underscoring the importance of introducing heterogeneous signal precisions. While business and economics students generally consider themselves to have a 30% better ability to assess broadband offers before purchase than students of the humanities, differences are even more striking when looking at males and females. Males believe to have an almost 75% better ability to judge broadband qualities before purchase than females.





H4

Examination of the relation between uncertainty and the magnitude of signal precision leads to confirmation of H4. The higher the perceived proportion of search qualities is, the lower is the level of perceived uncertainty before purchase. On the other hand, higher levels of experience and credence qualities are correlated with higher levels of uncertainty. All correlations are significant at the 5% level and except for experience qualities very strong at almost 0.6.

		Search Qualities	Experience Qualities	Credence Qualities
UNCERTAINTY	Pearson Correlation	-.597(**)	.164(**)	.574(**)
	Sig. (2-tailed)	.000	.002	.000
	N	365	365	365

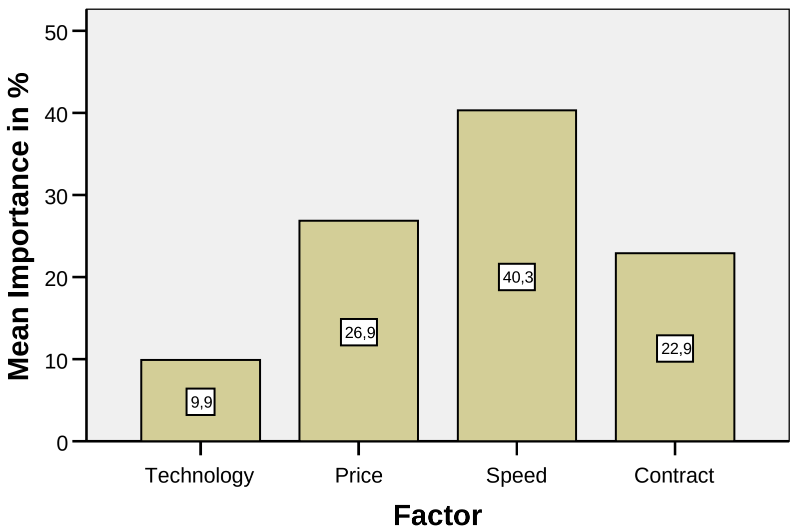
** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

H5

In order to examine H5, Conjoint Analysis results have to be evaluated in advance before utilizing them for estimation of individual and aggregated threshold levels of adoption. Although preference data was collected by ordinal rank scales, the estimation of part worth utilities was conducted by the use of OLS regression. Results do not significantly differ from non-metric procedures such as LINMAP or MONANOVA allowing for OLS estimates even when non-metric preference ordering is on hand (Carmone et al., 1978; Jain et al., 1979; Wittink/Cattin, 1981; Darmon/Rouziès, 1994). Linear relationships were presupposed between the four product features included and overall product utility. Aggregated results were calculated for 339 participants and confirm the expected relations. Whereas price and contract duration are generally associated with utility losses, with higher levels leading to higher losses, higher speed is considered a benefit, leading to higher levels of overall utility. DSL technology has a positive part worth utility, whereas Cable technology leads to utility losses. However, differences in technology only make up for roughly 10% of overall utility. Speed has a dominating importance of about 40% for overall utility, followed by price (approx. 27%) and contract duration (approx. 23%). Standardized β-coefficients are as follows: Price = -1.151; Speed = 1.748; Contract Duration = -0.364 and DSL = 0.142 (as a dummy variable).

		Utility Estimates	Standard Deviation
Technology	DSL	,142	,115
	Cable	-,142	,115
Price	29,90	-1,151	,132
	34,90	-2,302	,265
	39,90	-3,453	,397
Speed	1Mbit	1,748	,132
	4Mbit	3,497	,265
	8Mbit	5,245	,397
Contract	1Month	-,364	,132
	12Months	-,728	,265
	24Months	-1,091	,397
(Constant)		4,486	,473



Kendall-Tau correlation coefficient, expressing the correlation between actual and Conjoint ranks show is very high (0.944; $p<0.000$) indicating a very good reliability of the Conjoint measurement. On the other hand reversal examination reveals rather poor reliability, showing 174 times one reversal, 128 times two reversals, 26 times three reversals and one time four reversals, indicating that approx. 50% of all participants had at least one unexpected direction of the characteristics impact. However, Conjoint Analysis often shows that relations due to the forcing of a preference ordering. Eventually, evaluating validity shows an unusual high value of 83.9% (standard deviation = 15.85%). This can be traced back to the random selection of the presented stimuli within the validity check accidentally resulting in card sets with very high differences in product utilities, making it very easy for the participants to make a valid choice. True validity will therefore lie significantly below the value obtained and can only be roughly estimated.

Conjoint Analysis results can now be utilized to examine decisions on an individual level. The basis idea is to estimate individual levels of compensating utility of the Cable technology for given degree of diffusion levels of the DSL technology. To obtain these results the product cards involved in each participant’s decision were assigned with the associated utility values obtained from Conjoint Analysis. The ratio of the two cards, expressed as the Cable card utility divided by the DSL card utility is a measure for signal intensity of the Cable product (in relation to the DSL product). Visualizing signal intensity of the Cable offer on the ordinate and the degree of diffusion on the abscissa, for each participant five distinct points can be denoted, representing each individual decision.

Before calculating aggregated results three selection criteria were applied. First, only participants showing a validity of at least 80% were considered, which results in cutting off the lower 24.9% quantile of the remaining cases which translates into omitting additional 84 participants out of a total of 337 participants who completed the survey. Given the overestimated mean validity of 83.90% of the remaining 253 cases and common Conjoint Validity measures in between 50-60%, it should be safe to consider the top 74.1% of all cases without loosing valid observations. For participants below 80% we can be sure that Conjoint Analysis does not sufficiently well depict actual preferences. Second, decisions taken in less than 5 seconds were not considered in order to avoid bias through random decision making. Taking into account the time to read the displayed information, the time it takes to build up the site and the time to press the decision button, reasonable decisions can impossibly be taken within a very short time interval and rather represent randomly taken actions. The median of the decision time is 14 seconds and neglecting the sum of decisions below five seconds equals the lower 4.8 quantile and leads to elimination of 58 individual decisions. Third, only participants who decided at least one time for each of the two technologies were considered – otherwise no compensation levels could be identified. For those participants who decided five-fold for only one of the two technology alternatives we might infer that no compensating levels have been displayed within the five decisions. This step eliminated further 42 cases leaving 211 remaining valid cases for the final analysis.

The 211 final 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 respective degree of diffusion level of DSL present in the decision. Division results in an expression of relative advantage of Cable vs. DSL accounting for both, signal intensity and degree of diffusion level for each decision. Summing up all individual decisions for DSL and Cable, respectively and dividing by the number of decisions in favor of DSL and Cable, respectively we obtain for each individual j two values RA_{Cable} and RA_{DSL}:

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

and 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 of 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 in the chart delineated above lading 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 offer 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 technology on average. The range between the two lines contains combinations which represent stochastic uncertainty and therefore points at which the behavior cannot be foreseen by the estimates from the survey.

ANOVA testing for group differences between individuals with different numbers of decisions taken in favor of each technology shows significant differences in RA_{DSL} but not in RA_{Cable} values. However, due to the relative small number of 18 participants with less then five decisions which are divided into 4 groups with relatively small group sizes, results may be biased through the inclusion of these small groups. Accounting only for cases with five decisions which split up into four groups of 4:1, 3:2, 2:3 und 1:4 decisions of Cable vs. DSL, ANOVA does not display significant group differences (F-value of 1.055, p=0.370 and F-value of 1.694, p=0.170, respectively), hence allowing for aggregation of the individual data.

ANOVA

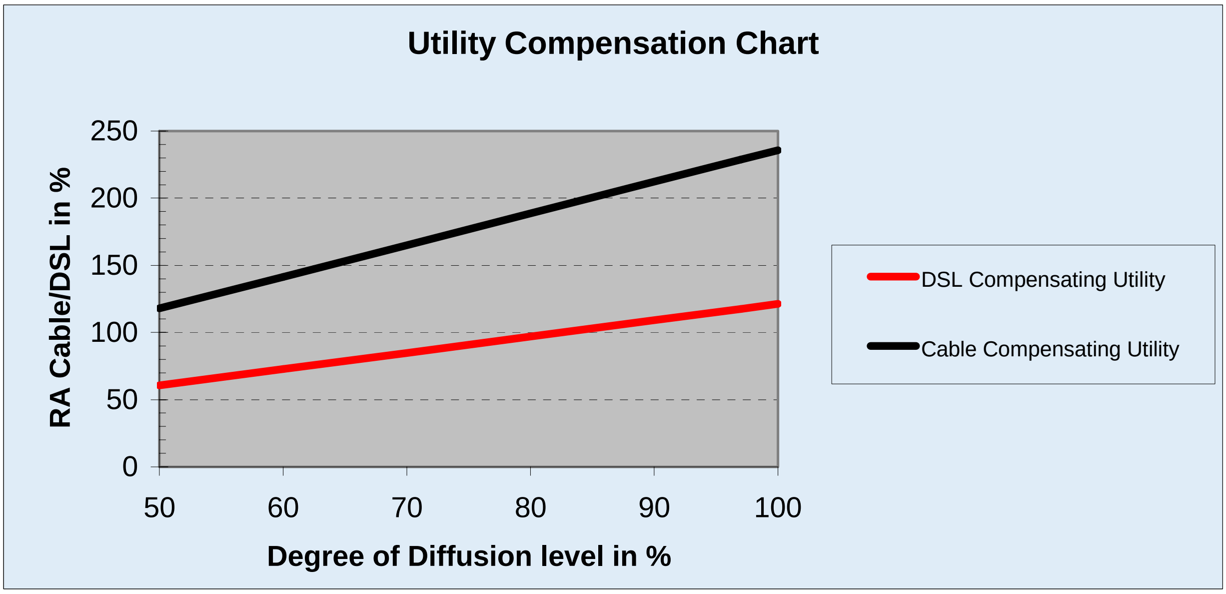
		Sum of Squares	df	Mean Square	F	Sig.
RA_DSL	Between Groups	.000	3	.000	1.055	.370
	Within Groups	.002	189	.000		
	Total	.002	192			
RA_CABLE	Between Groups	.001	3	.000	1.694	.170
	Within Groups	.030	189	.000		
	Total	.031	192			

Aggregating all individual estimates from the remaining 193 participants we obtain as mean values RA_{Cable} = 0.023574 and RA_{DSL} = 0.012122 showing an approx. 94% higher relative advantage of Cable that was present in Cable decisions than in DSL decisions as we would expect. Differences are significant below the 0.000 level.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RA_DSL	.012122	193	.0030178	.0002172
	MEANRVK_Kabel	.023574	193	.0127017	.0009143

Aggregated values can be displayed as slopes of two distinct straight lines representing compensation levels obtained from the survey. The chart shows both ways of interpreting threshold levels on the German broadband market, either as a minimum utility benefit requirement of Cable offers to be taken into consideration at all (labeled as DSL Compensating Utility) or as a minimum utility benefit requirement of Cable offers to be definitely chosen on average (labeled as Cable Compensating Utility). Any combinations between those two lines represent points of stochastic indeterminacy leading to confirmation of H5. As long as offers are between those two lines, the model does not precisely predict adoption decisions.



6. Discussion and Conclusions

From information cascades theory it follows that private signals for technology choice can be neglected in favour of information stemming from predecessors' adoption decisions – this information can be obtained by communication and observation behaviour. Based on that, the contribution of the paper is to show that such behaviour 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 a rise in expected utility for this alternative augment 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 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. Applying the empirical results to the actual degree of diffusion level of DSL on the German broadband market we obtain as a minimum requirement for Cable offers to be at least 18% better than comparable DSL offers to be taken into consideration on average at all. This figure represents the minimum lock-in level. However, Cable offers providing a 129% benefit advantage 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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