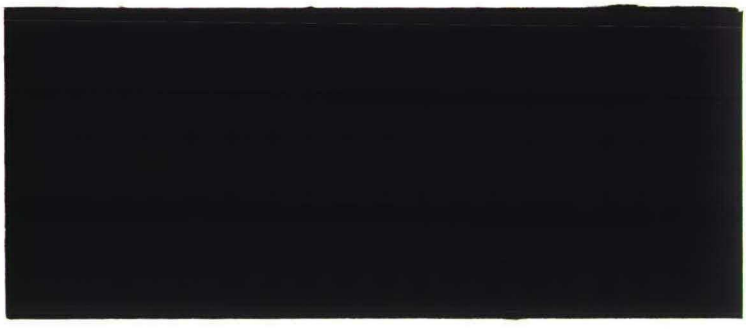
The diffusion of innovations

Frambach, R.T.

Publication date:
1991



DEPARTMENT OF ECONOMICS

RESEARCH MEMORANDUM

THE DIFFUSION OF INNOVATIONS: THE INFLUENCE OF SUPPLY-SIDE FACTORS

Ruud T. Frambach

FEW 494

THE DIFFUSION OF INNOVATIONS: THE INFLUENCE OF SUPPLY-SIDE FACTORS

by

Ruud T. Frambach*

June 1991

* Author's address: Tilburg University, Faculty of Economics, Department of Marketing and Market Research, P.O. Box 90153, 5000 LE Tilburg, The Netherlands. This paper has benefited from comments made by Gary Lilien, Bart Nooteboom and Berend Wierenga.

1. Introduction

Technology has become an important strategic business asset for many markets and firms. Since technology can be a distinctive competence of a firm, it may contribute significantly to its success in the marketplace. That is, technology may be the source of a competitive advantage. Therefore, managing technology effectively has become crucial in today's competitive environment (see e.g. Wilson, 1986).

An important issue in the management of technology is the development and marketing of technological innovations (Capon and Glazer, 1987; Ford, 1988). An innovation can be defined as 'an idea, practice, or object perceived as new by an individual' (Rogers, 1983). This definition often refers to innovations adopted by consumers. In the business-to-business market, however, innovations are to be viewed in the face of 'new production inputs, machines, processes, and techniques adopted by firms or entrepreneurs for their own use'.[2] From a (marketing) management point of view, it is especially interesting to identify the variables which determine the rate and speed of adoption of an innovation in the market. Diffusion theory can give more insight concerning the matter.[3] Shanklin and Ryans (1984) state that "the concept of diffusion of technological innovations ... is the basis for developing useful high-tech market insights, for effectively researching high-tech markets, and for formulating consequent marketing strategies that prove capable of achieving the company's goals" (p. 81). However, in *explaining individual adoption decisions* (e.g. consumers or firms) diffusion theory in general and research in marketing in particular have taken an adopter-side perspective, mostly ignoring the influence of the supplier of the innovation on the adoption process. Previous research points out the relevance of supply-side factors in explaining the process of adoption and diffusion of technological innovations (see e.g. in economics: Stoneman and Ireland, 1983; in geography: Brown, 1981; and in marketing: Robertson and Gatignon, 1986). This also includes the degree of interaction between the supply-side and adopter-side because of its potential influence on innovation adoption decisions (see e.g. von Hippel, 1988). Robertson and Gatignon (1986) have considered the influence of the supply-side on technology diffusion to some extent by incorporating the competitive environment of the supplier of the innovation in the diffusion paradigm. However, the proposed supply-side variables were limited to

---

[2] In this case the innovations are often termed *firm* or *technological innovations* (see Malecki, 1975, in: Brown, 1981).

[3] Although Metcalfe (1988, p. 561) makes the explicit distinction between *adoption analysis*, which considers the decisions taken by adoption agents to incorporate a new technology into their activities, and *diffusion analysis*, which is concerned with how the economic significance of a new technology changes over time, the research of variables influencing the (individual) adoption decision of an agent (behavioral) is often carried out under the heading 'diffusion research'. The present study is also part of such research.

structural factors and resource commitments to R&D and marketing (p. 2). An empirical test of this model only considered the degree of vertical coordination and the degree of supplier incentives as supply-side variables (Gatignon and Robertson, 1989).

The purpose of this paper is to derive propositions regarding variables influencing the process of organizational adoption and diffusion of innovations. This in order to derive a conceptual theoretical model of technology diffusion which does not only take an adopter-side perspective, but which incorporates supply-side factors as well. Figure 1 is a schematic representation of the model which we will discuss. It includes the scope of diffusion research up till now as well as the proposed extension.

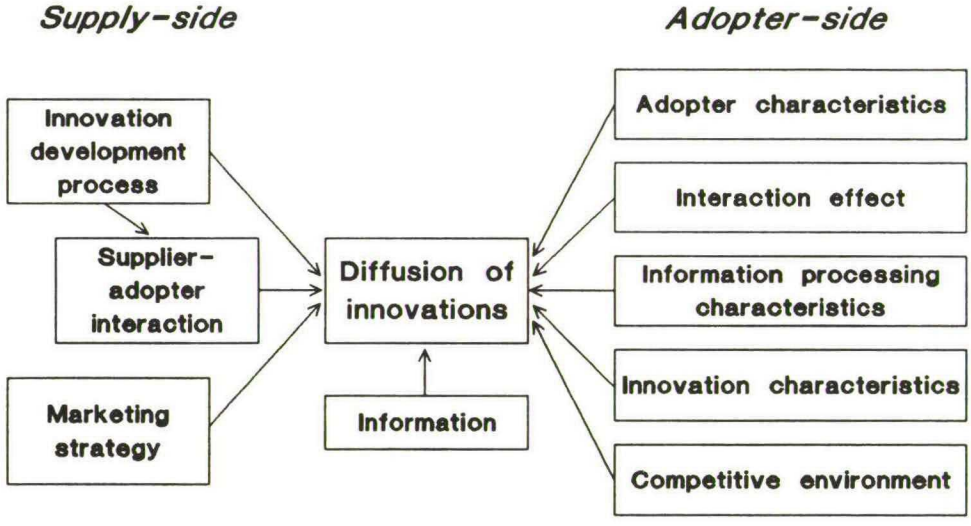


Figure 1: A conceptual model of technology diffusion

In the following section propositions based on the current diffusion paradigm will be derived. In section three, an extension of the diffusion paradigm will be discussed, primarily on the basis of innovation and marketing literature. This will lead to the formulation of additional propositions. Section four concludes this paper with an overview of the propositions as derived from the discussions.

2. The current diffusion paradigm

Research on the diffusion of innovations has been the interest of many scientific disciplines over the last few decades. As Rogers (1986) points out, innovation diffusion has emerged as one of the most multidisciplinary research topics in the social sciences today. This has led to the emergence of a common diffusion paradigm. The main elements of the process of diffusion of innovations have been described by Rogers (1983) as (1) an innovation, (2) which is communicated through certain channels, (3) over time[4], (4) among the members of a social system. The adoption process of a decision-making unit and the way it is influenced lies at the heart of the diffusion paradigm. In the last decade, diffusion research has been extended to the study of the innovation process in organizations (as adopters), the networks through which an innovation diffuses as well as the diffusion of new communication technologies (Rogers, 1986, p. 15).
In this section, after a brief discussion of the adoption process in organizations, several propositions concerning variables which influence the rate of adoption and diffusion of an innovation will be obtained on the basis of research conducted up to date.

The adoption process
In economics, the explanation of the diffusion process of an innovation and the identification of variables influencing this process has mostly been given form in analytical models (see e.g. Freeman, 1988, pp. 42-50). In a discussion of these models, Mahajan and Peterson (1985) make a distinction between three categories. The first category of models is based on 'external influence', representing the influence of change agents on the diffusion process (e.g. Fourt and Woodlock, 1960). In the second category, the rate of diffusion is treated solely as a function of interpersonal communication or social interaction between prior adopters and potential adopters in the social system (e.g. Mansfield, 1961). A third category of 'mixed influence' models takes both these influences into account (e.g. Bass, 1969). A number of researchers have stressed the importance of other variables and have questioned certain assumptions concerning the diffusion models.[5] For example, the complexity of the awareness, decision-making, evaluation and testing process within

[4] Time is involved in diffusion in (a) the innovation-decision process, which involves the mental stages through which an individual or other decision-making unit passes in adopting the innovation, (b) innovativeness, referring to the degree to which one adopts innovations relatively earlier than others, and (c) an innovation's rate of adoption.

[5] As such, the importance of the supply-side has been mentioned bij several authors. The relative profitability of an innovation as incentive to the adoption and diffusion of a new technology is especially stressed in this regard. In marketing, for example, researchers are increasingly making an effort to incorporate marketing-mix variables in diffusion models (see Mahajan, Muller and Bass, 1990).

firms as potential adopters of new technology is not taken into account. An assumption is that the diffusion process is binary, meaning that an innovation is either adopted or not. However this may prove to be a very useful assumption in order to build analytic models of diffusion on an aggregate level, it does not give any insight in the individual adoption decision process itself. In order to give a more accurate reflection of the empirical phenomenon of technology diffusion, a better understanding of the adoption process at the micro level is relevant (also see Mahajan, Muller and Bass, 1990, p. 20).

The innovation adoption process is defined by Rogers (1983, p. 163) as 'the process through which an individual or other decision-making unit passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision'. Other research (see e.g. Robertson, 1971) has outlined the adoption process in a similar way. In the case of the adopting unit being an organization, the adoption decision will often be made by a 'buying center' (see e.g Johnston and Bonoma, 1981). This is a decision-making unit, consisting of people who each play a different part in the buying process and therefore exert a definite influence on the adoption decision. Dependent on the buying situation (see Robinson, Faris and Wind, 1967), the adoption process will involve more people, will take longer and therefore will be more complex altogether. In this respect, the innovation adoption decision is the most complex one that an organization will be faced with, because no experience on the buying process of the particular product (the innovation) exists (in the words of Robinson et al.: 'new task'-buy). Adoption of an innovation is defined by Rogers (1983, p. 172) as 'a decision to make full use of an innovation as the best course of action available'. However, the actual decision to adopt or not to adopt an innovation is in fact not a dichotomous one. The non-adoption decision cannot be seen as the opposite of the adoption decision (Gatignon and Robertson, 1989). On this matter, Biemans (1989, p. 71) distinguishes between three types of non-adoption: (1) *a priori active rejection*, which occurs when adoption of the innovation is considered but later decided against, (2) *a posteriori active rejection* (or discontinuance), which occurs when reconsideration of adoption of the innovation results in rejection, and (3) *passive rejection*, which occurs when use of the innovation is never really considered.

Now we will take a closer look at the variables which are identified in research as being of influence on the innovation adoption decision. As such, characteristics of the adopting organization, characteristics of the innovation, the availability of information, the information-processing characteristics of the (potential) adopter, and the competitive environment of both the adopter and the supplier will be discussed.

Adopter characteristics

Before the 1960's, diffusion research in the social sciences focused on individuals as adopters of innovations. In economics, an amount of research on *industrial diffusion* emerged in the 1960's (e.g. Mansfield; see Freeman, 1988). However, this research sought to explain the observed patterns of diffusion in terms of rational decision-making by potential adopters (longitudinal), instead of seeking an explanation of the adoption decision by the individual firm through identification of the variables influencing this decision (cross-sectional). This can be explained by the fact that economists are interested in explaining economic growth at an aggregated level[6], while other social sciences are more interested in explaining individual (in this case organizational) behavior. Nowadays, we observe a growing interest in industrial diffusion in the latter disciplines; in the discipline of marketing, for example, diffusion research is now conducted in the business-to-business market (Robertson and Gatignon, 1986; Gatignon and Robertson, 1989), whereas in the past research has been focused primarily on consumers as the adopters of innovations (Day and Herbig, 1990).

A number of characteristics of an organization have been found to be of influence on the innovation adoption decision.[7] The variable most often found to be positively related to the adoption of an innovation is the *size* of an organization (Kennedy, 1983). Furthermore, several variables concerning the *organization structure* are of influence on the innovativeness of an organization. A higher level of *complexity* of an organization, as such being a function of the number of specialists in the organization and their professionalism (Hage and Aiken, 1970, p. 33), may facilitate adoption of an innovation. The diversity in background of the members of the organization may enlarge the number of information sources by means of which an organization may become aware of the existence of an innovation (Zaltman, Duncan and Holbek, 1973, p. 135; Cohn and Turyn, 1984). The same argument holds for the degree of *specialization* in an organization, which refers to the degree of division of labor (see Moch and Morse, 1977, p. 717). Other variables, such as the degree of *formalization* (the emphasis placed within the organization on following rules and procedures in performing one's job) and *centralization* of an organization (the degree to which power and control in a system are concentrated in the hands of relatively few individuals) have been found to be negatively related to its degree of

---

[6] In an interpretative survey on the diffusion of innovation, Metcalfe (1988) treats diffusion and structural economic change as synonyms.

[7] Zaltman, Duncan and Holbek (1973) consider the influence of organizational structure on the innovativeness of an organization at different stages of the innovation process (the inititation stage and the implementation stage). However, since the innovation adoption decision of an organization is the specific interest of this section (the initiation stage), the focus will be on the relationship between organizational structure characteristics of the potential adopter and the probability of adoption of an innovation.

innovativeness (Zaltman et al., 1973; Rogers, 1983).[8] The participation of members of an organization in an informal network of relations facilitates the spread of information on a certain innovation and, therefore, may have a positive influence on its rate of adoption (*'interaction effect'*, Zaltman et al., 1973, pp. 146-147).
The discussion in this section leads to the formulation of the following proposition:

Proposition 1: The probability of an organization adopting an innovation (sooner) increases with its
(a) size, and/or
(b) level of complexity, and/or
(c) degree of specialization, and/or
(d) members participating in informal networks on a more extensive basis;
The probability of an organization adopting an innovation (sooner) decreases with its
(e) degree of formalization, and/or
(f) degree of centralization.

Information
As was outlined earlier on, a potential adopter passes through certain stages before a decision is made on whether to adopt or reject an innovation. The extent and time of leaving behind certain stages in the adoption process is dependent on the information available and the information-processing characteristics of the potential adopter.
The probability that an organization adopts an innovation over a certain period of time may be influenced bij the *quantity*, *quality* and *value of* the *information* available (Webster, 1969). The availability of information depends considerably on the level of communication-activity of the supplier of the innovation on the one hand and on the extent to which adopters communicate their experiences on the other.[9] The former source of information was found to be of relatively greater importance during the 'knowledge'-phase of the adoption process, while the latter source of information was relatively more important in the stage of 'persuasion' (Rogers, 1983, p. 199). The quality of the information available refers to its ability of reducing uncertainty to the potential adopter of an innovation. The value of the

[8] The influence of the centralization variable on the innovativeness of a firm may depend on the organizational level at which information on a certain innovation is available first. In this respect, Kimberley and Evanisko (1981) hypothesized that adoption of administrative innovations is *positively* related to the degree of centralization of the adopter. However, the proposed relationship was not found to be significant.

[9] Advisors may be an important source of information to the potential adopter of an innovation as well.

information concerns the relative advantage which the information offers to the potential adopter. A proposition regarding the relationship between information on an innovation and the probability of an organization adopting this innovation can be stated as follows:

Proposition 2: The probability of an organization adopting an innovation (sooner) increases with
(a) the availability of information,
(b) the quality of the information available, and
(c) the value of the information available.

Information-processing characteristics

In a recent empirical study, Gatignon and Robertson (1989, p. 45) conclude that 'the decision-maker's information-processing characteristics contribute significantly in separating adopters from non-adopters' of an innovation. The more willing a potential adopter is to receive information on an innovation and the greater the capability of the recipient to process the information received, the higher the probability will be of the innovation being adopted. This all depends on the *absorbtion capacity* of the potential adopter, which refers to the knowledge and ability of an organization to judge and process certain information in order to make as efficient as possible use of the information within the organization (Baldwin and Scott, 1987, p. 117). It may be the case, especially for small companies, that an organization lacks the know-how to process potentially valuable information adequately (Nooteboom, Zwart and Bijmolt, 1990). In that case the information-processing activity has to be delegated to a third party. Two restrictions must be satisfied in order to do so successfully. Firstly, the third party must have no interest in advising wrongly on purpose. Secondly, the third party should be competent enough to give good advice based on the information received. Once a third party is found to be trustworthy, the advice given by him is valued highly by a decision-maker whose information absorbtion capacity is restricted.
It is proposed that:

Proposition 3: The higher the information absorbtion capacity of an organization, the more receptive it will be to innovations.

Innovation characteristics

Research has revealed a number of characteristics of an innovation, as perceived by a potential adopter, to be of influence on its rate and speed of adoption (Tornatzky and Klein, 1982; Rogers, 1983). Although in literature no standard classification of innovation characteristics, influencing the process of adoption, has been derived yet, the influence of several innovation characteristics has found empirical support on a

larger scale.

Rogers (1983) identifies five characteristics of an innovation which are generalized in their relation to the degree of adoption of that innovation in a social system. The *relative advantage* of an innovation, defined as 'the degree to which an innovation is perceived as being better than the idea it supersedes', has been found in research to be one of the best predictors of the rate of adoption of an innovation (Rogers, 1983, p. 218; also see Robinson, 1990). Especially the innovation adoption decision in the business-to-business market will be a result of the search for and prospects of relative advantages (i.e. improved profitability; Webster, 1969, p. 37; Chisnall, 1989, p. 83). The *compatibility* of an innovation, defined as 'the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters', is generalized to be positively related to its rate of adoption (Rogers, 1983, p. 226).[10] The more an innovation is compatible with the current situation of a potential adopter and his needs, the lesser are his switching costs and uncertainties, the more probable it is the innovation will be adopted. As regards the *complexity* of an innovation, defined as 'the degree to which an innovation is perceived as relatively difficult to understand and use', Rogers generalizes it to be negatively related to its rate of adoption (1983, p. 231). The *trialability* of an innovation and its *observability*[11] are generalized to be positively related to the rate of adoption of the innovation (Rogers, 1983, pp. 231-232).

The innovation characteristics put forward by Rogers should be supplemented with considerations of *uncertainty* (Nooteboom, 1989a).[12] Uncertainty is in several major ways involved in the adoption process of an innovation. Firstly, the potential adopter is uncertain as to whether advantages of the innovation (e.g. concerning cost saving or quality improvement), as promised by the supplier, will be realistic. The extent of the relative advantage of the innovation is not known for sure before adoption has taken place. Secondly, the potential adopter faces uncertainty regarding the implementation of the innovation in its organization. In order to bring the performance of the innovation up to the required or expected level, additional efforts, unknown prior to adoption of the innovation, may have to be made. Therefore, the uncertainty surrounding an innovation might make a potential adopter postpone the decision

---

[10] Although Robinson (1990) did not find a(n) (negative) impact on the initial market share of a supplier marketing an innovation which is incompatible with the customer's current way of doing things. Cooper and Zmud (1990), on the other hand, found support for the premise that the compatibility of an innovation with managerial tasks is a major factor in explaining information technology adoption behavior.

[11] Defined as 'the degree to which an innovation may be experimented with on a limited basis' and 'the degree to which the results of an innovation are visible to others' respectively.

[12] 'Uncertainty' is related to the risk as perceived by a potential adopter with regard to an innovation. The level of perceived risk is negatively related to the speed of adoption of an innovation (Gatignon and Robertson, 1985, p. 862).

to either adopt or reject the innovation. Furthermore, expectations of fast technological development among potential adopters of a certain technological innovation may retard its adoption.[13] It being the case, such expectations form an *inhibition* of the process of adoption and diffusion of the innovation, because the potential adopter considers the postponement of adoption of the innovation to be the most profitable strategy (Nooteboom, 1989b; also see Butler, 1988, p. 20).
Based on the preceeding discussion, it is proposed that:

Proposition 4: The relative advantage, compatibility, trialability and observability of a technological innovation, as perceived by potential adopters, are positively related to its rate of adoption; the complexity of an innovation, and the uncertainty surrounding its adoption are negatively related to the rate of adoption of the innovation.

Competitive environment
Recently, Robertson and Gatignon (1986) proposed an extended behavioral paradigm of technology diffusion among organizations in order to incorporate competitive effects on the diffusion process in the extant paradigm outlined by Rogers (1983).[14] The propositions made by Robertson and Gatignon are mainly based on the literature of industrial organization and include competitive effects on technology diffusion of both the supply-side and the adopter-side. However, empirical research does not always give clear support to the proposed relations. In most cases, unambiguous support is only found concerning the relation between the competitiveness of a market and the rate of diffusion of an innovation in that market (Kamien and Schwartz, 1982, p. 102; Baldwin and Scott, 1987, p. 143). A high level of competition among firms in a certain industry may enlarge the pressure on an individual firm to adopt a certain technological innovation after all. In case this firm would not do so, he may find that the adoption of that specific innovation by other firms may create a competitive disadvantage for it (see e.g. Romeo (1977) in: Stoneman, 1983, p. 95). Taking into account the research findings on the relationship between the competitiveness of an industry and the degree of innovativeness of organizations operating in that industry, the following is proposed:

Proposition 5: The speed and rate of adoption of an innovation by organizations in a certain industry will be positively related to the degree of competitiveness of that industry.

---

[13] Potential adopters may be uncertain as to the emergence of technology standards and the length of the technology life cycle (Gatignon and Robertson, 1991).

[14] They have incorporated similar variables in a model of consumer diffusion earlier (Gatignon and Robertson, 1985).

3. Extension of the diffusion paradigm

In the previous section a general survey was given of research findings concerning the variables influencing organizational innovation adoption behavior. It has become clear to us that so far the influence of the supply-side on the adoption process from a behavioral perspective has been given relatively little attention in literature.[15] However, some researchers have explicitly pointed out the relevance of such a perspective in theory development and empirical research (see e.g. Brown, 1981; Rogers, 1983; Robertson and Gatignon, 1986). In the field of consumer diffusion, Brown (1981) has developed a 'market and infrastructure perspective' which focusses upon the process by which innovations and the conditions for adoption are made available to individuals and households (p. 7), thus recognizing the supply aspect of diffusion. Based primarily on the industrial marketing literature, Brown concludes that the view that there exists a distinct supply-side in the diffusion of technological innovations finds support and he stresses the importance of the development of a conceptual framework of the diffusion of technological innovations in the business-to-business market (p. 169). Preliminary empirical research in this regard supports such a view (Gatignon and Robertson, 1989, p. 46: "Supply-side factors ... are found to be particularly important in explaining adoption"). However, the conceptualization of supply factors in the behavioral diffusion paradigm has been limited only to the Robertson and Gatignon-model (1986).

Diffusion researchers have identified areas of theoretical elaboration regarding the incorporation of supply-side variables in the conceptual diffusion model.
Firstly, the entire process of development of an innovation by a supplier firm can influence the acceptance of the innovation after its introduction in the marketplace. Rogers (1983) points out that

> "past diffusion investigations have overlooked the fact that a great deal of relevant activities and decisions usually occurred long before the diffusion process began ... . This entire prediffusion series of activities and decisions is certainly an important part of the innovation-development process, of which the diffusion phase is one component. The importance of what happens prior to the beginning of an innovation's diffusion (*especially those events that affect the nature of diffusion later on*) has been almost entirely ignored in past diffusion research. This serious deficiency in previous diffusion investigations should be overcome" (Rogers, 1983, p. 134-135)[emphasis added].

Prediffusion variables influencing the process of adoption and diffusion of an

---

[15] On the contrary, a number of authors in the field of economics and marketing have incorporated supply-side factors in analytical models of diffusion. In the behavioral domain, Robertson and Gatignon (1986) have incorporated supply-side variables in the technology diffusion paradigm to some extent.

innovation can be derived primarily from the literature on innovation management. Furthermore, in industrial marketing increasing attention is paid to the influence of supplier-buyer interfaces (among others) on the development process of an innovation and the process of its adoption and diffusion in the marketplace (see e.g. Håkansson, 1982; 1987; von Hippel, 1988). Therefore, this research should be taken into account here.
Secondly, the supplier of a technological innovation can exercise a direct influence on the diffusion process of the innovation by means of its marketing strategy. Brown (1981) states that

> "the diffusion of technological innovations also involves a conscious strategy on the part of the propagators that affects both the spatial and temporal patterns of diffusion" (Brown, 1981, p. 172).

Research on the diffusion of innovations has ignored the strategy pursued by the supplier of an innovation (Gatignon and Robertson, 1991). Since this may be found to be an important variable when explaining the adoption and diffusion process, it should be considered in the conceptual diffusion model. For this purpose we can draw from the strategic marketing literature.
This section will elaborate on the areas which are identified to be of importance in the diffusion process, but which have not been considered explicitly in theoretical conceptualizations of the process of adoption and diffusion of innovations in an organizational context. First of all, the development process which precedes the diffusion of an innovation will be discussed. Especially the impact of choices made at this stage of the innovation development process on the diffusion process later on, is of importance. Secondly, the influence of a supplier operating in a network of suppliers, (potential) buyers and other actors on the development and diffusion process of an innovation will be considered. Thirdly, attention will be given to marketing strategies of suppliers by means of which the rate of diffusion of an innovation can be accelerated.[16]

Innovation development process
The literature on strategic management has emphasized the importance of considering technology in the strategic posture of the firm (see e.g. Ansoff, 1984). Since technology may play an essential part in the success of an organization in the marketplace, it should be considered explicitly in the strategy formulation process (see e.g. Capon and Glazer, 1987; Rosenberg, 1988). In this respect, the firm will

[16] The influence of the supply-side variables on technology diffusion can be measured by asking (potential) adopters to what extent the *consequences* of the way in which suppliers have given attention to these variables influence their adoption decision. Therefore, the measurement of the supply-side factors is based on the perceptions of (potential) adopters.

have to formulate a technology strategy, which 'consists of policies, plans and procedures for acquiring knowledge and ability, managing that knowledge and ability within the firm and exploiting them for profit' (Ford, 1988). Choices have to be made as to whether new technologies will be developed within the firm or will be acquired from elsewhere.[17] Such decisions may have a significant influence on the success of products, derived from those technologies, in the market.

A relatively large body of research has emerged investigating the determinants of new industrial product performance.[18] This research is primarily based on the 'internal development' of a technological innovation. Lilien and Yoon (1989) have given an overview of empirical research on this subject. Based on this, they drew up a summary of the main determinants of industrial product performance. In regard of this, four categories of variables are identified which determine the success of an innovation in the marketplace:

(1) *Business strategic and organizational factors*, including general management's support and involvement; business-project fit; and R&D-manufacturing-marketing interaction. These factors are controllable by management at the corporate level in the long run.

(2) *R&D and production factors*, including the relative superiority or uniqueness of the innovation; experience and synergy effect in R&D and production[19]; user benefit or economic advantage of the innovation (c. 'relative advantage'); role of product champion; and patent protection. These factors are controllable by management through internal decisions and resources.

(3) *Marketing factors*, including experience and efficiency in marketing; and interaction with potential customers. These factors are also controllable through internal marketing decisions and allocation of resources. Interaction with potential customers can be given form in several ways. We will elaborate on this matter later on.

(4) Market and environmental factors, which include the degree of competition in the market (c. 'competitive environment'); and the market size and growth rate. These factors cannot be controlled by the decisions made by the individual firm's management.

---

[17] Because of the fact that most companies will not be capable of developing all of the required technologies on their own, they will participate in a 'technological infrastructure', which supports inter-organizational technology transfer (Weiss and Birnbaum, 1989).

[18] See e.g. Cooper (1979; 1983; 1988), Calantone and Cooper (1981), Maidique and Zirger (1984), Cooper and Kleinschmidt (1987), Lilien and Yoon (1989), Zirger and Maidique (1990).

[19] Referring to a production and engineering resource base which is both strong as well as compatible with the innovation project (Cooper, 1979). This also holds for marketing (see next category).

Determinants of industrial product performance which are controllable by management are dependent on the way in which the innovation development process is organized within the firm. The innovation development process consists of several stages. Therefore, it is defined by Rogers (1983) as 'all of the decisions, activities and their impacts that occur from recognition of a need or problem, through research, development, and commercialization of an innovation, through diffusion and adoption of the innovation by users, to its consequences' (p. 135).

Based on the product success and failure research, both Cooper (1983) and Zirger and Maidique (1990) have set up a model of new industrial product development, incorporating the critical factors necessary to develop successful new industrial products. The model proposed by Cooper (1983) is a normative seven-stage process model, which goes into the activities a firm has to undertake to a certain extent will it be able to create successful industrial products.[20] The Zirger and Maidique (1990) model is one of lesser detail. It describes the innovation development process in terms of the organizational and external entities that influence product outcome. Organizational entities include the three primary groups involved in product development: R&D, manufacturing and marketing (also see Gupta, Raj and Wilemon, 1986). The competences of the functional groups, their planning of the development process and the cooperation between the groups are considered in the model. External entities included in the model comprise market characteristics, such as degree of competitiveness, market size and growth. An empirical test of the model underlined the importance of variables comparable to the ones summarized by Lilien and Yoon (1989). The commitment of a capable organization to the development of an innovation, offering significant value to the potential adopter, is crucial in innovation development (Zirger and Maidique, 1990, p. 879-880). An important instrument for accomplishing this, is the understanding of the needs of the customers by interacting with them during the process of development.

From the discussion of the organization and execution of the innovation development process in this section, it is proposed that:

Proposition 6: The speed and rate of adoption of a technological innovation by organizations will be positively related to the extent that the supplier firm

(a) has given more support to the development of the innovation, and/or

(b) has given more attention to the incorporation of the innovation project in its overall strategic posture, and/or

(c) has given more attention to the creation of an innovative climate

[20] Cooper (1983) distinguishes the following stages: (1) idea, (2) preliminary assessment, (3) concept, (4) development, (5) testing, (6) trial, and (7) launch.

within the organization, and/or
(d) has given more attention to the development of a unique and superior product in the eyes of the potential adopter, and/or
(e) can take advantage of past experiences or synergy more easily than its competitors.

Proposition 7: The speed and rate of adoption of a technological innovation by organizations will be positively related to the extent that the supplier firm has a better level of organization and execution of the innovation-development process within its organization.

Supplier-buyer interactions and networks

The degree to which an innovation offers significant value to a potential customer and the degree of compatibility to its needs and wants were earlier on identified as important determinants in the success of the innovation. In other words, the extent to which a supplier succeeds in meeting customer needs when offering a new product, is essential to the performance of that product in the marketplace (c. Rogers, 1983, p. 319). Especially in the business-to-business market this will be a factor of crucial importance. For, in the case of industrial markets, innovations adopted by organizations will be implemented in the adopters' own business operations. Because of this, the innovation must often meet with certain specifications, or needs to be adjusted so as to meet with the adopter's specific needs.[21] In order to avoid potential problems and to be able to offer a product that meets well with the customer's needs, the supplier of an innovation may decide to cooperate with potential adopters during the process of development of the innovation.[22] In the literature this is known as the *'interaction approach'* to innovation development (see Håkansson, 1982).[23] Especially the International Marketing and Purchasing (IMP)-group has studied the development of innovations in such cases. An important condition for interaction between a supplier and buyer-party is the existence of an

[21] Therefore, the innovation adoption process in organizations is usually considered successful if it leads to implementation of the innovation and not just its adoption per se (Rogers, 1986, p. 19).

[22] Urban and Von Hippel (1988) conclude that so called 'lead user analysis' can improve the productivity of new product development in industrial markets (p. 579). 'Lead users' of a novel product are defined as 'those who display two characteristics with respect to it: (1) lead users face needs that will be general in a marketplace, but face them months or years before the bulk of that marketplace encounters them, and (2) lead users are positioned to benefit significantly by obtaining a solution to those needs' (p. 569).

[23] In case the supplier firm has taken the initiative to develop an innovation and dominates its development process, von Hippel speaks of the 'Manufacturer Active Paradigm' (MAP). On the other hand, in case the initiative is taken by the customer and this party dominates the innovation development process, the 'Customer Active Paradigm' (CAP) is relevant (Von Hippel, 1988).

explicit (long term) relationship between them.

The Swedish branche of the IMP-group has developed the concept of innovation development by means of interaction between supplier and buyer-parties further, by incorporating other parties in this process as well (Håkansson, 1987). Since the process of innovation development requires knowledge from diverse sources, the main parties involved in the development process will also have to interact with other parties in order to acquire such knowledge (c. 'technological infrastructure', Weiss and Birnbaum, 1989). Therefore, a *network* of interacting parties can be involved in the development of an innovation (also see e.g. Biemans, 1989). The existence of such a network may accelerate the rate of diffusion of the innovation by the time it finds introduction in the marketplace (Reddy, 1989). Therefore, the following is proposed:

Proposition 8: The speed and rate of adoption of a technological innovation by organizations will be positively related to the extent that the supplier firm has interacted with other parties (especially potential adopters of the innovation) more intensively during the innovation development process.

Marketing strategy of the supplier

The most fundamental choice a supplier will have to make when marketing a new product, is whether to be a 'market pioneer' or a 'follower', i.e. *when* to enter the market. This decision will concern a trade-off of the risks of premature entry (enter too early) and the problems of missed opportunities (enter too late)(Lilien and Yoon, 1990).[24] Within this broad framework, a firm has to decide next *how* to enter the market.[25] Based on a review of academic literature, the business press and interviews with marketing managers of high technology companies, Easingwood and Beard (1989) have identified four main groups of market launch strategies of new industrial products, aimed at accelerating the rate of early adoption.

The first alternative to consider is the possibility of *working with other producers* in order to educate potential users and expand total primary demand. The cooperation can take two important forms. One is to share the technology with others so as to increase total demand (especially in the case of network externalities, or to increase total marketing effort in the marketplace) and prevent users being confronted with

---

[24] Based on the economic and marketing literature, Lilien and Yoon (1990) have developed a set of propositions about the timing of new product entry.

[25] Several researchers have derived typologies of marketing strategies which firms confronted with a high level of environmental turbulence (e.g. technnological development) might pursue (Ansoff and Stewart, 1967; Freeman, 1974; Miles and Snow, 1978). Since these strategies have a very broad character, it is difficult to hypothesize their relation to innovation diffusion. Therefore, they will not be discussed here.

competing and incompatible technologies (by setting a technology standard). The other is to educate a target audience (i.e. other producers of similar technologies; the target market) as to the workings of the new technology. This can provide the basis to an accelerated diffusion of the innovation.

The second marketing strategy to consider concerns the *positioning of the innovation in the marketplace*. By identifying the potential 'early adopters' in the market, marketing efforts can be concentrated on these groups in order to accelerate the initial rate of adoption of the innovation. Such can be accomplished by either approaching innovative adopters, heavy users of the product category, or heavy users of the preceeding technology. Innovative adopters are those early buyers of new products who are undeterred by the risk of early adoption. Other groups of early adopters include heavy users of the general product category from which the innovation comes and heavy users of the technology that the new product is intended to replace. Especially the effect of adoption of an innovation by early adopters on the adoption decision of others in the market is important for the diffusion process to take off ('contamination effect'). Analytical new product diffusion models in marketing have examined such effects (see Mahajan, Muller and Bass, 1990). Another possibility of achieving a fast market penetration is to pursue a *rapid-penetration strategy*, which consists of launching the new product at a low price and spending heavily on promotion (Kotler, 1991, p. 355).

The third group of marketing strategies, as observed by Easingwood and Beard, which are being used by companies to accelerate diffusion, were directly intended to *reduce the risks associated with early adoption*. Risk and uncertainty are in several ways factors involved in the adoption of an innovation (Nooteboom, 1989a). The supplier of the innovation can use several approaches to reduce the risk of adoption. First, the innovation may be given on trial to the customer for a certain period of time. Second, the supplier may decide to absorb the total risk of adoption. In some cases of high technology marketing this may be necessary to gain market acceptance. Ultimately, success of an innovation depends on the reputation it gathers in the marketplace. Therefore, *winning market support* can be identified as another important category of marketing strategies. A supplier can try to gain market support

in several ways. The research conducted by Easingwood and Beard revealed three approaches. The first approach is to win the endorsement of opinion leaders. In the business-to-business market one may think of approaching key persons in decision making units of firms, or persons from outside the firm who may influence the adoption decision (i.e. consultants, accountants). The second approach is to establish a "winner" image in the marketplace by creating instant success. This may be accomplished by investing substantial resources into the launching of the new product. The final approach identified by Easingwood and Beard is to "legitimize" the product by publicizing the names of those organizations that have already

adopted the innovation and whose endorsement contributes an air of "legitimacy". Ideally, this would create a substantial word-of-mouth communication from adopter to potential adopters.
Based on the discussion of marketing strategies, which a supplier of an innovation might pursue in order to accelerate the rate of adoption and diffusion of the innovation in the market, the following proposition can be formulated:

Proposition 9: The speed and rate of adoption of an innovation by organizations will be positively related to the extent that the supplier firm has pursued a marketing strategy of
(a) cooperation with other suppliers by sharing the technology or educating some target audience (including other producers), and/or
(b) positioning the innovation in the market by approaching innovative adopters, heavy users of the product category, heavy users of the preceeding technology and/or setting a penetration price, and/or
(c) reducing the risk of adoption by offering a trial period or absorbing all the risk involved for the potential adopter, and/or
(d) winning market support by winning the endorsement of opinion leaders, establishing a winner image, or legitimizing the product in the marketplace.

4. Conclusion

In the above, a set of propositions regarding variables influencing the process of diffusion of innovations has been suggested. These propositions are partly based on the research on innovation diffusion and partly on research in marketing and innovation management in general. An overview of the proposed relations between the variables and organizational adoption behavior is given in table 1.
Both theory and preliminary empirical research support the proposition that supply-side factors are of importance in explaining innovation adoption behavior. Therefore, future research should focus on these factors in order to test theoretical conceptualizations, such as the one outlined in this paper, empirically.[26] This may deepen our knowledge on the process of the diffusion of innovations significantly.

[26] The theoretical model as presented in this paper is presently being tested, examining the process of adoption and diffusion of 'electronic banking' on the business-to-business market in the Netherlands.

TABLE 1: PROPOSITIONS ON ORGANIZATIONAL INNOVATION DIFFUSION

VARIABLE	RELATION TO DIFFUSION	PROPOSITION
Adopter characteristics		
size	+	1a
complexity	+	1b
specialization	+	1c
interpersonal relations	+	1d
formalization	-	1e
centralization	-	1f
Information		
availability	+	2a
quality	+	2b
value	+	2c
Information-processing characteristics		
absorbtion capacity	+	3
Innovation characteristics		
relative advantage	+	4
compatibility	+	
complexity	-	
trialability	+	
observability	+	
uncertainty	-	
obstruction	-	
Competitive environment		
competitiveness adopter industry	+	5
Innovation development		
management support	+	6a
incorporation in strategic posture	+	6b
innovative organizational climate	+	6c
superior product	+	6d
experience and synergy effects	+	6e
organization/execution of development	+	7
Network participation		
level of interaction	+	8
Marketing strategy		
cooperation with other suppliers	+	9a
positioning innovation in the market	+	9b
reducing the risk of adoption	+	9c
winning market support	+	9d

References

Ansoff, H. Igor (1984), *Implanting Strategic Management*. Englewood Cliffs, N.J.: Prentice Hall.

Ansoff, H. Igor; John M. Stewart (1967), 'Strategies for a technology-based business'. *Harvard Business Review* (November-December), pp. 71-83.

Baldwin, William L.; John T. Scott (1987), *Market Structure and Technological Change*. Chur, Switzerland: Harwood Academic Publishers GmbH.

Bass, Frank M. (1969), 'A New Product Growth Model for Consumer Durables'. *Management Science*, Vol. 15 (January), pp. 215-227.

Biemans, W.G. (1989), *Developing Innovations within Networks*. Ph.D.-thesis University of Technology, Eindhoven, The Netherlands.

Brown, Lawrence A. (1981), *Innovation Diffusion*. London/New York: Methuan & Co.

Butler, John E. (1988), 'Theories of technological innovation as useful tools for corporate strategy'. *Strategic Management Journal*, Vol. 9, pp. 15-29.

Calantone, Roger; Robert G. Cooper (1981), 'New Product Scenarios: Prospects for Success'. *Journal of Marketing*, Vol. 45, No. 2 (Spring), pp. 48-60.

Capon, Noel; Rashi Glazer (1987), 'Marketing and Technology: a Strategic Coalignment'. *Journal of Marketing*, Vol. 51 (July), pp. 1-14.

Chisnall, Peter M. (1989), *Strategic Industrial Marketing*. Englewood Cliffs, N.J.: Prentice Hall.

Cohn, Steven F.; Romaine M. Turyn (1984), 'Organizational Structure, Decision-Making Procedures, and the Adoption of Innovations'. *IEEE Transactions on Engineering Management*, Vol. EM-31, No. 4, November, pp. 154-161.

Cooper, Robert G. (1979), 'The Dimensions of Industrial New Product Success and Failure'. *Journal of Marketing*, Vol 43 (Summer), pp. 93-103.

Cooper, Robert G. (1983), 'A Process Model for Industrial New Product Development'. *IEEE Transactions on Engineering Management*, Vol. EM-30, No. 1, February, pp. 2-11.

Cooper, Robert G. (1988), 'Predevelopment Activities Determine New Product Success'. *Industrial Marketing Management*, Vol. 17, pp. 237-247.

Cooper, Robert G.; E.J. Kleinschmidt (1987), 'Success Factors in Product Innovation'. *Industrial Marketing Management*, Vol. 16, pp. 215-223.

Cooper, Randolph B.; Robert W. Zmud (1990), 'Information Technology Implementation Research: A Technological Diffusion Approach'. *Management Science*, Vol. 36, No. 2 (February), pp. 123-139.

Day, Ralph L.; Paul A. Herbig (1990), 'How the Diffusion of Industrial Innovations is Different from New Retail Products'. *Industrial Marketing Management*, Vol. 19, pp. 261-266.

Easingwood, Chris; Charles Beard (1989), 'High Technology Launch Strategies in the U.K.'. *Industrial Marketing Management*, Vol. 18, pp. 125-138.

Ford, David (1988), 'Develop your Technology Strategy'. *Long Range Planning*, Vol. 21, No. 5, pp. 88-95.

Freeman, Christopher (1974), *The Economics of Industrial Innovation*. Baltimore: Penguin Books.

Freeman, Christopher (1988), 'Diffusion: The Spread of New Technology to Firms, Sectors, and Nations'. In: *Innovation, technology, and finance*, Arnold Heertje (ed.), Oxford/New York: Basil Blackwell.

Fourt, L.A.; J.W. Woodlock (1960), 'Early Prediction of Market Success for Grocery Products'. *Journal of Marketing*, Vol. 25, October, pp. 31-38.

Gatignon, Hubert; Thomas S. Robertson (1985), 'A Propositional Inventory for New Diffusion Research'. *Journal of Consumer Research*, Vol. 11, March, pp. 849-867.

Gatignon, Hubert; Thomas S. Robertson (1989), 'Technology Diffusion: An Empirical Test of Competitive Effects'. *Journal of Marketing*, Vol. 53, January, pp. 35-49.

Gatignon, Hubert; Thomas S. Robertson (1991), 'Diffusion of Innovation'. In: *Handbook of Consumer Theory and Research*, Harold H. Kassarjian; Thomas S. Robertson (eds.), Englewood Cliffs, N.J.: Prentice Hall.

Gupta, Ashok K., S.P. Raj, David Wilemon (1986), 'A Model for Studying R&D-Marketing Interface in the Product Innovation Process'. *Journal of Marketing*, Vol. 50, April, pp. 7-17.

Hage, J.; M. Aiken (1970), *Social Change in Complex Organizations*. New York: Random House.

Håkansson, Håkan (ed.) (1982), *International Marketing and Purchasing of Industrial goods; An Interaction Approach*, Chichester: John Wiley.

Håkansson, Håkan (ed.) (1987), *Industrial Technological Development; A Network Approach*, London: Routledge (1989 reprint).

Johnston, Wesley J.; Thomas V. Bonoma (1981), 'The Buying Center: Structure and Interaction Patterns'. *Journal of Marketing*, Vol. 45, Summer, pp. 143-156.

Kamien, Morton I.; Nancy L. Schwartz (1982), *Market Structure and Innovation*. Cambridge: Cambridge University Press.

Kennedy, Anita M. (1983), 'The Adoption and Diffusion of New Industrial Products: A Literature Review'. *European Journal of Marketing*, Vol. 17, pp. 31-88.

Kimberley, John R.; Michael J. Evanisko (1981), 'Organizational Innovation: The Influence of Individual, Organizational, and Contextual Factors on Hospital Adoption of Technological and Administrative Innovations'. *Academy of Management Journal*, Vol. 24, No. 4, pp. 689-713.

Kotler, Philip (1991), *Marketing Management; analysis, planning, implementation, and control* (seventh edition). Englewood Cliffs, N.J.: Prentice Hall, Inc.

Lilien, Gary L.; Eunsang Yoon (1989), 'Determinants of New Industrial Product Performance: A Strategic Reexamination of the Empirical Literature'. *IEEE Transactions on Engineering Management*, Vol. 36, No. 1, February, pp. 3-10.

Lilien, Gary L.; Eunsang Yoon (1990), 'The Timing of Competitive Market Entry: An Exploratory Study of New Industrial Products'. *Management Science*, Vol. 36, No. 5, May, pp. 568-585.

Mahajan, Vijay; Robert A. Peterson (1985), *Models for Innovation Diffusion*. Beverly Hills, CA: Sage Publications Inc.

Mahajan, Vijay; Eitan Muller; Frank M. Bass (1990), 'New Product Diffusion Models in Marketing: A Review and Directions for Research'. *Journal of Marketing*, Vol. 54, January, pp. 1-26.

Maidique, Modesto A.; Billie Jo Zirger (1984), 'A Study of Success and Failure in Product Innovation: The Case of the U.S. Electronics Industry'. *IEEE Transactions on Engineering Management*, Vol. EM-31, No. 4, November, pp. 192-203.

Mansfield, Edwin (1961), 'Technical change in the rate of imitation'. *Econometrica*, pp. 741-766.

Metcalfe, J.S. (1988), 'The diffusion of innovation: an interpretative survey'. In: *Technical Change and Economic Theory*, Giovanni Dosi; Christopher Freeman; Richard Nelson; Gerald Silverberg; Luc Soete (eds.), London/New York: Pinter Publishers.

Miles, R.E.; C.C. Snow (1978), *Organizational Strategy, Structure and Process*. New York: McGraw-Hill.

Moch, Michael K.; Edward V. Morse (1977), 'Size, Centralization and Organizational Adoption of Innovations'. *American Sociological Review*, Vol. 42, October, pp. 716-725.

Nooteboom, B. (1989a), 'Diffusion, uncertainty and firm size'. *International Journal of Research in Marketing*, Vol. 6, pp. 109-128.

Nooteboom, B. (1989b), 'Inhibition of Progress and Risk of Introduction: Two Problems in the Marketing of New Technology'. In: *Industrial and New Technologies Marketing*, proceedings XVIth International Research Seminar in Marketing, I.R.E.T. La Londe les Maures, May 17-19, pp. 230-246.

Nooteboom, B.; P.S. Zwart; T.H.A. Bijmolt (1990), 'Vraagstukken in de advisering aan middelgrote en kleine bedrijven' [Problems in advising medium-sized and small companies]. *Maandblad voor Accountancy en Bedrijfseconomie*, Vol. 64, No. 10 (September), pp. 378-387.

Reddy, N. Nohan (1989), 'The Domain of Technology Diffusion: Concept of Innovation Community'. In: *Industrial and New Technologies Marketing*, proceedings XVIth International Research Seminar in Marketing, I.R.E.T. La Londe les Maures, May 17-19, pp. 268-284.

Robertson, Thomas S. (1971), *Innovative Behavior and Communication*. New York: Holt, Rinehart and Winston, Inc.

Robertson, Thomas S.; Hubert Gatignon (1986), 'Competitive Effects on Technology Diffusion'. *Journal of Marketing*, Vol. 50, July, pp. 1-12.

Robinson, Patrick; Charles Faris; Yoram Wind (1967), *Industrial Buying and Creative Marketing*. Boston: Allyn and Bacon.

Robinson, William T. (1990), 'Product Innovation and Start-Up Business Market Share Performance'. *Management Science*, Vol. 36, No. 10 (October), pp. 1279-1289.

Rogers, Everett M. (1983), *Diffusion of Innovations*, 3rd ed. New York: The Free Press.

Rogers, Everett M. (1986), 'Three Decades of Research on the Diffusion of Innovations: Progress, Problems, Prospects'. Paper presented at the *Conference on Innovation Diffusion*, Venice, March 18-22, 1986.

Rosenberg, Richard D. (1988), 'Integrating strategy, industrial product innovation and marketing research'. *International Journal of Research in Marketing*, Vol. 5, pp. 199-211.

Shanklin, William L.; John K. Ryans, Jr. (1984), *Marketing High Technology*. Lexington, Mass.: Lexington Books.

Stoneman, Paul (1983), *The Economic Analysis of Technological Change*. Oxford: Oxford University Press.

Stoneman, Paul; N. Ireland (1983), 'The role of supply factors in the diffusion of new process technology'. *Economic Journal*, Vol. 93.

Tornatzky, Louis G.; Katherine J. Klein (1982), 'Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings'. *IEEE Transactions on Engineering Management*, Vol. EM-29, No. 1, February, pp.

28-45.
Urban, Glen L.; Eric von Hippel (1988), 'Lead User Analyses for the Development of New Industrial Products'. *Management Science*, Vol. 34, No. 5, May, pp. 569-582.
Von Hippel, Eric (1988), *The Sources of Innovation*. New York/Oxford: Oxford University Press.
Webster, Frederick E. Jr. (1969), 'New Product Adoption in Industrial Markets: A Framework for Analysis'. *Journal of Marketing*, Vol. 33, July, pp. 35-39.
Weiss, Andrew R.; Philip H. Birnbaum (1989), 'Technological Infrastructure and the Implementation of Technological Strategies'. *Management Science*, Vol. 35, No. 8, August, pp. 1014-1026.
Wilson, Ian (1986), 'The Strategic Management of Technology: Corporate Fad or Strategic Necessity?'. *Long Range Planning*, Vol. 19, No. 2, pp. 21-22.
Zaltman, G.; R. Duncan; J. Holbek (1973), *Innovations and Organizations*. New York: Wiley.
Zirger, Billie Jo; Modesto A. Maidique (1990), 'A Model of New Product Development: An Empirical Test'. *Management Science*, Vol. 36, No.7, July, pp. 867-883.

IN 1990 REEDS VERSCHENEN

419 Bertrand Melenberg, Rob Alessie
A method to construct moments in the multi-good life cycle consumption model

420 J. Kriens
On the differentiability of the set of efficient (μ,σ^2) combinations in the Markowitz portfolio selection method

421 Steffen Jørgensen, Peter M. Kort
Optimal dynamic investment policies under concave-convex adjustment costs

422 J.P.C. Blanc
Cyclic polling systems: limited service versus Bernoulli schedules

423 M.H.C. Paardekooper
Parallel normreducing transformations for the algebraic eigenvalue problem

424 Hans Gremmen
On the political (ir)relevance of classical customs union theory

425 Ed Nijssen
Marketingstrategie in Machtsperspectief

426 Jack P.C. Kleijnen
Regression Metamodels for Simulation with Common Random Numbers: Comparison of Techniques

427 Harry H. Tigelaar
The correlation structure of stationary bilinear processes

428 Drs. C.H. Veld en Drs. A.H.F. Verboven
De waardering van aandelenwarrants en langlopende call-opties

429 Theo van de Klundert en Anton B. van Schaik
Liquidity Constraints and the Keynesian Corridor

430 Gert Nieuwenhuis
Central limit theorems for sequences with m(n)-dependent main part

431 Hans J. Gremmen
Macro-Economic Implications of Profit Optimizing Investment Behaviour

432 J.M. Schumacher
System-Theoretic Trends in Econometrics

433 Peter M. Kort, Paul M.J.J. van Loon, Mikulás Luptacik
Optimal Dynamic Environmental Policies of a Profit Maximizing Firm

434 Raymond Gradus
Optimal Dynamic Profit Taxation: The Derivation of Feedback Stackelberg Equilibria

435 Jack P.C. Kleijnen
Statistics and Deterministic Simulation Models: Why Not?

436 M.J.G. van Eijs, R.J.M. Heuts, J.P.C. Kleijnen
Analysis and comparison of two strategies for multi-item inventory systems with joint replenishment costs

437 Jan A. Weststrate
Waiting times in a two-queue model with exhaustive and Bernoulli service

438 Alfons Daems
Typologie van non-profit organisaties

439 Drs. C.H. Veld en Drs. J. Grazell
Motieven voor de uitgifte van converteerbare obligatieleningen en warrantobligatieleningen

440 Jack P.C. Kleijnen
Sensitivity analysis of simulation experiments: regression analysis and statistical design

441 C.H. Veld en A.H.F. Verboven
De waardering van conversierechten van Nederlandse converteerbare obligaties

442 Drs. C.H. Veld en Drs. P.J.W. Duffhues
Verslaggevingsaspecten van aandelenwarrants

443 Jack P.C. Kleijnen and Ben Annink
Vector computers, Monte Carlo simulation, and regression analysis: an introduction

444 Alfons Daems
"Non-market failures": Imperfecties in de budgetsector

445 J.P.C. Blanc
The power-series algorithm applied to cyclic polling systems

446 L.W.G. Strijbosch and R.M.J. Heuts
Modelling (s,Q) inventory systems: parametric versus non-parametric approximations for the lead time demand distribution

447 Jack P.C. Kleijnen
Supercomputers for Monte Carlo simulation: cross-validation versus Rao's test in multivariate regression

448 Jack P.C. Kleijnen, Greet van Ham and Jan Rotmans
Techniques for sensitivity analysis of simulation models: a case study of the CO_2 greenhouse effect

449 Harrie A.A. Verbon and Marijn J.M. Verhoeven
Decision-making on pension schemes: expectation-formation under demographic change

450 Drs. W. Reijnders en Drs. P. Verstappen
Logistiek management marketinginstrument van de jaren negentig

451 Alfons J. Daems
Budgeting the non-profit organization
An agency theoretic approach

452 W.H. Haemers, D.G. Higman, S.A. Hobart
Strongly regular graphs induced by polarities of symmetric designs

453 M.J.G. van Eijs
Two notes on the joint replenishment problem under constant demand

454 B.B. van der Genugten
Iterated WLS using residuals for improved efficiency in the linear model with completely unknown heteroskedasticity

455 F.A. van der Duyn Schouten and S.G. Vanneste
Two Simple Control Policies for a Multicomponent Maintenance System

456 Geert J. Almekinders and Sylvester C.W. Eijffinger
Objectives and effectiveness of foreign exchange market intervention
A survey of the empirical literature

457 Saskia Oortwijn, Peter Borm, Hans Keiding and Stef Tijs
Extensions of the τ-value to NTU-games

458 Willem H. Haemers, Christopher Parker, Vera Pless and
Vladimir D. Tonchev
A design and a code invariant under the simple group Co_3

459 J.P.C. Blanc
Performance evaluation of polling systems by means of the power-series algorithm

460 Leo W.G. Strijbosch, Arno G.M. van Doorne, Willem J. Selen
A simplified MOLP algorithm: The MOLP-S procedure

461 Arie Kapteyn and Aart de Zeeuw
Changing incentives for economic research in The Netherlands

462 W. Spanjers
Equilibrium with co-ordination and exchange institutions: A comment

463 Sylvester Eijffinger and Adrian van Rixtel
The Japanese financial system and monetary policy: A descriptive review

464 Hans Kremers and Dolf Talman
A new algorithm for the linear complementarity problem allowing for an arbitrary starting point

465 René van den Brink, Robert P. Gilles
A social power index for hierarchically structured populations of economic agents

IN 1991 REEDS VERSCHENEN

466 Prof.Dr. Th.C.M.J. van de Klundert - Prof.Dr. A.B.T.M. van Schaik
Economische groei in Nederland in een internationaal perspectief

467 Dr. Sylvester C.W. Eijffinger
The convergence of monetary policy - Germany and France as an example

468 E. Nijssen
Strategisch gedrag, planning en prestatie. Een inductieve studie binnen de computerbranche

469 Anne van den Nouweland, Peter Borm, Guillermo Owen and Stef Tijs
Cost allocation and communication

470 Drs. J. Grazell en Drs. C.H. Veld
Motieven voor de uitgifte van converteerbare obligatieleningen en warrant-obligatieleningen: een agency-theoretische benadering

471 P.C. van Batenburg, J. Kriens, W.M. Lammerts van Bueren and R.H. Veenstra
Audit Assurance Model and Bayesian Discovery Sampling

472 Marcel Kerkhofs
Identification and Estimation of Household Production Models

473 Robert P. Gilles, Guillermo Owen, René van den Brink
Games with Permission Structures: The Conjunctive Approach

474 Jack P.C. Kleijnen
Sensitivity Analysis of Simulation Experiments: Tutorial on Regression Analysis and Statistical Design

475 An $O(nlogn)$ algorithm for the two-machine flow shop problem with controllable machine speeds
C.P.M. van Hoesel

476 Stephan G. Vanneste
A Markov Model for Opportunity Maintenance

477 F.A. van der Duyn Schouten, M.J.G. van Eijs, R.M.J. Heuts
Coordinated replenishment systems with discount opportunities

478 A. van den Nouweland, J. Potters, S. Tijs and J. Zarzuelo
Cores and related solution concepts for multi-choice games

479 Drs. C.H. Veld
Warrant pricing: a review of theoretical and empirical research

480 E. Nijssen
De Miles and Snow-typologie: Een exploratieve studie in de meubelbranche

481 Harry G. Barkema
Are managers indeed motivated by their bonuses?

482 Jacob C. Engwerda, André C.M. Ran, Arie L. Rijkeboer
Necessary and sufficient conditions for the existence of a positive definite solution of the matrix equation $X + A^T X^{-1} A = I$

483 Peter M. Kort
A dynamic model of the firm with uncertain earnings and adjustment costs

484 Raymond H.J.M. Gradus, Peter M. Kort
Optimal taxation on profit and pollution within a macroeconomic framework

485 René van den Brink, Robert P. Gilles
Axiomatizations of the Conjunctive Permission Value for Games with Permission Structures

486 A.E. Brouwer & W.H. Haemers
The Gewirtz graph - an exercise in the theory of graph spectra

487 Pim Adang, Bertrand Melenberg
Intratemporal uncertainty in the multi-good life cycle consumption model: motivation and application

488 J.H.J. Roemen
The long term elasticity of the milk supply with respect to the milk price in the Netherlands in the period 1969-1984

489 Herbert Hamers
The Shapley-Entrance Game

490 Rezaul Kabir and Theo Vermaelen
Insider trading restrictions and the stock market

491 Piet A. Verheyen
The economic explanation of the jump of the co-state variable

492 Drs. F.L.J.W. Manders en Dr. J.A.C. de Haan
De organisatorische aspecten bij systeemontwikkeling
een beschouwing op besturing en verandering

493 Paul C. van Batenburg and J. Kriens
Applications of statistical methods and techniques to auditing and accounting