The Impact of Direct and Indirect Network Effects on the Diffusion of Communication Standards

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Abstract

Expectations about stand-alone and network benefits determine the adoption decision of customers and hence the diffusion of standards. To increase the number of adopters of a communication standard like EDI, not only the ability to exchange messages (as a source of direct network effects), but also the provision of complementary services such as standardized master data, e.g., by establishing a central, industry-wide EDI data pool (as a source of indirect network effects) is important. We thus examine the differing impact of direct and indirect network effects on the adoption and diffusion of communication standards. The incorporation of both network benefits into an agent-based simulation model may help to better understand the underlying diffusion problem.

1. Introduction

The need for efficient communication arises whenever independent business partners have to coordinate their interdependent activities. Communication standards meet these demands in order to automate and improve business processes within and between organizations. The difficulty with communication standards is that an adopter's benefit largely depends on her business partners' adoption and use of the same standard. As a result, the decisions of otherwise autonomous adopters become interdependent and network externalities emerge. In the economic literature, the resulting coordination problem has been discussed as the standardization problem [9]. Subsequently, less advantageous diffusion results of the standardization process may emerge, i.e. often networks of standard users are too small [44]. The basic argument in network effect theory is that direct network effects imply a start-up problem, i.e. no one wants to be the first to invest in standardization and risk being left with a standard that does not attract enough adopters to become profitable enough to use [3]. In the case of Electronic Data Interchange (EDI), the actual diffusion has remained below expectations, even in highly developed countries and industries [31, 40, 42]. While at first sight it is simple to explain this phenomenon using the network effect argument above, the challenge remains to explain why there are clusters of successful standard users (e.g., among small and medium-sized enterprises (SMEs) in Denmark or Germany [8]).

This research intends to contribute to the diffusion of standards literature by formally separating direct and indirect network effects and by examining the different impacts of these drivers on the diffusion process. Overall, the explanatory power of most existing models is limited as large parts of the literature only consider the direct network effects associated with EDI communication and neglect the impact of indirect effects (with exception of research conducted by Damsgaard & Lyytinen [19, 20] or Beck & Weitzel [6]). Therefore, we focus on the dynamic interplay of both network externalities and their impact on diffusion without any central coordinator subsidizing new adopters (see [37, 43]). A further extension to previous literature is the consideration of heterogeneity in actor sizes. Based on a formal agent-based simulation model and on empirical EDI data from the German office supply industry, we conduct simulations in order to reveal the adoption decision of SMEs based on benefits from network effects and the impact to the overall diffusion pattern in the industry. Section 2 provides a review dealing with the related literature on network effect theory. From there, a diffusion model is developed to determine the influence of direct and indirect network effects on adoption and diffusion (section 3). Section 4 applies the diffusion model to an agent-based simulations approach and also provides details of the underlying EDI diffusion case in the German office supply industry. Section 5 provides a conclusion and outlines further research demands in this field.

2. Literature Review

As theoretical foundation for our conceptual framework, we draw from network effects theory and the literature on EDI and discuss the implications of direct and indirect network effects on EDI diffusion.

The diffusion of communication standards and especially EDI among SMEs seems to be one of the most challenging tasks in information technology adoption [6, 13, 30]. While traditional EDI among large enterprises has been discussed for decades in the context of efficiency potentials and costs savings from standardization, it has been almost impossible to incorporate SMEs into electronic supply chain networks [28]. The main reasons discussed in literature are the high setup and maintenance costs for EDI, as well as the often missing IT know-how among SMEs [7], as an overview of EDI adoption studies among SMEs suggests [12]. Often, the return on investment into an EDI solution is only calculated by the savings of information exchange (as part of the direct network effects), neglecting the fact that SMEs rarely reach a level of EDI messages justifying adoption (see [41, 48] for a multidimensional EDI evaluation). In general, small firms do not have enough order, invoice, or logistic messages to justify the high setup costs, or even lack the ability to process EDI data [28].

While traditional network effect theory contributes greatly to the understanding of standards and compatibility issues [18, 22, 25, 26], externalities and positive feedback effects [1, 2, 21], critical mass phenomena [23, 24], bandwagon [32, 38, 39] or lock-in effects [17, 27] associated with the evolution of networks, much research is still needed.

This is especially true when trying to understand many observable real world phenomena. In particular, the specific interaction of potential standard adopters within their economical environment is often neglected. This means that most research approaches assume identical network effects for all network participants, regardless of the network topology and "network embeddedness". As a result, important phenomena of modern network effect markets, such as the coexistence of different standards despite strong network effects or the fact that strong players in communication networks force other participants to use a certain solution cannot be sufficiently explained using the existing approaches [33, 46]. Consequently, the diffusion of a network-constituting standard does not necessarily depend on a few early innovators but on the benefit accompanied by the adoption of a new standard recognized by a larger group of adopters in the same industry or market. A review of the literature shows that the distinction between direct and indirect effects is commonplace in the introductions to most articles on network effects. Nevertheless, the distinction is not often applied to the analyses as illustrated in Table 1. The table also provides an overview on prior standardization models that have been used and adapted for the research model described in this paper.

Table 1: Conceptual grounding and prior standardization models applying network effects

Authors	Approach	Important results and conclusions	Limitations
Clements 2004 [15]	Models hardware and software paradigm for an equilibrium analysis	→ Direct and indirect network effects cannot be conflated, since they have different impacts on standardization (tendentially under-provision in the first case and over-provision of standardization in the second case). → Focus: compatibility, continuum of compatibility.	→ No interdependencies modeled: The paper considers effects of direct and indirect network effects separately from each other.
Clements & Ohashi 2004 [16]	Analysis of the U.S. video game market focused on hardware adoption and software provision by using an adapted model and empirical data	→ The market is characterized by too few indirect network effects or undersupply of complementary software → The elasticity of adoption with respect to console price and software variety over the life cycle of the video game console is estimated. → The estimation results suggest that, while a sufficiently large set of software (i.e., indirect network effects) may be necessary to launch a system, a platform provider should use penetration pricing (i.e., subsidies) to encourage adoption in the start-up phase. Awider variety of software might be crucial for attracting later adopters to the platform.	→ The model neglects possible direct network effects and consequently impacts on the adoption decision, e.g., in the case of online video game communities. → The diffusion model used considers only indirect network effect.
Lim, Choi	Simulation ap-	→ The late take-off phenomenon can be partially explained	→ diffusion model discusses

& Park 2003 [35]	proach applies the parameters of a diffusion model (threshold concept).	by to the low heterogeneity in the threshold value distribution of the potential adopters. → Subsidies or zero pricing are discussed as a possible solution to the start-up problem by early promotion diffusion to reach the critical mass earlier.	subsidies as start-up solution but remains imprecise how to solve decentralized problem. → model only takes direct network effects into account.
Weitzel et al. 2003 [47]	Simulation approach based on the decentralized standardization model	→ The authors introduce information asymmetry and uncertainty into the standardization model. → Potential adopters now have to estimate the probability that their partners will also standardize. → Network topologies have a significant influence on the diffusion result.	→ As in centralized standardization model, model does not differentiate between direct and indirect effects. → start-up problem of standard diffusion not discussed.
Buxmann 2001 [10]	Analysis of standard software market and influence of penetration pricing on diffusion.	→ Apart from direct and indirect network effects, the paper also discusses possible stand-alone benefits associated with the adoption. → The used simulation model incorporates direct network effects and an installed base in order to analyze the standardization of software markets. Subsidies (penetration pricing) help to break into a market.	→ Although direct and indirect network effects as well as stand-alone benefits are discussed, only direct network effects are considered in the model.
Buxmann et al. 1999 [11]	Analysis of individual adoption decision-making problems.	→ The model introduced solves the central standardization problem by calculating the optimal number of network participants based on given communication costs savings (direct network effects) and standardization costs.	→ The standardization model introduced is centrally or hierarchically oriented and cannot be applied on markets. → The model considers only direct network effects.

2.1. Literature conclusion

For an individual standards adopter, negligence to adopt a standard can be explained by incomplete information about the standard at the time of the adoption decision, heterogeneous preferences among potential adopters or uncertainties about the adoption decision of the other market participants. As a consequence, it is individually dominant to wait for others to adopt first since early adopters face the risk of being left with a standard that might turn out to be unsuccessful later [14]. This start-up problem can prevent any adoption at all. Also, existing diffusion models do not consider direct and indirect network effects and their interplay. However, a simultaneous analysis seems to be pivotal in explaining the diffusion of network effect goods.

3. Research Model

In this section, we develop a formal model used for agent-based simulations to examine the impact of direct and indirect network effects on both individual adoption and global diffusion processes. The model is based on a previous generic model on standardization behavior by Weitzel et al. [45]. Differences and extensions are outlined during the model description.

In contrast to a random or close topology used in Weitzel et al.'s work, our model consists of two clusters of actors – SME retailers (R), represented by index i, and larger suppliers (S), represented by index j. Both groups interact along a supply chain and therefore exchange commercial data (e.g., via fax, mail, or EDI) but not within each cluster.

The parameters are defined as follows:

N^R = total number of **r**etailers in the network

B_t^R = number of **r**etailers using the standard in period t (i.e., installed **b**ase)

N^S = total number of **s**uppliers in the network

B_t^S = number of **s**uppliers using the standard in t (i.e., installed **b**ase)

i = index of retailers, j = index of suppliers

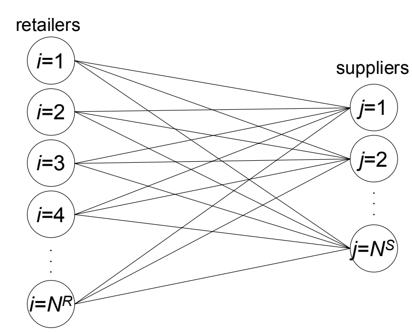

Figure 1. Network structure

All actors are able to adopt a superior standard for achieving cheaper communication. (In the following, we will use extensively the example of adopting an EDI standard in favor of previously used fax technology.)

The model assumes all actors deciding independently in favor of or against adopting EDI. The model assumes multiple periods, which allows actors to revise their decision based on observations of their communication partners' decision behavior. The decision calculus considers costs for setup and operations vs. cost savings from cheaper communication and benefits from indirect network effects.

Setup and Maintenance Costs: If firms have never used EDI before (defined as state 1), but decide to use the available EDI standard in favor of a fax machine, they will have to invest at least in software for the EDI converter (used to map the internal data with the EDI message structure and vice versa). Apart from these setup costs, there are periodical software maintenance and service fees. After the technology investment has been completed (i.e. state 2), the deprecations are sunk costs, not anymore relevant to future decisions about using EDI or not. The following cost parameters are used in the model:

k_{it}^{R1} = decision-relevant fixed costs of retailer i in state 1 (i.e. no EDI converter) and period t

k_{it}^{R2} = decision-relevant fixed costs of retailer i in state 1 (EDI converter available) and period t

k_{jt}^{S1} = decision-relevant fixed costs of supplier j in state 1 (no EDI converter) and period t

k_{jt}^{S2} = decision-relevant fixed costs of supplier j in state 1 (EDI converter available) and period t

The differentiation between setup and operations costs, leading to different fixed costs in state 1 vs. state 2, represents a slight deviation from the original standardization model from Weitzel et al.

Direct Network Effects (DNE): Conforming with the literature, for the following simulation model we assume that the value of the standard increases with each new adopter of the same standard [25, 29]. Nevertheless, for an individual actor, DNE are only relevant if the same standard is adopted by a communication partner (i.e., a connected actor in the network shown by Figure 1) [47]. This leads to direct periodical cost savings per link defined as follows:

c_{ijt}^{R} = retailer i's communication savings in period t, if i and j use the same standard

c_{jit}^{S} = supplier j's communication savings in period t, if j and i use the same standard.

Indirect Network Effects (INE): With an increasing number of retailers adopting a standard, it is increasingly beneficial for larger industry partners to offer additional services, e.g., standardized high-quality product- and price-data for a central EDI data pool hosted by an intermediary. In contrast to DNE, INE are based on the utilization of complementary services and thus increase with *every* additional adopter.

To explore the impact of INE in a local and controllable setting, we assume that only the retailers' benefits are affected by INE, but not the suppliers'. The resulting individual benefit for retailer i is modeled as a function of the proportion of adopters B^R compared to the underlying total population of retailers N^R, following a monotonically increasing function at a decreasing rate (equation 1). This is in accordance with previous work [4, 5]. The idea behind using the number of EDI-adopting retailers as basis for this estimation is that providers of complementary services are the more motivated to offer these (which, in turn, deliver the benefit to the focal retailer), the more retailers have adopted EDI.

$$INE_{it} = u_{it}^{I} \cdot \left(\frac{B_{t-1}^{R}}{N^{R}}\right)^{\beta} \quad (1)$$

= retailer i's individual benefit from **INE** in period t with u_{it}^{I} as an individual INE coefficient (for retailer i and period t) and β as a constant parameter between but not equal to 0 and 1. We use a conservative estimator by estimating the INE in period t based on the installed base B^R of the previous period t-1. Nevertheless, this is a quite straightforward assumption that can easily be changed and tested by applying other mechanisms. The introduction of INE into our model represents the major difference between our model and the original standardization model of Weitzel et al.

Decision Calculus: Each retailer evaluates the net benefit from adopting a new standard by comparing the anticipated benefits from direct and INE vs. the costs for setup and operations. As this decision is based on uncertainty about the partners' adoption decision (uncertainty in a *game-theoretical* sense: actors might exchange information but there is no binding agreement on mutual adoption), the decision calculus is formed by an expectation function of net utility U_{it}^{R} summing up the expected benefits and subtracting fixed costs k_{it}^{R}:

$$Exp\left[U_{it}^{R}\right] = Exp\left[\sum_{j=1}^{J} c_{ijt}^{R}\right] + Exp\left[INE_{it}\right] - k_{it}^{R}$$

$$Exp\left[U_{it}^{R}\right] = \sum_{j=1}^{J} p_{ijt}^{R} \cdot c_{ijt}^{R} + Exp\left[INE_{it}\right] - k_{it}^{R} \quad (2)$$

with $k_{it}^{R}=k_{it}^{R1}$ or $k_{it}^{R}=k_{it}^{R2}$, depending on an already existing EDI-solution (state 1 vs. state 2, cf. above).

In the second line of equation 2, the expectation of DNE has been substituted by probability p_{ijt}^{R}, which represents retailer *i*'s estimation about supplier *j*'s adoption decision in period *t*. We assume that each retailer knows the adoption state of every business partner on the supplier side, and vice versa. If the business partner is already using EDI, then p_{ijt} is equivalent to one. If this is not the case, an expectation probability must be estimated:

$$p_{ijt}^{R}=\frac{N^{R}\cdot c_{jit}^{S}-k_{jt}^{S}}{N^{R}\cdot c_{jit}^{S}} \tag{3}$$

In order to determine p_{ijt}^{R}, it is assumed that retailer *i* knows supplier *j*'s fixed costs k_{jt}^{S} and the DNE directly associated with him (i.e., c_{jit}^{S}), as well as the number of *j*'s communication partners (assumed to be potentially all retailers N^R). The numerator in (3) describes the first-best net standardization benefits of *j*. To estimate a partner's benefits, retailer *i* assumes the known c_{jit}^{S} to be representative for all other links of supplier *j*. The denominator normalizes the anticipated benefits of supplier *j* as a value from zero to one. If the fraction is negative, then p_{ijt}^{R} = 0 holds. This is the estimator of the original standardization model [45].

Analogous to the utility expectation and probability for the retailers, the corresponding equations of the supplier can be described (where U_{jt}^{S} is supplier *j*'s net benefit from adoption in period *t*).

$$E\left[U_{jt}^{S}\right]=\sum_{i=1}^{I}p_{jit}^{S}\cdot c_{jit}^{S}-k_{jt}^{S} \tag{4}$$

$$p_{jit}^{S}=\frac{N^{S}\cdot c_{ijt}^{R}-k_{it}^{R}+E\left[INE_{it}\right]}{N^{S}\cdot c_{ijt}^{R}} \tag{5}$$

with $k_{it}^{R}=k_{it}^{R1}$ or $k_{it}^{R}=k_{it}^{R2}$ and $k_{jt}^{S}=k_{jt}^{S1}$ or $k_{jt}^{S}=k_{jt}^{S2}$, depending on retailer *i* and supplier *j* being in state 1 or state 2 (cf. above).

As explicated above, the utility function of the supplier does not contain INE. $E\left[INE_{it}\right]$ in eq. (5) represents the expected utility from INE which supplier *j* believes retailer *i* will benefit from.

Based on the expected utility, each actor decides for (if $E\left[U_{it}^{R}\right]$ or $E\left[U_{jt}^{S}\right]$ > 0) or against (if $E\left[U_{it}^{R}\right]$ or $E\left[U_{jt}^{S}\right]$ ≤ 0 respectively) adoption of the standard. Retailers and suppliers can decide anew in each period for or against the standard. According to the bounded and dynamically adapted information available from past technology adoption decisions of retailer *i*'s competitors and suppliers *j*, they can adopt the standard in one period and drop it the next. (This is a realistic side condition as outlined below.)

4. Analysis

4.1. Application domain and data

As application domain, we chose the German office supply industry. With more than 95% of the retailers being SMEs, establishing EDI has been a difficult venture. We have chosen the office supply industry years ago since their topology and history in unsuccessful and successful EDI approaches to integrate SMEs offered an ideal setting to analyze the assumed network dynamics. Also, one of the authors has worked there for nearly a decade. In this industry, an intermediary was established to endorse an EDIFACT subset and to accelerate its diffusion among 9048 SMEs known in this sector. To analyze the decision whether or not to adopt an EDI solution and why, a questionnaire was sent to all EDI-using retailers (representing 5.0% of all office supply retailers in Germany) with a response rate of 15.3% in 2000. Apart from supporting SMEs in their effort to adopt EDI, the intermediary also provides a central data pool for SMEs that contains product and customized price data of all participating EDI-using industry partners.

<u>Setup and Operations Costs:</u> The EDI converter software is available to SMEs for € 1,990. Apart from the setup costs, there are monthly license fees of € 25 and monthly service fees of € 40 for the EANCOM system. Furthermore, an International Location Number (ILN) for each EDI user is necessary (5.40 €/month). Altogether, EDI readiness requires a monthly base fee of € 70.40. On supplier side, 173 large industry partners exist which have to invest on average € 30,500 in EDI converter software with additional monthly maintenance costs of approx. € 5,250.

<u>Benefits from Direct Network Effects</u>: EDI communication costs depend on telephone communication costs and the costs for the store-and-forward EDI telebox where the EDI messages are stored. According to our survey, at least € 0.26 is charged for submitting a typical EANCOM order message. If no EDI-solution is

installed, the conventional communication channel is using fax. The fax-based ordering process induces marginal material costs and communication costs of approximately € 0.65 per message (without personnel costs). Thus, switching to EDI saves on average at least € 0.39 per message. In case of fax, automatic update or data transfer between the retailer's material management system (MMS) and the supplier's ERP system is not possible. On the supplier side, savings from switching from fax to EDI are around € 5.10 per message. Our survey found 450 retailers (= 5.0%) and 66 (=38%) suppliers already using EDI in their communication. On average, a retailer sends 1.17 messages per month to each of the suppliers (standard deviation = .234).

Benefits from Indirect Network Effects: In our application domain, INE are based on the utilization of a *master data pool* as complementary service, comprising all price and product data of suppliers already deploying EDI in the office supply industry. Through the possibility of downloading up-to-date and proven high quality data a retailer firm can add this information to its MMS system, in order to, e.g., automate price calculation, or automate cashing with point of sale scanners. These indirect benefits of EDI increase with each additional supplier offering standardized master data to the industry data pool. In the survey, this has been reported to be a strong adoption incentive for SMEs. Suppliers, in turn, will be more motivated to insert product master data into the pool if more retailers adopt EDI as described by equation 1. The decision whether or not to adopt EDI is by no means as complex for the suppliers. As our survey has revealed, the amount of incoming orders as a source of DNE benefits easily justifies the usage of EDI systems. The firms can adopt EDI and drop it quite flexibly in a following period as SMEs have the right to withdraw their EDI activities at any time, and some really did, switching back to fax.

4.2. Simulation setting

The EDI adoption dynamics in the German office supply industry are simulated as follows: First, a virtual instance of the network of retailers and suppliers is created. Each retailer is connected with each supplier, thereby saving communication costs of c_{ijt}^{R} and c_{jit}^{S} per period t in case both retailer i and supplier j adopt EDI.

Table 2: Empirical parameters for the computer-based simulation

	Retailer	Supplier
Network size	$N^R = 9048$ retailers	$N^R = 173$ suppliers
Base already using EDI in the initial period (t=0)	$B_0^R = 450$ (retailers using EDI in t=0)	$B_0^S = 66$ (suppliers using EDI in t=0)
Monthly fixed costs (state 1: setup + maintenance + fees)	$k_{it}^{R1} \sim ND(153.32;30.66)$ in €	$k_{jt}^{S1} \sim ND(6097.22;1219.44)$ in €
Monthly fixed costs (state 2: maintenance + fees)	$k_{it}^{R2} \sim ND(70.40;14.08)$ in €	$k_{jt}^{S2} \sim ND(5250.0;1050.00)$ in €
Benefit:DNE (savings per message)	$c_{ij}^{R,message} = 0.39$ €/message	$c_{ji}^{S,message} = 5.10$ €/message
Number of messages sent from i to j in period t	$m_{ijt} \sim ND(1.17;0.234)$	
Benefit: DNE (savings per link, period)	$c_{ijt}^{R} = c_{ij}^{R,message} \cdot m_{ijt}$	$c_{jit}^{S} = c_{ji}^{S,message} \cdot m_{ijt}$
Actor i's utility from INE	$u_{it}^{I} = u_{i}^{I}\ \forall t$ (i.e., constant over time), normally distributed with a variation coefficient of .2, varied during simulations, $\beta = 0.5$	N/A

For each agent the fixed costs of EDI for state 1 and 2 and the INE parameter u_{it}^{I} are determined. Afterwards, a specific number of retailers (B_0^R) and suppliers (B_0^S) will be "pre-equipped" with EDI converter software (i.e. they are set to state 2) in order to resemble the current empirical situation and to use it as a starting point for the simulations. In the following periods, each actor can periodically decide whether or not to use EDI, based on the observed standardization decisions and the expected decision behavior of their business partners (applying decision calculi (2) and (4)). The parameterization is based on the described empirical results, summarized in Table 2. Some of the parameters such as fixed costs or the number of messages are normally distributed (ND) with mean and standard deviation given in parentheses. Since all empirical data is available on a monthly basis and the firms are able to terminate EDI service contracts within a month, we use months as the unit of simulation periods. Due to the short amortization duration of three years for EDI converter software, the setup costs of €1,990 for retailers and €30,500 for suppliers are linearly distributed over 36 months. The simulation routine itself has been implemented in JAVA 1.5.

4.3. Simulation results

Figure 2 presents the cumulative number of EDI adopters in the stationary state (i.e. after the last adoption activities have been observed), depending on the level of the INE coefficient u_i^I. Each data point represents a single simulation run. We find a sigmoid relationship between an increase of the INE coefficient and the number of adopters. While only a few retailers adopt EDI at low benefits from INE, at high values an apparently very large number of retailers adopt EDI (exemplary diffusion paths over time are depicted in Figure 4). The "tippiness" of the network can be seen in the range of $\mu(u^I) \approx 100$, where the number of adopters reaches a critical mass leading to the majority of the network adopting EDI due to additionally offered master data and services (INE). Nevertheless, due to the heterogeneity in the cost and benefit structure of the retailers, the EDI diffusion does not cover the whole network, even at very high $\mu(u^I)$. On the supplier side, the expected DNE utility of EDI is large enough to standardize the whole supplier side immediately (no figure). Unlike other network simulations in previous research, the standardization process in this model takes quite a long time (up to 60 months) due to the more realistic supply chain network structure (cf. Figure 3).

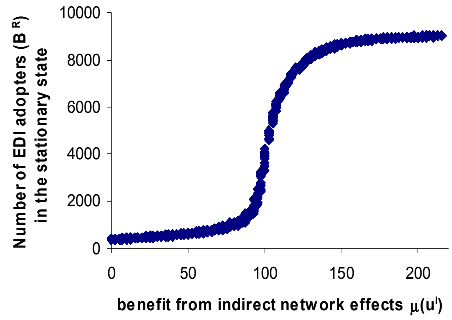

Figure 2: Number of EDI adopters in the stationary state

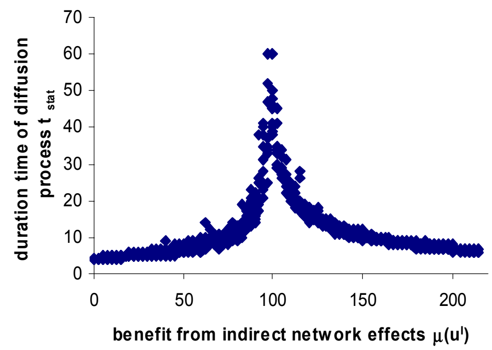

Figure 3: Occurrence time of stationary state for different u^I

Figure 4 provides two different exemplary diffusion paths of EDI among retailers (note different scales). For medium values of $\mu(u^I)$ (upper diagram), the diffusion path follows a declining function, while at higher values (above $\mu(u^I) \approx 115$) it has a sigmoid shape. In the upper case, the adoption process takes a long time and standardizes less than half of all retailers. In the early periods only those retailers standardize who have strong individual net benefits. In contrast to the lower case, this only has marginal consequences on the expected benefits of the other retailers. In the case depicted in the lower diagram, the behavior of the early adopters suffices to provide positive expected net savings to the remaining retailers. Consequently, a large part of retailers follows resulting in a typical diffusion curve described as imitative diffusion [34, 36]. By contrast, the declining diffusion described in the upper diagram resembles innovative or exponential diffusion [34, 36].

In both examples of Figure 4, the number of EDI-using retailers decreases in the first period because they only take 66 EDI-using suppliers into their forecast according to the underlying survey where only 66 industry partners where EDI-capable in the first period. At the same first period, the number of EDI-deploying suppliers increases to 173 (standardization of all suppliers in the industry), resulting in increasing DNE. However, the utility resulting from 100% EDI availability on the supplier side is not enough to accelerate the diffusion process of EDI among retailers significantly (see lower left branch of diffusion curve in Figure 2).

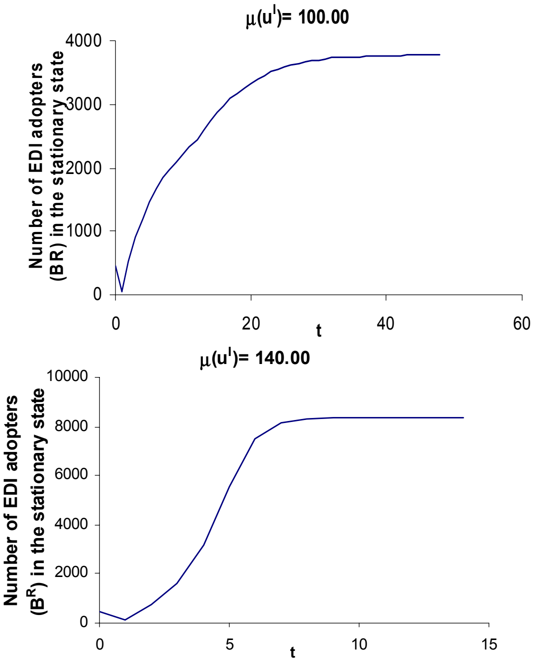

Figure 4: Exemplary EDI diffusion paths

Figure 5 depicts the monetary net utility U^R (average over all retailers) from direct savings (sav^R = sum of average communication cost savings for all retailers) and INE for retailers. Due to the pre-standardization of retailers and suppliers, all suppliers standardize in the first period. On the other hand, due to low expected benefits a number of retailers decide to drop EDI. Thus, the remaining retailers only have to pay k^{R2} while no new ones adopt EDI. In period t=1, retailers can observe the standardization behavior of suppliers from period t=0 and start to adopt EDI themselves. The bandwagon process starts and an increasing number of retailers adopt EDI by investing k^{R1}, resulting in negative savings during the following standardization phases. Due to the chosen parameter values and the constant number of EDI messages, the chosen level of indirect network benefits is responsible for the resulting EDI network size.

Figure 6 provides the results previously depicted in Figure 2 but with varying both network effects: the indirect $\mu(u^I)$, as well as the direct $\mu(m_{ij})$ (i.e. the number of exchanged messages between a retailer *i* and a supplier *j*).

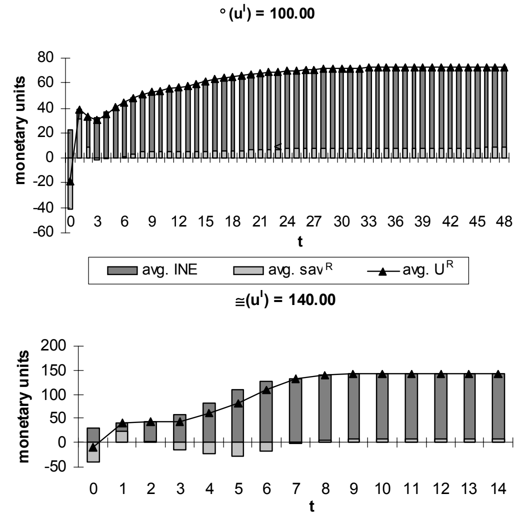

Figure 5: Progression of average indirect network effects (*INE*), communication savings (sav^R), and overall utility (U^R) for SMEs

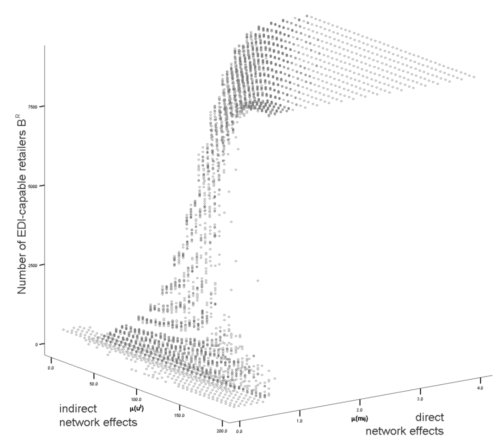

Figure 6: Diffusion of EDI from direct (µ(m_{ij})) and indirect network effects (µ(u_I))

Low INE ($\mu(u^I)$ < 100) hinder the diffusion, resulting in a sticky cluster on the bottom of the diagram, equivalent to many partially standarized networks (1000 <($B^R_{t_{stat}}$) < 8000). At higher $\mu(u^I)$ >100, a marginal number of only $\mu(m_{ij})$=1.16 EDI messages is sufficient to start the diffusion process.

Based on correlation analyses, the substitution rate between DNE and INE is equivalent to € 65 for 1 message and vice versa for different $B^R_{t_{stat}}$. If retailers could increase the number of monthly EDI messages over $\mu(m_{ij})$=3.4, then the diffusion process would be mainly driven by DNE as in the case of large suppliers in the office supply industry. Beneath this level, the incorporation of INE is necessary to start the diffusion process for small EDI-using enterprises. As the EDI network grows (more EDI messages and/or more participants), the ratio of achievable direct vs. indirect network benefits grows and varies in an upward process with positive interplay with each other.

5. Conclusion

Given a fixed number of orders, early SMEs adopting EDI need high INE benefits to standardize. Large EDI-using business partners adopt EDI immediately, gaining nothing but benefits from DNE. As long as the master data of the data pool is not owned by a single market player selling it to EDI-deploying SMEs, the value of the master data cannot be quantified in pecuniary terms as having the same value for all users. Therefore, the resulting INE benefits depend not only on estimations of the accessible set of master data in the future, but also on the in-house usage of this data. In contrast to other network effect related markets, where DNE are the main driver of diffusion, e.g., in the mobile phone market, the diffusion of EDI among SME retailers with little message exchange is primarily driven by INE benefits. The simulation has shown that for launching EDI diffusion among SMEs the varying importance of DNE and INE should be taken into account. While early adoption reasons are driven by the indirect improvements of internal processes, adopters in later diffusion stages will calculate with increasing benefits from direct data exchange. The knowledge of this interrelated system of DNE and INE may help to increase the speed of diffusion of new standards.

6. References

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