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The diffusion of interactive communication innovations and the critical mass: the adoption of telecommunications services by German banks☆

Alwin Mahler[a,*], Everett M. Rogers[b]

[a]*MCIWorldCom, Deutschland GmbH, Solmsstraße 73, 60486 Frankfurt am Main, Germany*
[b]*Department of Communication and Journalism, University of New Mexico, Albuquerque, NM 87131-1171, USA*

Abstract

Interactive innovations are distinctive in that their adoption depends on the perceived number of others who have already adopted the innovation. Thus their rate of adoption does not take off in the familiar "S" shape until a critical mass of adopters has been reached. Data on the adoption of 12 telecommunications services by 392 German banks are used to explore our theoretical perspective on the role of the critical mass in the diffusion of interactive innovations. The most important obstacle to the adoption of new telecommunications services by banks is a low degree of diffusion (which suggests the general importance of the critical mass). These obstacles do not differ for the innovators and other adopter categories. The importance of direct network externalities in influencing the rate of diffusion of new telecommunications services should be determined for each new service, rather than assumed to always exists.

Keywords: Diffusion of innovations; Interactive innovations; Critical mass; Telecom services adoption

1. Introduction

The purpose of this paper is (1) to formulate a theoretical perspective on the role of the critical mass in the diffusion of interactive[1] innovations, and (2) to explore certain aspects of this theory

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* Corresponding author. Tel.: + 49-69-972-68-933; fax: + 49-69-972-68-930.

E-mail address: alwin.mahler@wcom.de (A. Mahler)

[1] *Interactivity* is the degree to which participants in a communication system can exchange roles in, and have control over, their mutual discourse (Williams, Rice & Rogers, 1988).

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with data from German banks about their adoption of telecommunications innovations. The diffusion of such new ideas provides a particularly fertile situation in which to investigate the role of the critical mass; in fact, most writing about the critical mass has concerned telecommunications innovations.

However, we argue that telecommunications innovations with strong network externalities[2] (which are interactive in nature and therefore whose externalities are direct[3]) should be expected to have a more pronounced critical mass in their rate of adoption. While the rate of adoption for every innovation may display somewhat of a critical mass effect, for interactive innovations the critical mass is particularly crucial (Rogers, 1995). Thus, for example, the rate of adoption for such innovations as fax, electronic mail, and videoconferencing have displayed a relatively strong critical mass. In comparison, such other telecommunications innovations as mobile telephones and voice mail are characterized by a critical mass to a much lesser degree.[4] We gathered data about 12 telecommunications innovations, some of which are interactive, from 392 German banks in order to explore certain of our theoretical expectations about the critical mass in the rate of adoption of the 12 innovations.

2. The critical mass in the diffusion of interactive innovations

Our thinking about the critical mass is particularly influenced by David Allen's (1988) article, "New Telecommunications Services: Network Externalities and Critical Mass." Allen argued that the critical mass does not apply to existing telecommunications services where each new subscriber adopts as an individual joining all of the existing subscribers. Such a mature system has necessarily moved beyond the point at which a critical mass might have occurred. For example, an individual adopting a telephone today knows that almost all other households in the nation already have telephone service. Thus the utility of adopting depends almost entirely on factors internal to the individual, rather than on such externalities[5] as the perceived proportion of others with whom the individual wishes to communicate by telephone (and who already have this service).

[2] *Network externalities* are a quality of certain goods and services such that they become more valuable to a user as the number of users increases. For example, the telephone was of little value to the first individual to have one; with each additional telephone adopter, this innovation became more valuable to all of its users. Our present definition is based on that of Economides (1991), who stated that network externalities occur when "The buyer of the last unit of a good has a higher benefit than the buyer of the first unit because the sale of the earlier units has created some benefits in a related dimension."

[3] Direct network externalities are typical for two-way networks, as in the example of the telephone. In typical one-way networks, the externality is only indirect. In this case, an extra customer yields indirect network externalities to other customers by increasing the demand for components and thereby potentially increasing the number of varieties of each component that are available in the market (see Economides, 1996).

[4] The rate of adoption for mobile telephones in the United States appeared to be characterized by a critical mass, so direct network externalities may not be necessary for an innovation's rate of adoption to have a critical mass.

[5] The considerable literature on the role of externalities in the adoption of telecommunications services includes: Rolfs (1974), Antonelli (1989), Thum (1994), and Schoder (1996).

However, for interactive telecommunications services that are new, and that are thus perceived as an innovation,[6] the prior adoption by others with whom the individual wishes to communicate via the telecommunications service is crucial.[7] In this case the value of the innovation for the individual depends on how many others have adopted. As Allen (1988) argued: "Prospective subscribers perceive more value as the subscriber pool grows." So the utility of an interactive innovation depends on the size of the user community.

In the early stages of the diffusion of an interactive innovation, when relatively few individuals have adopted, the rate of adoption proceeds extremely slowly. The cumulative rate of adoption is characterized by almost a straight line with a long tail to the left. But eventually enough adopters are reached when many individuals in the system perceive that "everybody's doing it." At this point enough other individuals have adopted so that an individual considering adoption of the innovation perceives that the innovation would have sufficient utility to justify its adoption.

The *critical mass* is defined as the minimal number of adopters of an interactive innovation for the further rate of adoption to be self-sustaining.[8] The term critical mass comes originally from nuclear physics where it referred to the amount of radioactive material needed for a pile to "go critical" in a self-sustaining reaction. Whether or not such a critical mass problem is involved in the diffusion of a telecommunications innovation depends in part on the innovation's degree of interactivity. However, the diffusion of mobile telephones, as noted previously, did not have to overcome the externality problem of interactive telecommunications services, as mobile phone adopters connected to the existing base of *all* telephone users and therefore achieving critical mass was not crucial. Had mobile phones been designed so that each adopter could only talk with other mobile phone users, a critical mass would have been much more important in the diffusion of this innovation. In fact, such a case was represented by CB radios, which diffused rapidly in the late 1970s to a specialized audience mainly composed of hobbyists and truck drivers in countries like the USA.

Past scholarly literature on the diffusion of telecommunications innovations has not clearly distinguished between new services that are highly interactive in nature (and which have a high degree of direct externalities) versus those that are not interactive. The critical mass is more directly involved in the former, and less so in the latter. For some new interactive services, however, the externality problem might not arise and therefore the critical mass might not be involved (as in the mobile telephone illustration, above). Fax, e-mail, and video conferencing seem to have been characterized by a critical mass in their rate of adoption, while certain other telecommunications innovations, like voicemail, were not. Previous publications indicate that the role of the critical mass in the diffusion of certain telecommunications services has often been derived from the diffusion of "plain old telephone service", which initially spread very slowly for several decades. We urge instead that such expectations should be reviewed critically in order to determine if they apply to the particular new telecommunications service being discussed.

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[6] An *innovation* is defined as an idea perceived as new by an individual or an organization (Rogers, 1995).

[7] A related matter to externalities in affecting the rate of adoption of a new telecommunications service is its compatability with standards. Examples of the literature on standards include Katz and Shapiro (1985), Besen and Farrell (1994), and David (1990,1994).

[8] This definition is based on Rogers (1990, 1995), Schoder (1996), Weiber (1992, 1995), and Valente (1995).

3. Perceptions count: watching while being watched

Reaching critical mass may depend less on the *objective* number of adopters of an interactive innovation than on the *perceived* number of other adopters. As in understanding other types of human behavior change, perceptions count.[9] As Allen (1988) stated: "Each person has, as it were, an individual vision of what constitutes critical mass … upon everybody watching while being watched … critical mass for the group floats it seems on shifting perceptions of what the group outcome may be." Thus the critical mass is socially constructed by individuals, based on their communication with relevant others in their system, as meaning is given to the uncertain and ambiguous situation surrounding a telecommunications innovation.

Given the importance of the critical mass in explaining the adoption of interactive innovations, why does *anyone* adopt before the critical mass is reached? No one would, if all individuals had the same degree of resistance/attraction to the innovation. But past diffusion research, summarized by Rogers (1995), indicates that individuals vary in their resistance thresholds to an innovation, with a few individuals (the innovators, who have a threshold of almost zero) so venturesome that they will adopt a new idea before anyone else in their system has adopted. A *threshold* is the number of other individuals who must be engaged in an activity before a given individual will join that activity.[10] In the case of the diffusion of an innovation, an adoption threshold is the number of other individuals who must have adopted before a given individual will adopt the new idea; thus the threshold indicates the degree to which an individual (or organization) is resistant to adopting.

Weiber (1995)[11] argued that factors which act to slow the rate of adoption of an interactive innovation *before* the critical mass is reached, then serve to speed the adoption rate *after* the critical mass is attained (Fig. 1). For example, crucial factors among the so-called "market-related" facilitators/obstacles to diffusion include (1) the size of the installed base, and (2) the "demand synergies" due to externalities (described previously). Weiber (1992) suggested that these two factors reduce the attractiveness of a new telecommunications service before the critical mass is reached, and augment it afterwards, so as to increase the rate of adoption of an innovation.

The effect of network externalities on the rate of adoption of telecommunications innovations is related to compatibility standards, as mentioned previously. Direct network externalities were not involved in the introduction of mobile telephones because of their compatibility with the installed base of telephone subscribers, as discussed above. Also, in the case of indirect network externalities, two standards for VCR equipment (Beta and VHS) were provided by opposing camps of Japanese electronics manufacturers during the first decade of VCR diffusion. Undoubtedly this lack of a single standard slowed the overall rate of adoption of VCRs by consumers. When an innovation is interactive in nature, a lack of standardization means that a critical mass of adopters must be achieved for *each* of the standards, if the innovation is to diffuse widely. Perhaps a critical mass of adopters will be reached by only one of the standards, and the other will fail in the marketplace. Perhaps neither standard will reach a critical mass, and both will fail.

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[9] The social science notion that perceptions count traces to W.I. Thomas' dictum, stated in 1919, that if individuals perceive a situation as real, it is real to them in all of its consequences (Rogers, 1994).

[10] This definition is based on Rogers (1995). The original notion of individual thresholds comes from Granovetter (1978).

[11] A similar point is made by Liebowitz and Margolis (1994).

However, it often is difficult to specify what degree of standardization might be ideal for the rapid diffusion of a new telecommunications service. A high degree of standardization means a reduction in the variety of the new telecommunications service that is available to potential users, which presumably reduces the perceived relative advantage of the new service. So there is often a trade-off between standardization versus variety of a telecommunications service.

Five characteristics of an innovation affect its rate of adoption: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability (Rogers, 1995). Network externalities of a new telecommunications service are an important aspect of *relative advantage* (the degree to which an innovation is perceived as superior to the idea that it replaces) because they create utility for the adopter as other adopters increasingly adopt the service. An adopter's perceived relative advantage of a telecommunications service is also influenced by the degree to which all of the "systemgoods" components (such as a terminal, networks, contents, etc.) work together. Until they do, the relative advantage of the new service cannot be accurately evaluated by a potential adopter. In some cases a lengthy period of use of the new service may be necessary before the user can perceive accurately the innovation's relative advantage (these telecommunications services are often called "experience goods").

Other aspects of compatibility (than standardization) may also effect the rate of adoption of telecommunications innovations. In addition to the previously described technological perspective of compatibility, there is an organizational perspective: How the innovation is compatible with the organizational structure of a company/adopter — and from a personnel perspective, the compatibility of the innovation with the customs and habits of the organization's employees. The perceived complexity of such innovations means that the several components must work together.[12] These aspects (mentioned above) also play a role in the perception of the other attributes of an innovation. Trialability and observability may be conveyed to an individual by the number of other users at the time that the individual decides to adopt a new telecommunications innovation. Perhaps these perceived attributes become important only after a critical mass in the rate of adoption has been reached. As Allen (1988) pointed out, "Critical mass, it devolves, is a sort of portal through which the other features must pass if those features are to make their impact."[13]

4. Backward flowing utility

One further distinctive aspect of interactive innovations affects their rate of diffusion: The perceived number of other adopters influences not only the utility of the innovation to all *future* potential adopters (as is the case with non-interactive innovations), but also affects the utility of the innovation for all *past* adopters (Markus, 1987; Markus, 1990a, b). The S-shaped curve (describing

[12] These components are often supplied by different players which do not always coordinate their activities with respect to different standards. This incompatability makes it difficult for the adopter to understand and evaluate the innovation.

[13] Technological improvement of a telecommunications innovation, in addition to its critical mass and other factors, may also affect the new idea's rate of adoption. For example the take-off in the rate of adoption of fax was boosted by faster transmission rates, the greater user-friendliness of fax terminals, and their decreased price.

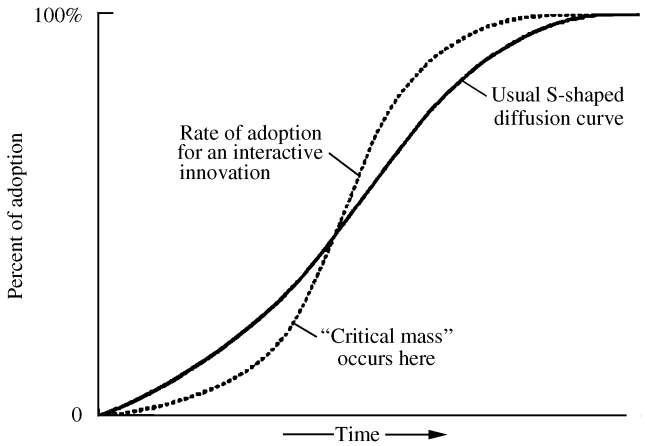

Fig. 1. The rate of adoption for a noninteractive innovation (solid line) and for an interactive innovation (dotted line). Source: Based on Rogers (1995).

the cumulative number of adopters of an innovation over time) ordinarily occurs because positive messages are spread interpersonally from satisfied adopters in a system to potential adopters who are thus persuaded to adopt. As the number of satisfied adopters gradually increases in a system, and as the volume of positive messages about an innovation being communicated increases accordingly, the rate of adoption takes off after an initial period of relatively slow diffusion (see Fig. 1). In essence, the diffusion process occurs as positive perceptions of the innovation are communicated from satisfied adopters to potential adopters over time.[14] Eventually, however, fewer and fewer individuals with a strong resistance to adoption remain, and the rate of adoption gradually levels off. This process results in the S-shaped diffusion curve for most innovations (see Fig. 1).

In comparison to this process for a non-interactive innovation, an interactive innovation diffuses relatively more slowly initially until a critical mass of adopters is reached (see Fig. 1). Because the main purpose of an interactive telecommunications innovation is to connect the potential adopter with others who have adopted the innovation, the innovation has little perceived utility for an individual until others with whom the individual wishes to communicate have adopted. Once a critical mass is reached, the interactive innovation is thereafter perceived as valuable by potential adopters. But, as Markus (1987) recognized, the innovation also becomes of increased utility to every *previous* adopter, who can now use the telecommunications service to communicate with more and more others. This backward flow of increased utility[15] of the innovation presumably leads all past adopters to spread even more positive perceptions about the innovation to others in their system.[16]

[14] Research is needed on how positive (and nagative) messages about an innovation flow through interpersonal networks in a system.

[15] Called reciprocal interdepence by Markus (1987).

[16] And also for all past adopters to use the interactive innovation more heavily. Telecommunications service providers may be as interested in the amount of use of an innovation as they are in the number of adopters (Markus, 1990a).

Not only can the critical mass of interactive innovations, once reached, speed up the rate of adoption, but the critical mass can also speed the collapse of use of an interactive innovation (Markus, 1990a). For example, say that an e-mail system in an organization is not used by certain adopters (perhaps they are too busy to respond to the overload of messages sent to them). Their pattern of nonresponse soon becomes evident to others in their organization, who then stop sending them further e-mail. Discontinuance of the interactive innovation may then spread rapidly, speeded by the effect of the critical mass.

5. Strategies for reaching critical mass

A provider of a new telecommunications service that is interactive in nature often faces formidable problems in getting the innovation to critical mass, but thereafter can almost halt further promotional activities as the diffusion process becomes self-sustaining. What diffusion strategies can be utilized by a provider to get to critical mass?

Allen (1988) identified the strategies used by the French PTT in promoting Minitel, a videotext service that was successfully introduced during a decade in which numerous other efforts, many costing several hundred million dollars, had been unsuccessful in the United States, England, and Germany. Only a small percentage of the intended adopters were achieved in the case of these failures, which did not reach critical mass.[17]

How was the French PTT able to persuade 6 million French households (more than 25 percent of all telephone subscribers) to adopt Minitel during the first decade of this telecommunications innovation's diffusion?[18]

1. A subsidized price was provided for the videotext service until a critical mass was reached, such as by giving free Minitel terminals to heavy telephone users in France. The strategy was to make initial access to the interactive innovation free, or at least relatively cheap, so as to increase the perceived relative advantage of the innovation at a time when its externalities were relatively low.[19]
2. Adoption of an interactive telecommunications service was tied to a necessary individual-to-machine service in the case of Minitel, so as to reduce the initial uncertainty in the unfamiliar activity of using the new service. The French PTT initially refused to provide paper telephone

[17] The German videotext system, originally called Birdschirmtext (BTX) but later renamed T-Online, reached only about 340,000 adopters by 1993 (12 yr after its introduction), but then seemed to have passed criticial mass, reaching more than 3,000,000 adopters by mid-1999. This take-off in the rate of adoption occurred in conjunction with the breakup of the German PTT. The resulting organization responsible for videotext, Deusche Telekom, joined with a private marketing company (1&1), to promote the innovation in new ways and to add Internet and other services.

[18] This definition is based on Rogers (1990, 1995), Schoder (1996), Weiber (1992, 1995), and Valente (1995).

[19] A similar strategy was used by the Public Electronic Network (PEN) in Santa Monica, CA by providing free-to-user public terminals in public libraries, government buildings, and other public places (Schmitz, Rogers, Phillips, & Paschal, 1995).

directories to Minitel users, thus forcing them to use their videotext equipment to obtain other individuals' telephone numbers.[20]

3. The innovation was introduced in intact parts of the system where its prospects were brightest, so as to achieve a critical mass there, before the new telecommunications service was launched in other parts of the total system. The French PTT introduced Minitel service sequentially in one geographical region of France after another, beginning with regions where it was most likely to be accepted, such as upper-middle suburbs of Paris.

Similarly, an electronic-mail system is often introduced in the R&D unit of a work organization, where potential users are most receptive. This strategy of sequential introduction of an interactive innovation means that the larger system is disaggregated into a series of smaller-sized sub-systems. A critical mass is easier to achieve in each (Hohn & Schneider, 1991). We explore whether the diffusion process for more interactive innovations, in which a critical mass is presumably more involved, is different from non-interactive innovations. Essentially we determine which perceived attributes of telecommunications services are of greatest importance in determining their rate of adoption.

One can imagine additional strategies for getting to critical mass; for example, special efforts may be devoted to gaining initial adoption of an interactive innovation by high-status individuals in a system who are well-known and who will enthusiastically support the new service. An illustration is a US university president who was the first adopter of a new e-mail service, and whose photograph using the equipment appeared in the university's employee's publication. Getting to critical mass is not a fixed impediment to diffusion, but rather is a special quality of interactive innovations that demands the use of particular strategies by the service provider.

6. The diffusion of telecommunications innovations among German banks

The above discussion of the critical mass in the diffusion of interactive innovations suggests a number of hypotheses and research questions for investigation in future research. Although a number of theoretical discussions of the critical mass have appeared in recent years, there is relatively little empirical study of how the critical mass effects the diffusion of innovations. Here we present data from an investigation of the diffusion of telecommunications innovations among German banks. We explore three research questions: (1) What is the rate of adoption and the most important reasons for not adopting telecommunications innovations by German banks? (2) Do the reasons for not adopting telecommunications innovations vary by the innovativness of the banks? and (3) What is the role of direct network externalities and the critical mass in explaining the rate of adoption of telecommunications innovations by German banks? We explore whether the diffusion process for more interactive innovations, in which a critical mass is presumably involved, is different from non-interactive innovations. Essentially, we determine which perceived attributes of telecommunications services are of greatest importance in determining their rate of adoption.

[20] In fact the interactive nature of Minitel was not originally envisioned by the French PTT engineers who designed this videotext system. Instead, in 1981, some Minitel hackers in Strasburg (one of the pilot cities in which Minitel was introduced) discovered that the system could be used for "chatting" about sex-related message content, and eventually this type of conversational use became the most popular aspect of Minitel (Rogers, 1995). In this case, the "killer application" of the telecommunications service was created by the users of the innovation, as they gave their own meaning to the new technology, rather than by the systems's designers.

Table 1
Twelve new telecommunications services investigated in the present study

Electronic Funds Transfer with private customers (home banking)
Videoconferencing
Voicemail
Electronic Funds Transfer in combination with authorization at POS or ATMs
New Telephone Services (like toll-free numbers or audioconferencing)
Electronic Data Interchange (EDI)
E-Mail
Electronic Funds Transfer with corporate customers
Btx/T-Online (Videotext)
Managed Network Services
Electronic Funds Transfer with banks (e.g., SWIFT)
Online Database Services (real-time information services)

Note: Electronic funds transfer (EFT) can be subdivided into the electronic transmission of financial data with other banks, with private customers (home banking), with corporations, or in combination with authorization at the point of sale or at ATMs. Beside these various EFT applications, new services included in the present study focus mainly on internal usage within the organization, like the use of online database services or managed network services, which concern the operation and management of telecommunications networks. Other new telecommunications services are videoconferencing, e-mail, or Btx (the German videotext service, now called T-Online), or voice-mail. We also study new telephone services (for example, toll-free) which enable customers to contact their bank. Electronic Data Interchange (EDI) allows a bank to contact a corporate business partner for the structured exchange of documents (in contrast to e-mail, which provides an unstructured exchange of documents).

7. Research methodology

German banks — as is generally the case for banks in other nations — pioneer in the adoption of many new telecommunications services. Perhaps more than in any other industry, due to its basis in the information sector, banking is heavily influenced by telecommunications technologies. So the banking industry in Germany was chosen for an investigation of the role of the critical mass in the diffusion of new telecommunications services.

The 12 innovations of study (Table 1) were the main technologies diffusing among German banks at the time the present investigation was conducted in 1992. Several of the 12 innovations only concern banking (such as electronic funds transfer), but other innovations (for example, e-mail) are of more widespread use. One criterion in selecting the 12 innovations of study was that they be relevant to all German banks.[21] It was assumed that eventually all banks would adopt these innovations, but that those banks adopting relatively earlier (if they also implement the innovations in an effective way) could gain a considerable competitive advantage over later adopting banks.

[21] This relevancy was determined by interviews by one of the present authors with banking industry experts. The 12 innovations of study were the main new telecommunications services diffusing among German banks at the time the present study was conducted in 1992, according to results of studies previous to the present investigation. These studies are summarized by Stoetzer (1991,1992).

Table 2
Characteristics of banks in Germany

Bank's total asset (in million DM)	Percentage of banks (%)	Percentage of employees (%)
Under 100	46.1	4.9
100–250	23.7	7.1
250–500	12.4	7.6
500–1000	7.1	9.7
1000–5000	8.5	29.4
5000 and over	2.2	41.3
Totals[a]	100.0	100.0
Private banks	7.1 (330/7366)[b]	33.3
Saving banks[c]	14.2 (691/19510)	40.9
Cooperative banks	78.7 (2776/17599)	25.8
Totals[a]	100.0	100.0

[a]No specialized banking insitutions are included here (e.g., specialized building societies). Calculations are based on 1991 data (the present statistics do not include the new German states after reunification).
[b]The figures in parenthesis are the number of banks and domestic branches.
[c]Community-owned.
Source: Deutsche Bundesbank Frankfurt, Arbeitgeberverband des privaten Bankgewerbes e.V. and calculations by the ifo institut, München.

Table 2 shows the three main types of banks (representing over 90 percent of all banks in the German banking industry): 79% are cooperative banks, 14% are savings banks, and 7% are private banks. However, the second and third categories represent 41% and 33%, respectively, of the roughly 600,000 employees in the German banking industry. Some 90% of the banks are smaller and medium-sized banks with total assets of less than 1 billion DM. Cooperative banks dominant the small-sized banks. The relatively high percentage of all banking employees in private banks is mainly due to the five largest banks, which represent approximately one-fifth of all employees in the banking industry. So the German banking industry is characterized by a small number of extremely large banks (for example, Deutsche Bank) and a large number of small banks. The larger banks tend to acquire smaller banks, which perhaps is partly due to the critical size needed for efficient use of the technological innovations of study.

8. Data-gathering

The data were gathered in 1992 from 392 German banks by the ifo-Institut für Wirtschaftsforschung,[22] Munich, on behalf of WIK. The ifo-Institut mailed the questionnaire to 1,191 banks,

[22] The ifo-Institute is one of Germany's leading economic research institutes. They conduct regular panels of companies in various industries, with a special focus on innovations and economic trends.

Table 3
Size (number of employees) of the 392 German banks in the present sample

Bank size (in number of employees)	Private banks	Savings banks	Cooperative banks	Others/specialized banks	Totals
Under 100	—	2	38	1	41 (10.5%)
100–250	1	11	65	1	78 (19.9%)
250–500	2	22	45	—	69 (17.6%)
500–1000	2	45	18	—	65 (16.6%)
1000–5000	2	97	9	2	110 (28.1%)
5000 and more	6	16	3	4	29 (7.4%)
Frequency totals	13	193	178	8	392
Percentage totals	(3.3%)	(49.2%)	(45.4%)	(2.1%)	(100.0%)

a representative sample of the banking sector in Germany. The ifo-Institut guaranteed anonymity to these banks. The questionnaire was tested by the ifo-Institute in 20 personal interviews with bank representatives in charge of telecommunications. The questionnaire was collaboratively designed by the ifo-Institut and WIK. A 33% response rate was received. The 392 responding banks (from the sample of 1,191 banks) represented 42% of the bank employees in Germany. The responding banks fit closely with official statistics on total revenues and the number of people employed by banks, which suggests that the responding banks are fairly representative.[23] No follow-up with non-respondent banks was conducted. Table 3 summarizes the characteristics of the 392 banks in the present sample, by size (total assets) and type of bank. The various size classes and types of German banks are represented in our sample (the category of private banks contains the five largest banks in Germany).

9. Findings

Research Question #1 asked: What is the rate of adoption and the most important reasons for not adopting 12 telecommunications innovations by German banks?

[23] Larger banks are generally overrepresented in the survey. The sample is weighted in a manner which makes it more representative, according to the annual statistics of the number of banks by size, provided by Deutsche Bundesbank (see Table 2). We used the 392 banks in most of our data-analyses, such as the diffusion of innovations among all banks (see the second column in Table 4). However, for certain analyses, such as the reasons for not adopting the innovations, the weighted sample was not used, and only the 324 banks that answered our questions regarding their adoption versus nonadoption were used.

9.1. Rate of adoption and reasons for not adopting

The second column of Table 4 shows the weighted rate of adoption of the 12 innovations in the 1992 survey of 392 German banks. Some innovations were widely diffused among the banks (like videotext, EFT in combination with authorization, and Online Database Services). Other innovations show a low rate of adoption (like videoconferencing, voicemail, and EDI).

Table 5 shows the reasons for not adopting the 12 innovations. The most important reason for not adopting the 12 innovations is "low diffusion", followed by "bad price/value ratio", "bad information from the supplier" and "organizational problems". The other reasons played a minor role in the rate of adoption.

In order to investigate the obstacles to adoption by innovation (shown in Table 4), each reason for not adopting a particular innovation was calculated as the number of banks not using that innovation who gave a particular reason for not adopting the new telecommunications service. For example, the 136 banks that had not adopted EFT with private customers (home banking), four banks (2.9%) gave "bad information from the supplier" as the reason for not adopting that innovation (see Table 4). In addition, a factor analysis of the reasons given for not adopting was conducted. Three factors were extracted from this analysis as shown in Table 6 (the criterion for assignment of reasons to a certain factor was a minimum factor loading of 0.25). One reason for not adopting, bad price/value ratio, was loaded almost equally on Factors I and II.

Factor I is highly loaded on such items as "bad service", "resistance from employees", "long waiting period", "bad information from supplier", and "bad price/value ratio". Factor I may stand for a more general dimension of poor service from the supplier, which was usually the monopolistic Deutsche Telekom. Factor II is loaded on such reasons as "bad data security", "lack of sufficient standards", and "organizational problems", which we label as "socio-technical" reasons for not adopting innovations. Factor III, with only one item, is "low diffusion."

9.2. Innovativeness and reason for not adopting

Innovativeness is the degree to which an individual or organization is relatively earlier in adopting innovations (Rogers, 1995). We calculated an innovativeness score as the number of the 12 telecommunications innovations adopted by each bank, with the innovations that were less widely diffused among German banks given a greater weight. Thus banks that adopted telecommunications services relatively earlier were given a higher score for adopting that innovation. The adopter categorization of the German banks was achieved by assigning each bank to one of the adopter categories (banks with the highest 2.5% scores on innovativeness were classified as innovators, the next 13.5% as early adopters, and so on). Fig. 2 shows the distribution of the innovativeness scores and the adopter categorization of the 324 banks of study.

Strong relationships exist between innovativeness scores and various indicators of bank size, such as total assets, employees, number of branches, number of subsidiaries, and number of customers (Table 3). Bank growth, however, is not significantly correlated with innovativeness (Table 7).

In order to explore Research Question #2 as to whether the reasons for not adopting the 12 innovations differ by the five adopter categories of banks on the basis of their innovativeness, we sought to quantify the obstacles to adoption of the 12 telecommunication innovations. Each bank

Table 4
Rate of adoption and reasons for not adopting by German banks

The 12 Innovations of study	Direct network extenalities involved	Rate of adoption among banks (%)	Reached critical mass (in relevant market)?	Reasons for not adopting										
				Bad information from supplier	Bad price/ value ratio	Low rate of diffusion	Bad service	Lack of sufficient standards	Poor data security	Organ-izational problems	Resis-tance by bank employees	Long waiting period	Others	No reason for not adopting
1. EFT with private customers	Yes	44.0	No	4[a] 2.9%[b] 136[c]	12 8.8% 136	60 44.1% 136	0 0.0% 136	7 5.1% 136	0 0.0% 136	11 8.1% 136	1 0.7% 136	0 0.0% 136	21 15.4% 136	53 39.0% 136
2. Video conferencing	Yes	2.0	No	41 12.8% 320	37 11.6% 320	88 27.5% 320	0 0.0% 320	2 0.6% 320	0 0.0% 320	32 10.0% 320	7 2.2% 320	1 0.3% 320	63 19.7% 320	92 28.8% 320
3. Voicemail	No	2.0	No	66 21.1% 313	22 7.0% 313	88 28.1% 313	0 0.0% 313	1 0.3% 313	1 0.3% 313	24 7.7% 313	12 3.8% 313	0 0.0% 313	62 19.8% 313	84 26.8% 313
4. EFT in combination with authorization	Yes	80.0	No	1 1.9% 52	8 15.4% 52	11 21.2% 52	0 0.0% 52	0 0.0% 52	0 0.0% 52	6 11.5% 52	0 0.0% 52	1 1.9% 52	3 5.8% 52	25 48.1% 52
5. New telephone services (e.g., toll-free)	No	4.0	No	53 16.9% 313	26 8.3% 313	81 25.9% 313	0 0.0% 313	1 0.3% 313	0 0.0% 313	24 7.7% 313	6 1.9% 313	0 0.0% 313	61 19.5% 313	88 28.1% 313
6. EDI	Yes	4.0	No	62 20.7% 300	16 5.3% 300	120 40.0% 300	0 0.0% 300	11 3.7% 300	2 0.7% 300	34 11.3% 300	5 1.7% 300	2 0.7% 300	42 14.0% 300	63 21.0% 300
7. E-Mail	Yes	10	No	52 18.2% 286	25 8.7% 286	114 39.9% 286	1 0.3% 286	10 3.5% 286	4 1.4% 286	41 14.3% 286	7 2.4% 286	2 0.7% 286	45 15.7% 286	53 18.5% 286
8. EFT with corporations	Yes	44.0	Not evident	6 4.5% 134	10 7.5% 134	36 26.9% 134	1 0.7% 134	6 4.5% 134	0 0.0% 134	18 13.4% 134	0 0.0% 134	1 0.7% 134	27 20.1% 134	38 28.4% 134
9. Btx/Videotext	Yes	66.0	Not evident	1 1.5% 66	12 18.2% 66	32 48.5% 66	1 1.5% 66	0 0.0% 66	2 3.0% 66	8 12.1% 66	2 3.0% 66	0 0.0% 66	12 18.2% 66	10 15.2% 66
10. Managed network services	No	22.0	Yes	39 16.3% 239	12 5.0% 239	56 23.4% 239	1 0.4% 239	2 0.8% 239	1 0.4% 239	21 8.8% 239	3 1.3% 239	0 0.0% 239	43 18.0% 239	80 33.5% 239
11. EFT with other banks	Yes	60.0	Yes	9 8.4% 107	10 9.3% 107	18 16.8% 107	0 0.0% 107	0 0.0% 107	1 0.9% 107	13 12.1% 107	2 1.9% 107	0 0.0% 107	25 23.4% 107	34 31.8% 107
12. Online Data base Services	No	75.0	Yes	9 9.7% 93	22 23.7% 93	20 21.5% 93	1 1.1% 93	5 5.4% 93	1 1.1% 93	10 10.8% 93	3 3.2% 93	0 0.0% 93	16 17.2% 93	24 25.8% 93

[a]Number of banks saying they are not adopting for this particular reason.
[b]As a percentage of total number of banks not using that innovation.
[c]Total number of banks not using this innovation.

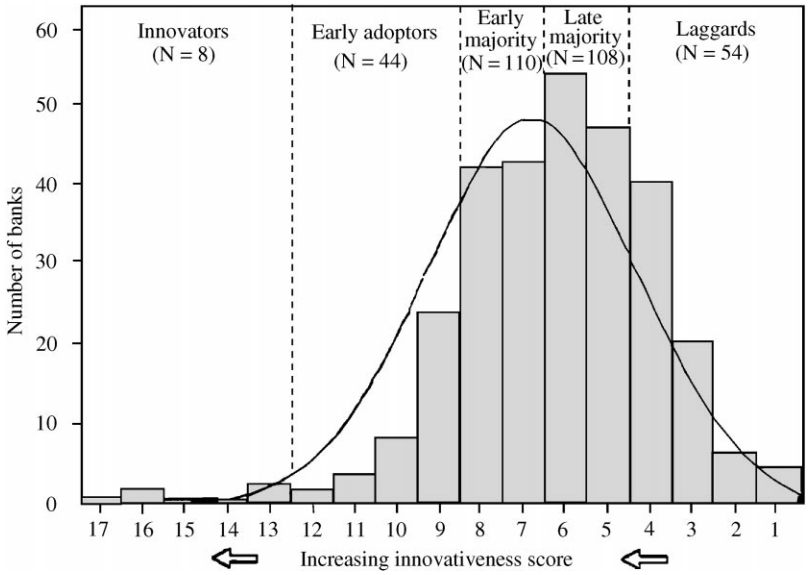

Fig. 2. Adopter categorization of 324 German banks on the basis of their innovativeness scores.

Table 5
Reasons for not adopting 12 innovations as a percentage of the total possible reasons given by 392 German banks

Reasons for not adopting	Percent of all reasons (%)
1. Low rate of diffusion	41
2. Bad price/value ratio	15
3. Bad information from supplier	15
4. Organizational problems	14
5. Lack of sufficient standards	3
6. Resistance by bank employees	2
7. Poor data security	< 1
8. Bad service	< 1
9. Long waiting period for processing order and installation	< 1
Total	≈ 92

This column does not sum to 100% because the category of reasons "others" (due to its vague nature) was not included in the present analysis of obstacles to adoption of the 12 innovations. Futher, some banks indicated two reasons for not adopting an innovation.

for each of the 10 reasons (including "others") for not adopting an innovation was scored (1) "2" if it did not adopt an innovation for that particular reason, (2) "0" if it did not adopt the innovation but did not give that reason, and (3) "1" if it had adopted that innovation. The score for a particular reason and bank over all 12 telecommunications innovations was calculated. For example, assume a bank adopted 6 of the 12 innovations and of the other 6 not adopted, it did not adopt two

Table 6
Factor analysis of reasons for not adopting 12 telecommunications innovations by German banks

Reasons for not adopting	Factor I "service"	Factor II "socio-technical"	Factor III "low diffusion"
1. Bad service	0.82	0.18	0.16
2. Resistance by bank employees	0.43	0.10	− 0.07
3. Long waiting period	0.41	0.21	0.05
4. Bad information from supplier	0.28	0.02	0.19
5. Bad price/value ratio	0.25	0.23	0.17
6. Lack of sufficient standards	0.07	0.71	0.11
7. Poor data security	0.12	0.42	0.08
8. Organizational problems	0.15	0.28	− 0.10
9. Low rate of diffusion	0.05	0.05	0.59
Eigenvalues	2.25	1.16	1.10
(Percentage of variance explained)	(25.0%)	(12.9%)	(12.3%)

Note: Underlining indicates the clear factorloadings on each factor.

innovations because of "low diffusion". The bank's score for the reason "low diffusion" is 6 + 4 + 0, or 10. So for the 12 innovations of study, the total scores could range from 0 to 24.

Table 8 shows that the reason "low diffusion" is important for all five adopter categories. The reason "bad information from the suppliers" is not crucial for innovators, compared with other adopter categories. The reason "organizational problems", however, is more crucial for innovators in comparison to other adopters, as are - although to a lesser degree — the reasons "bad data security", "lack of sufficient standards", and "long waiting period for processing order installation". "Bad price/value ratio" is the most important reason for innovators and for the early majority. "Bad service" is a relatively unimportant reason for all adopter categories, as is "resistance from bank employees".

Our factor analysis also helped us to explore the relationship between the obstacles to adoption and the innovativeness of German banks for the three main obstacles: "service", "socio-technical" and "low diffusion". We scored each adopter category as to their reasons for not adopting each of the 12 telecommunications innovations. For example, two innovator banks gave only "socio-technical" reasons for not adopting e-mail; therefore the percentage for these two banks for this dimension of obstacles to adoption is 100, and for the other two innovator banks is 0. Further, for each of the 12 telecommunications innovations, each bank was given a factor-weighted score for each of the three factor-dimensions (resulting from the factor analysis): (1) service, (2) socio-technical and (3) low diffusion. For e-mail, the mean score for early adopters for Factor I is .038; for Factor II, .045, and for Factor III, .146.[24] A low rate of diffusion is the dominant reason for not

[24] Three scores for each innovation were computed from the factorweights for the reasons for not adopting. Overall, for the 12 telecommunications services the mean factors for each adopter category, and factor, were computed by adding all of the means for a specific factor and grouping the 12 telecommunications services, and dividing by 12 (in the case of innovators, the means for some factors were 0; in this case, the average score was calculated by only dividing by the number of services with scores other than 0).

Table 7
Correlates of the innovativeness of 324 German banks

	Correlations with innovativeness scores
1. *Size of the Bank*	
• Total assets	0.75[d]
• Number of employees	0.70[d]
2. *Bank Growth (within the last* 3 yr)	
• Increase in total assets	0.05[NS]
• Increase in number of employees	0.06[NS]
3. *Organisational Structure of the Bank*	
• Number of branch banks	0.69[d]
• Number of subsidiaries[a]	0.69[d]
4. *Computerization*	
• Percentage of work places with PCs or computer terminals	0.04[NS]
5. *Outsourcing*	
• Own systems/systems from outside	0.42[d]
6. *Customers*	
• Number of customers	0.71[d]
• Number of large corporate customers[a]	0.19[d]
• Number of foreign customers[a]	0.48[d]
7. *Existing technological equipment and skills*	
• Data processing equipment[b]	0.38[d]
• Basic communication tools[c]	0.42[d]

[a]In the present analysis, a correlation between the number of subsidiaries, big corporate customers or foreign customers, and the innovativeness score was computed only for those banks that indicated that they have subsidiaries, big corporate customers or foreign customers.
[b]A score for was computed, containing the following data processing equipment: PCs, computer terminals, LANs, central data processing facility.
[c]A score for was computed, containing the following basic cummincation tools: National/International leased line, ISDN, VSAT, telephone line/modern (analog) × 25.
[d]Significantly different from zero at the 1% level of significance.
NS: Not significantly different zero at the 5% level of significance.

adopting for all five adopter categories, except the innovators. For them "socio-technical" reasons matter most. For adopter categories other than innovators, the service reasons are more important than socio-technical reasons. Generally, the four adopter categories other than innovators do not differ much in their reasons for not adopting the 12 telecommunications services, with a clear dominance of the low rate of diffusion for all adopter categories. However, for innovator banks, such socio-technical reasons as a perceived lack of standardization, security, and organizational problems are more relevant than is a low rate of diffusion.

9.3. Role of direct network externalities and the critical mass

Research Question #3 asked: What is the role of direct network externalities and the critical mass in explaining the rate of adoption of 12 telecommunications innovations by German banks?

Table 8

Average scores for reasons for not adopting 12 telecommunications innovations by innovativeness of German banks

Adopter category (N)	Bad information from supplier (I)		Bad price/value ratio (I)		Low rate of diffusion (III)		Bad service (I)		Lack of sufficient standards (II)		Poor data security (II)		Organizational problems (II)		Resistance by bank employees (I)		Long waiting period for processing order and installation (I)		Other reasons	
	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
1. Innovators (8)	6th	(10.6)	1st	(12.0)	2nd	(11.4)	6th	(10.6)	4th	(11.1)	5th	(10.9)	2nd	(11.4)	10th	(10.1)	6th	(10.6)	9th	(10.6)
2. Early adopters (44)	3rd	(8.0)	2nd	(8.4)	1st	(10.8)	10th	(6.6)	6th	(7.2)	8th	(6.8)	4th	(7.7)	6th	(7.2)	9th	(6.7)	5th	(7.3)
3. Early majority (110)	2nd	(8.0)	4th	(6.6)	1st	(10.2)	7th	(5.5)	7th	(5.5)	9th	(5.4)	5th	(6.5)	6th	(5.6)	10th	(5.3)	3rd	(7.3)
4. Late majority (108)	3rd	(6.2)	5th	(5.3)	1st	(8.2)	6th	(4.7)	6th	(4.7)	9th	(4.3)	4th	(6.0)	6th	(4.5)	9th	(4.3)	2nd	(7.1)
5. Laggards (54)	3rd	(4.4)	5th	(3.4)	1st	(7.4)	6th	(2.7)	6th	(2.7)	9th	(2.2)	4th	(4.1)	6th	(2.3)	10th	(2.1)	2nd	(7.5)

Note: A higher score indicates that a specific reason for not adopting was perceived as more important by the German bank in that adopter category.

9.3.1. The interactivity/externality relationship

Not every new telecommunications service displays such strong direct network externalities as the classical case of telephone service when it was introduced. However, some new telecommunications services, like videoconferencing, EDI, e-mail and electronic funds transfer with other banks, have strong externalities. Btx/Videotext has many possible applications that can be realized via this telecommunications service. E-mail, which displays strong direct network externalities, is one application for example. Access to information stored on databases is another application. For instance, a database of train schedules has considerable utility for all potential users. There are no direct network externalities involved in this latter case.[25] The same holds true for certain other of the 12 innovations of study, like voicemail and new telephone services like toll-free numbers.

Sometimes direct network externalities, supposedly one of the most crucial issues in the diffusion of a new telecommunications service, not only depend on the nature of the specific service but also on whether the perspective of the supplier or the buyer of the service is considered; for the innovation of electronic funds transfer between a bank and a customer, direct network externalities are not relevant for the customer, who may not care how many other customers are banking electronically. No increase in utility occurs when another customer adopts this innovation. However the customer's utility is increased if he or she can electronically connect with more banks. This phenomenon resembles the software/hardware paradigm (Katz & Shapiro, 1994) or indirect network externalities, which characterize many innovations other than telecommunications services. Now consider network externalities from the perspective of a single bank, the supplier, of the service of electronic funds transfer.[26] The number of customers that can be reached by an electronic database and how many are actually using electronic banking become very important. Each is a potential communication partner with whom to conduct business. Presumably the utility calculations of a bank considering the adoption of electronic banking to private customers will be influenced directly by this innovation's externalities.

The perspective of the bank is most relevant in the present study as the reasons for adopting or rejecting the 12 innovations. From the banks' perspective, the innovations of voicemail, new telephone services, managed network services, and the connection to online database services do not seem to have direct network externalities (see Table 4, first column).

9.3.2. The critical mass

Weiber (1995) explained the left-skewed diffusion curve and the critical mass at the early stages of diffusion by market-related factors, especially the problem of interdependent demand and that these innovations are "experience goods". He argued that these factors first hamper the rate of diffusion and later, after reaching critical mass, accelerate the diffusion process. In the present study the reasons for not adopting such as a low rate of diffusion and bad information, should be particularly crucial in the initial period before the innovation reaches critical mass. After the critical

[25] This point was emphasized by suppliers of telecommunications services. For example, Eric Danke at Deutsche Telkom, the official responsible for T-Online at that time, does not think that direct network externalities are very important for the success of Btx/T-Online (personal interview with E.M. Rogers, June 12, 1996).

[26] For electronic funds transfer, a bank might be one of the many component suppliers for the new telecommunications service.

mass is reached, these reasons should theoretically accelerate diffusion and play only a minor role as reasons for banks not to adopt. The perceived bad price/value ratio should behave in a similar way.

The critical mass point in the diffusion process is generally expected to occur approximately between 10 and 20% adoption (Rogers, 1995; Valente, 1995). As Markus (1990a) pointed out, we should distinguish between new telecommunications services for internal communication within an organization, external communication, or a mixture. We suggest that in addition to distinguishing between external and internal communication, as already indicated, it may be important to consider whether the external communication is from the perspective of suppliers or of users of a new telecommunications service. Also of interest is whether the partners for a new telecommunications service are organizations in the same industry (as for the innovation of electronic funds transfer between banks), whether all organizations are relevant (as for EDI), or whether the public represents the potential adopters, as for e-mail.[27] According to this distinction, the third column of Table 4 classifies the 12 telecommunications innovations as to whether or not the critical mass point was reached.[28]

The most-cited reasons for not adopting (low rate of diffusion, 41%; bad information, 15%; and bad price/value ratio, 15%) are the most relevant for the 12 innovations, whether or not their critical mass point was reached. In two of the three cases of innovations that are past critical mass, the low rate of diffusion is the most important reason for not adopting (see Table 4). Therefore Weiber's hypothesis that certain factors first retard and, after reaching critical mass, accelerate diffusion, is not supported by our data. Even if only telecommunications services are considered which display direct network externalities and have reached critical mass, like EFT (electronic funds transfer) with banks, a low rate of diffusion is still the most-cited reason for not adopting.

The present analysis also suggests that whether or not the diffusion process has reached critical mass, the obstacle to adoption of a low rate of diffusion generally is of relevance for all 12 telecommunications services of study, whether direct network externalities are involved or not. For example, for voicemail, with no direct network externalities, the percentage of banks reporting a low rate of diffusion (as a barrier to adoption) is higher than for videoconferencing or for EFT for authorization. We find that direct network externalities are not related to the perceived obstacle of a low rate of diffusion for not adopting in the present investigation. The relevance of a low rate of diffusion for all 12 telecommunications innovations, whether or not direct network externalities are involved, suggests that direct network externalities, generally assumed to be of central importance for the diffusion of telecommunications innovations, was not perceived as such by our German banks of study. This issue, however, needs further investigation with a larger sample of innovations, including those with, and without, externalities.

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[27] A new telecommunications service is typically used initially within the organization, then with the organization's major business partners in the industry or in several industries (such as the organization's suppliers), and eventually with all potential customers.

[28] We assumed that all 12 telecommunications services are relevant for external communication, although they might at the time the data were gathered have been used primarily within the bank (such as videoconferencing or e-mail). For electronic funds transfer with private customers and for authorization, however, the relevant markets are customers, and the level of diffusion is below 10%. EFT with banks, managed network services, and online database access had spread within the business sector at a level of over 20% at the time of our data-gathering.

We found that precisely measuring the critical mass point in the rate of adoption of an innovation, other than from observation of the rate of adoption, was difficult, in large part because it is often a problem to determine when further diffusion becomes self-sustaining.[29] Presumably this critical mass point would occur when the rate of adoption increases sharply at the same time as a decrease in the amount of promotion of the innovation, such as by the seller of the telecommunications service. We could not measure accurately this degree of promotion of the 12 telecommunications services in the present research. So important improvements in measuring the critical mass point await further investigation.

10. Conclusions

This paper suggested a theoretical perspective of the role of the critical mass in the diffusion of interactive innovations, and explored this theory with data from a sample of 392 German banks concerning their adoption of 12 telecommunications innovations. The *critical mass* is defined as the minimal number of adopters of an interactive innovation for the further rate of adoption to be self-sustaining. We argued that telecommunications innovations with strong network externalities, which are highly interactive in nature and which are characterized by direct externalities, are expected to have a more pronounced critical mass in their rate of adoption over time.

The first research question guiding the present investigation was: What is the rate of adoption and the most important reasons for not adopting telecommunications innovations by German banks? We found that the rate of adoption for the 12 telecommunications services (in 1992, when the data were gathered), ranged from a low of 2% for videoconferencing and voicemail, to a high of 80% for EFT in combination with authorization and 75% for online databases services. The most frequently mentioned reasons for nonadoption of the 12 innovations were a perceived low rate of diffusion (mentioned by 41% of all banks), followed by "bad information" about the innovation (15%) and a "bad price/value ratio" (15%).

A second research question guiding the present investigation was: Do the reasons for not adopting telecommunications innovations vary by the innovativeness of the banks? *Innovativeness* is the degree to which an organization is relatively earlier in adopting innovations than other organizations in the system. We measured the innovativeness of the 392 German banks as the number of the 12 innovations each had adopted, with each innovation weighted by its rate of adoption (so that a bank received more points for adopting an innovation with a low rate of adoption, like videoconferencing, than for adopting a widely adopted innovation like online database services). The 392 banks were then classified into the five adopter categories, with the 2.5% of banks with the highest innovativeness scores considered innovators, the next 12.5% early adopters, and so forth.

[29] The self-sustaining point in the rate of adoption for a telecommunications innovation would seem to occur when there is a decrease in the average cost of adopting (due to the increasing number of adopters) and an increase in the average utility of the innovation (because of network externalities and for other possible reasons). The critical mass point would theoretically occur when the cost curve crosses the utility curve. In the present study we were not able to measure the cost and perceived utility variables for the 12 innovations diffusing among the German banks of study.

We found that the frequency with which the banks mentioned 10 different reasons for nonadoption did not vary much by the banks' innovativeness (that is, adopter categories). The process of diffusion of the telecommunications innovations among the 392 German banks was one of "watching other banks' adoption, while being watched" (Allen, 1988). Diffusion is a social process in which new ideas are evaluated by talking with others about their experience with an innovation, thus creating a shared meaning for the new idea.

The third research question that we explored was: What is the role of direct network externalities and the critical mass in explaining the rate of adoption of telecommunications innovations by German banks? We conclude that direct network externalities characterize some telecommunications services, but are not relevant for all new telecommunications services. Our findings suggest that adopters' perceptions of the degree to which an innovation has externalities did not explain the innovation's rate of adoption: No matter which telecommunications service is considered (whether it has direct network externalities or not and whether it has reached critical mass or not), the reason of a low rate of diffusion is dominant. This finding suggests that German bankers may evaluate the utility of a telecommunications innovation, at least in part, on the basis of other bankers' adoption decisions and their experience with the innovation. Thus each banker might perceive a somewhat different critical mass point for a telecommunications innovation (however, when these perceptions are aggregated for all banks, the resulting critical mass point may lead the diffusion curve to take off). A perceived "low rate of diffusion" for a telecommunications innovation, the most frequently reported reason for nonadoption of each of the 12 innovations of study, suggests the importance of the critical mass. It seems that perceptions count in explaining human behavior. But further work is needed to clarify the exact nature of the critical mass in the diffusion of interactive innovations, and, particularly, in measuring when the critical mass point occurs.

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