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Explaining innovative efforts of SMEs. An exploratory survey among SMEs in the mechanical and electrical engineering sector in The Netherlands

Jimme A. Keizer *, Lieuwe Dijkstra, Johannes I.M. Halman

Eindhoven University of Technology, Faculty of Technology Management, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Abstract

Innovations are among the most important means through which small and medium sized enterprises contribute to increased employment, economic growth and economic dynamics. A lot of research has been carried out to determine which factors enhance innovative efforts of SMEs. This study uses a regression-based methodology to examine the importance of each factor, controlling for the other factors. The study is based on data collected through telephone interviews with managers of Dutch SMEs in the metal-electro-sector. In the analyses innovative efforts are used as the dependent variable. Out of 14 potentially independent variables, three appear to contribute significantly to innovative efforts: using innovation subsidies, having links with knowledge centres, and the percentage of turnover invested in R&D. This article suggests that innovativeness is the result of a deliberately chosen and pursued policy. If governmental and or sectoral institutions want to stimulate SMEs to become and remain innovative, they should encourage these companies to implement an innovation directed policy. Without such a policy, SMEs seem unable to digest successfully stimulating measures and subsidy schemes.

Keywords: Innovation; SME; Mechanical engineering; Electrical engineering; Multiple and logistic regression analysis; Predictors of innovative efforts

1. Introduction

Small and medium sized enterprises (SMEs) have a reputation as boosters of employment, economic growth and economic dynamics. One of the most important means through which SMEs are able to make these contributions is their capability to realise innovations. Therefore, in both developed and developing countries and regions, many efforts have been made during the last few decades to stimulate SMEs to realise innovations. SMEs have been encouraged to make use of funding schemes and to utilise the services of knowledge centres. However, in spite of these efforts there still is a lack of knowledge about the nature and extent of SME support needs and the mechanisms for delivering it effectively. The result is that the policy environment is characterised by a wide range of experimentation (Bessant, 1999).

In recent years a lot of research has been done to find out which factors contribute to innovation efforts by SMEs, to build a more thorough theoretical foundation for the mechanisms behind innovations and to substantiate practical interventions. These studies revealed that activities directed to innovation correlate with a considerable number of variables. An important characteristic of these studies is that so far, little or no attention has been focused on uncovering possible interactions between variables. From a theoretical as well as from a managerial perspective, it seems to be relevant to know which variables contribute most to innovation efforts.

In this paper, the results of an exploratory survey among managers of SMEs are presented. The aim of the survey was to find a relatively small set of variables within a larger number that are reported to be important for innovation, which suffice to "explain" the differences between SMEs being involved in innovative efforts and others that are not.

* Corresponding author. Tel.: +31-40-2472659; fax: +31-40-2468054.

E-mail address: j.a.keizer@tm.tue.nl (J.A. Keizer).

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First, the conceptual background will be described. It includes a literature review of recent publications about variables contributing to innovation efforts of SMEs. Next the survey's design and methodological set-up are explained. After that, the results of the statistical analysis and the interpretation of the results are presented. Finally, we discuss the major findings.

2. Theoretical background

To find out which variables can be considered as possible predictors of innovation efforts, a number of recent publications were reviewed. Our conclusion was that the variables could be classified as *external variables* and *internal variables*. External variables refer to opportunities an SME can seize from its environment. Internal variables refer to characteristics and policies of an SME. The variables found in the review are summarised in Table 1.

For most of the variables summarised in Table 1, the suggestion is that they have a direct and positive relationship with innovative efforts of SMEs. In some cases, researchers have reported relationships that are more complex. We can think of different reasons for these confusing reports. One reason may be that in these cases both generic and context specific conditions play a role. A second cause may lie in the difference between "espoused theory" — what SME managers say they do — and "theories in use" — the way SME managers act in practice (cf. Argyris and Schön 1978, 1996). A third reason may be that the variables concerned interact with other variables.

Below we will mention some of the most remarkable "deviant outcomes". The results of our study will hopefully lead to a better understanding of the way in which such variables contribute to innovative performances.

Different views are found on the impact of links to *sources of knowledge*. Hoffman et al. (1998) point to some contradictions in literature about sectoral differences in the use of external knowledge sources. Some authors find that many SMEs, particularly in high-technology sectors, have diverse and intensive links with external sources of knowledge (public and private), while others have found evidence that counters many of the positive assumptions made about the value and extent of such links. Le Blanc et al. (1997) discovered geographical differences. Japanese

Table 1
Summary of literature review about variables influencing innovative efforts of SMEs

External variables	Internal conditions
Collaboration with other firms: • Collaboration with suppliers to overcome size constraints and to spread new technology costs and risks. Continued interactions with suppliers lead to low formalised relations that could be difficult to achieve over long distances (Lipparini and Sobrero, 1994). • Close working relationships with suppliers and customers in co-design and co-makership (Birchall et al., 1996; Meer et al., 1996; Dutch Ministry of Economic Affairs 1993, 1996; Docter and Stokman, 1988; Davenport and Bibby, 1999; Keeble et al., 1999) • Customers are the main source of improved technology for SMEs in the USA (Le Blanc et al., 1997) • Strategic alliances as an integral part of the firm's development plan (Forrest, 1990; Cooke and Wills, 1999)	*Strategy:* • Explicit strategies to increase and stimulate internal creativity and risk taking behaviour (Birchall et al., 1996; Carrier, 1994) • Sound day-to-day and strategic business-management practices (Anonymous, 1999) • Strategies to implement state-of-the-art production technology and automation (Aronson, 1998; Abdul-Nour et al., 1999) *Structure:* • Application of project management structures (Larson et al., 1991; Meer et al., 1996)
Linkages with knowledge centres: • Contributions by professional consultants, university researchers and technology centres (Le Blanc et al., 1997; Hoffman et al., 1998; Oerlemans et al., 1998) • Contributions by innovation centres and Chambers of Commerce (Oerlemans et al., 1998)	*Technology policy:* • Planning for the future (Docter and Stokman, 1988) • Number of technology policy instruments used by the firm (Oerlemans et al., 1998) *Level of education:* • Level of education of founder/manager and employees (Docter and Stokman, 1988) • Presence of qualified engineers (Le Blanc et al., 1997; Hoffman et al., 1998)
Utilising financial resources or support regulations: • Availability of R&D funding (Le Blanc et al., 1997; Birchall et al., 1996; Hoffman et al., 1998) • Government financial aid (Dutch Ministry of Economic Affairs, 1993)	*Investments in R&D:* • Percentage of sales volume invested in R&D (Birchall et al., 1996; *Geographical location:* • Rural or urban location (Hoffman et al., 1998)

SMEs rate networks with university researchers as useful, while US SMEs rate on-site direct assistance at low costs and training for managers as useful. The survey of Birchall et al. (1996) comparing Portuguese, UK and French SMEs revealed that the Portuguese reported a stronger impact from external knowledge sources on innovation than the British and French did.

With respect to the role of *financial funding* different views do exist. Le Blanc et al. (1997) discuss the role of the availability of sufficient financial resources. They found that 43% of the managers in US SMEs consider finance as the dominant limitation for product and process development. Birchall et al. (1996) also see financial resources as a key success factor to innovation. Hoffman et al. (1998) point to contradictory findings. On the one hand, they refer to a report of the Small Business Research Centre presenting strong evidence that financial resources (or rather the lack thereof) limit expansion and introduction of new technologies for SMEs. On the other hand, they conclude that only a very small number of SMEs seeking financial resources failed to succeed.

In addition, the *proportion of turnover spent on R&D* raises a few questions. Oerlemans et al. (1998) suggest a direct positive relationship between R&D spending and innovations. Birchall et al. (1996) suggest a more complex relationship. They found no relationship between the proportion of turnover spent on R&D and formal links with external R&D organisations as a source of innovation. They suggest that this implies that SMEs spending little or nothing on R&D are just as likely to achieve product/service innovation through such formal relations as those whose spending on R&D is relatively high. However, in both cases the impact on recent successful innovations is believed to be low.

In some literature, the use or non-use of the patent system and patent information is suggested to be associated with innovation. However, Hall et al. (2000) recently concluded that approaches to SMEs' use of patent information have hitherto been too simplistic. They found that there is a broad variation in the way SMEs use or do not use patent information. They distinguished three segments: inept, unaware and aware. The latter group can be further broken down into six types, depending on the strategic choices made. Due to its complexity, the use or non-use of patent information is not included in the list of variables.

3. Research model

As explained before, the aim of this study was to find out which variables within the whole range of variables contribute significantly to innovation efforts. Most external and internal variables found in the literature (Table 1) were included in the survey.

Dependent variable:

1. Innovation: are you currently involved in innovation projects (development, production and sales of new products/improvement or renewal of production processes and production systems)?

External:

2. Innovation subsidies: are you currently using innovation subsidy schemes initiated by government? (Inn.subs)
3. Links to knowledge centers: do you have current relations with one or more knowledge centers, e.g. technology institutes and universities? (KCs)
4. Transfer of knowledge: are you currently using government regulations meant to stimulate transfer of knowledge to SMEs? (Know.subs)
5. Collaboration with other firms: are you working on a new product or service in collaboration with one or more other firms? (Collab.)
6. Collaboration stimulating subsidies: are you currently using subsidies meant to stimulate collaborations between SMEs? (Coll.subs)
7. Financial resources and or support regulations: are you currently using services of specifically industry-oriented financial institutions, e.g. the National Investment Bank? (Finances)

Internal:

8. Higher/academic level of education: percentage of employees with higher/academic education (Empl.h/ac.educ).
9. Middle level of education: percentage of employees with middle level education (Empl.m.educ).
10. Education of the general manager: level of education (Mgr.educ).

The decision was made to include operational features of strategy, culture and technology policy instead of broad concepts of these variables:

Internal:

11. Production equipment: total economic replacement value (Prod.Eq.val).
12. Investments in production equipment: percentage of replacement value invested annually (Prod.Eq.inv).
13. Payback period: (PBP).
14. Automation and information technology: degree of advancement compared to colleagues/competitors in same sector (Aut/Inf).
15. Investments in R&D: percentage of sales volume invested in R&D (R&D).

The geographical location variable mentioned in the literature was not included in the survey. Our data were gathered among SME-managers in the southern industrial area of The Netherlands (Brabant) where the distances between cities and the differences between urban and rural parts are much smaller than usually found in the literature. It is therefore most unlikely that this variable is of any importance in this case.

In Fig. 1, the variables are summarised in an “input–throughput–output model”. In this paper, the external conditions are considered to be input variables. They refer to connections of the company with external parties that can provide knowledge.

Internal conditions are seen as throughput variables: characteristics a company has chosen and developed that largely determine whether and how innovation stimulating input from the environment is received and processed.

The output variable we have chosen is innovation efforts: are you currently involved in innovation projects (development, production and sales of new products/improvement or renewal of production processes and production systems)?

4. Research methodology

The data for this research were gathered through telephone interviews. SME managers were called and invited to co-operate. They were personally interviewed. If a manager was not available during the first trial, an appointment was made for an interview at a more suitable time. The data gathering activities could be carried out in a short time. The SMEs all belonged to the metalectro sector. Companies with 25–250 employees were considered to be an SME. The number of SME managers who participated was 151 (a response rate of 65%). This is quite satisfying.

Six variables were nominal: 1, 2, 4, 5, 6, 7 (all dichotomous: yes/no); three were ordinal: 3, 10, 14, and 6 were continuous: 8, 9, 11, 12, 13, 15 (percentages or absolute values).

Two approaches are appropriate in our case. First, a linear regression approach, consisting of correlation, partial correlation and multiple regression, and secondly, logistic regression. In both linear and logistic regression, the independent variables (or predictors) should be at the interval level of measurement. In linear regression, the dependent variable is also an interval variable, whereas in logistic regression the dependent variable is nominal (or “binary”). Logistic regression includes procedures for the treatment of nominal and ordinal predictors (“dummification”). In linear regression, however, nominal and ordinal predictors can only be handled as interval variables. As a consequence, in the latter case the assumptions of normal distributions and equal variances (“homocedasticity”) are violated.

The interpretation of the logistic model is usually given in terms of relationships instead of causality because the model does not include elements of path structures. Linear regression, on the other hand, matches our research design with respect to causal interpretations. After considering the pros and cons in the light of our research objective, we decided to use a twofold concurrent design. In the discussion we comment on this choice. Both approaches were applied independently such that the results could be compared to the fullest extent. In both approaches, the analyses were carried out for identical subsets of respondents in as far as possible. Appendix A includes an outline of the statistical terms and procedures used in this paper.

In the linear regression approach, the first step consists

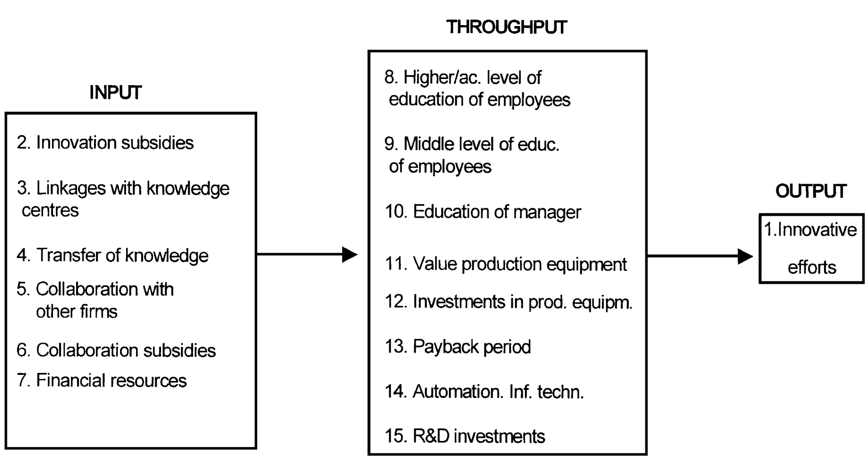

Fig. 1. Model of variables influencing innovative efforts of SMEs.

of computing bivariate correlations between the dependent variable (innovation efforts) and successive independent variables or predictors (Table A1). In the second step, partial correlations were computed between the dependent variable and successive predictors (Table A3). The objective of computing partial correlations was to determine to what extent correlations in Table A1 were the product of interactions. In the third step, step 2 was repeated for a reduced subset of variables that seemed to be important after the first two steps (Table A3). In the fourth and final step several models of linear regression were examined, to check the results of the preceding analyses (Table A4).

In the logistic regression approach, the first step consists of computing bivariate models for successive predictors (Table A1). In the second step, several models of logistic regression were examined for a reduced subset of predictors that seemed to be important after the first step (Table A5). Our strategy was to examine models and to evaluate differences between nested models with different sets of variables.

The total explained variance was about 30%, which is normal for this type of data.

5. Results

Table A2 presents a general qualitative outline of results. Details on which Table 2 is based, are reported in Tables A1–A5. In the discussion, we comment on the agreement between the results of the two approaches. Here, we present the results in a simultaneous review of both approaches. The general tendencies are presented in Table 2.

In the first place, four predictors can immediately be excluded from further analysis:

- Two external facilities specifically designed to help SMEs to become and remain innovative: Var6, Collaboration stimulating subsidies (r=0.04) and Var7, Financial resources and or support regulations (r=0.06).
- Two internal conditions: Var9, Middle level education (r=0.02) and Var12, Investments in production equipment (r=0.03).

Both the linear regression and the logistic sections in Table A1 justify this decision. From the linear regression perspective, Table A3 reinforces this because from the partial correlations it is clear that these predictors do not have a significant contribution to innovation activities.
In this paper, we can only guess at the reason why some supposedly influencing variables do not correlate with innovation efforts. Maybe the procedures are not well known or the reason is the complexity and time-consuming subsidy application procedures about which SME managers often complain. Concerning the use of the services of specifically industry oriented institutions, SMEs often rely on their accountant and on their bank account manager with whom they have built up a relationship of confidence. They will not easily change banks because of specific projects.

High investments in production equipment are probably not typical for innovating firms. In addition, firms that are not active in the field of product and process innovations need to invest and re-invest in their production equipment. Regarding the relation between innovative efforts and education level of employees, innovative efforts are probably more the domain of employees with higher education than of employees with middle level education.

Secondly, in both the linear regression and the logistic section in Table A1, it is doubtful whether four more predictors should be included in further analysis:

Var4: Transfer of knowledge.
Var8: Higher/academic level of education.
Var11: Value of production equipment.
Var14: Automation and information technology.

They can also be removed because there is no significant partial correlation with innovation activities (see Table A3). Using government regulations meant to stimulate transfer of knowledge to SMEs appears not to be related to innovative efforts. Neither does the level of education of the general manager.

The position of Var10 is even more doubtful than 4, 8, 11 and 14, but less questionable than 6, 7, 9 and 12. This holds for both sections in Table A1. However, contrary to predictors 4, 8, 11 and 14, Var10 maintains its doubtful character in Table A3. For this reason, we decided to not yet exclude Var10 in this phase of the analysis.

To check the results up to this point, the partial analysis was repeated for the remaining independent variables (see Table A3):

Var2: Using innovation subsidies.
Var3: Having links with knowledge centres.
Var5: Collaboration with other firms.
Var10: Level of education of the manager (−).
Var13: Length of the payback period (−).
Var15: Percentage of turnover invested in R&D.

Predictors 2, 3, 15 remain significant. Substantially deviating from zero but not significant are 5, 10, and 13. (It is should be noted that listwise deletion of missing values for this subset of variables results in the admittance of 24 more respondents to the analysis, compared to 83 respondents under listwise deletion for all 15 variables. Earlier we have mentioned that our data include a large number of missing values.)

Table 2
General results: Tables A1–A5 (Appendix A) in summary. Dependent variable: 1 innovation efforts[a]

Analysis	Approach							
	Linear regression				Logistic regression			
	Bivariate correlation	Partial correlation		Multiple regression	Bivariate		Multiple	
Predictors included	All	All	Reduced	Reduced	All		Reduced	
Symbols (see tables)	*r*, *F*	*r*, *F*	*r*, *F*	R^2, *F*	R^2	*p*	R^2	*p*
Table number in appendix	A1	A3	A3	A4	A1	A1	A5	A5
2 Innovation subs.	*	*	*	*	L	*	L	*
3 Knowledge C's	*	(*)	*	*	L	*	L	*
4 Knowledge subs.	(*)				S	*		
5 Collaboration	*	(*)	(*)	(*)	S	*		
6 Collaboration subs.								
7 Finances								
8 Empl. h./ac. educ.	(*)				S	*		
9 Empl. mdl. educ.								
10 Manager educ.	(*)	(*)	(*)	(*)				
11 Prod. eqmt. val.	(*)							
12 Prod. eqmt. inv.								
13 Payback period	*	(*)	(*)	(*)	S	*		
14 Autom. Inform.	*	(*)			S	*		
15 R&D	*	*	*	*	L	*	L	*

[a] *Significant at 5% level; (*) not significant but substantially deviant from 0; L relatively large contribution to explained variance; S relatively small contribution to explained variance.

At this point, we are saddled with an unexpected phenomenon, as the sign of one of the associations changes. Under pairwise deletion, the correlation between innovation efforts (Var1) and manager's educational level (Var10) is slightly positive; there are no missing values (see Table A1). However, in both cases under listwise deletion, the signs are negative (see Table A2). A reconstruction shows that a rather strong positive correlation exists for 68 (N=83) and 44 (N=107) respondents, who are excluded from the analyses in Table A2 under listwise deletion. Consequently, the complement of the weakly positive overall relationship under pairwise deletion in Table A1, is the weak negative relationship for the respondents that remain in the analysis under listwise deletion in Table A2.

Because of this, we checked all variables for the effects of listwise deletion. There was no variable, including the manager's educational level, for which we found a significant difference between the distribution of values in the analyses and the excluded values under listwise deletion. Therefore, the effects of listwise deletion can safely be considered as random. This is confirmed by the bivariate relationships in Table A2, which are not remarkably different from the corresponding values under pairwise deletion in Table A1. The only exception is the earlier mentioned weakly negative relationship between innovation efforts and manager's educational level in Table A2, after a weakly positive relationship under pairwise deletion in Table A1. The only reasonable interpretation is that we found a meaningless negative relationship between innovation efforts and the manager's educational level under listwise deletion, caused by accidentally strongly correlated excluded values of these variables.

The final step in the linear regression approach is multiple regression. The focus was on the significance of models and the contribution of the included predictors to the explained variance. A complete model, consisting of the remaining independent variables 2, 3, 5, 10, 13, and 15 from the preceding step (see Table A3), was compared with reduced models with predictors systematically omitted. In conformity with the earlier results of this approach, variables 2, 3 and 15 are indispensable, whereas variables 5, 10 and 13 do not make a significant contribution (see Table A4).

The final step in the logistic approach is a process of so-called forward and backward steps. Starting from the predictor with the largest contribution, variables are added to and removed from a current model, every time evaluating their contribution. This results in a large amount of information from repeated analyses. Table A5 presents the moment at which no additional predictor makes a significant contribution to the explained variance. Similar to the linear regression analysis, predictors 2, 3, 15 are indispensable, whereas variables 5, 10, 13 do not make a significant contribution.

The agreement between the results of both approaches once more becomes clear from the structural similarity of the information in Table A4 for model 9 and Table A5 for model 3.

The final model suggests that innovation in SMEs is a product of building a set of effective policies, conditions and resources. Links with knowledge centres are only fruitful if a company has some idea what it is looking for. The same line of reasoning can be seen behind the use of innovation subsidies. Being successful in acquiring innovation subsidies requires considerable and persistent efforts of people who are experienced in dealing with the often complex subsidy regulations, while SMEs almost always have limited employee resources. Moreover, an articulated vision is required on the goals and results of the intended innovations.

Another three variables come close to the significance level. They can possibly provide additional hints for a comprehensive characterisation of innovative efforts in SMEs: Collaboration with other firms (Var5); Level of education of the manager (Var10); and Length of the payback period (Var13). These variables give more colour to the picture. The profile that looms up is that of calculated and managed risks preferably taken in small steps, with an open mind to seize opportunities from outside. We emphasise, however, that in one respect our results are not in accordance with obvious suppositions. A negative relationship between the manager's educational level and innovation activities, does not make sense here at first. In the discussion, we come back to this point in more detail.

Finally, in Fig. 2 the results of our analyses are presented. Within the model given in Fig. 1 the variables that we found to be important determinants of innovative efforts of SMEs are being depicted.

6. Discussion of findings

The objective of this paper was to determine which variables from a list of variables are related to innovative efforts, controlling for other variables in the analysis. The study focuses on expanding our knowledge of why some firms are innovative and others are not. Governmental and sectoral institutions meant to stimulate SMEs to become and remain innovative can learn what the target variables are from the study.

The study reveals that the most innovative SMEs have three basic characteristics in common: links with knowledge centres, entries to governmental innovation subsidy schemes, and a relatively high R&D budget. The outcomes of the study suggest that innovativeness is the result of a deliberately chosen and pursued policy. If governmental and/or sectoral institutions want to stimulate SMEs to become and remain innovative, they should encourage management to implement and maintain an innovation-directed policy. Without such a policy, SMEs seem unable to effectively digest stimulating measures and subsidy schemes. Small organisation size, low influence and scarce resources are the inherent consequences of the small firm. These limitations can lead to the choice of strategic decisions that fit the small firm's character. The implementation of the combination of the three basic characteristics found in our analyses is postulated as fostering the innovativeness of these companies.

At this point we can look again at a few controversies which we have found in the innovation literature. Birchall et al. (1996), Le Blanc et al. (1997) and Hoffman et al. (1998) have noticed different findings with respect to the importance of links to sources of knowledge. They found that there are sectoral and geographical differences in the impact of this factor on innovativeness. Our study reveals that having links to external knowledge centers is one of the few really critical factors contributing to innovative efforts of SMEs in the mechanical and electronical engineering sector.

Birchall et al. (1996), Le Blanc et al. (1997) and Hoffman et al. (1998) also pointed at different findings regarding the role of financial funding. Some studies show evidence that financial resources are key for innovativeness, others do not. In our study collaboration stimulating subsidies and the use of financial support regulations did not come out as significant predictors of innovativeness.

Also, with respect to the proportion of turnover spent on R&D, the literature shows different observations. Oerlemans et al. (1998) suggested a direct positive relationship between R&D spending and innovations, while Birchall et al. (1996) suggest a more complex indirect relationship. Our findings support the suggestion about a direct positive relationship.

One critical question is whether non-innovative firms can and should be persuaded to develop such a profile of key characteristics. An important issue here is to what extent SMEs can be seen as a group with basically common characteristics. Some scepticism seems to be justified. Vos (2000) shows that there is a crucial difference between companies that produce and deliver self-specified products and companies that make their capability available for production according to specifications of their customers. One company, for instance, describes its capability as "making precision stampings from ferro and non-ferro metals, within very tight tolerances, followed by forming, hardening and surface treatment to customer specifications". Our study does not have the

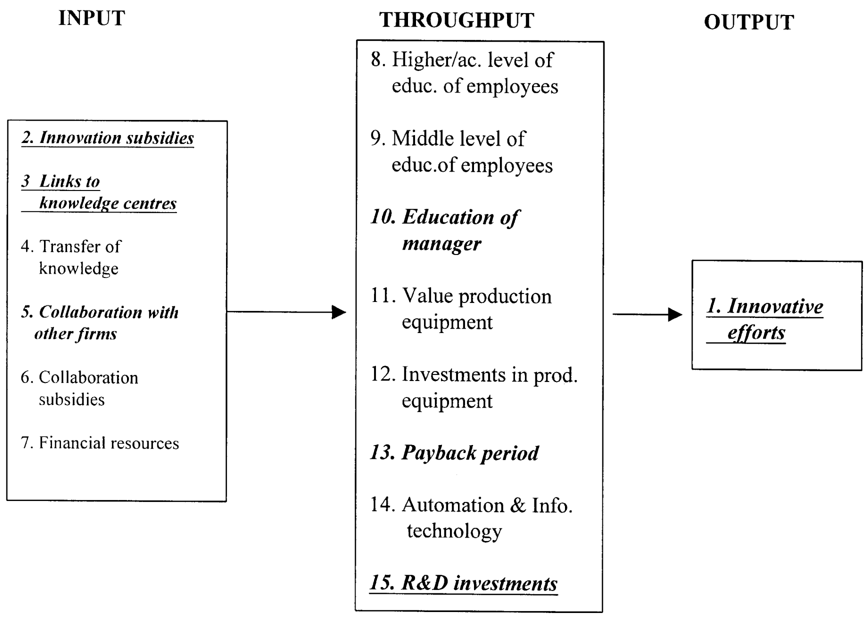

Fig. 2. Model of variables influencing innovative efforts of SMEs after analysis (bold italics underlined: statistically indispensable variables for explaining innovative efforts; bold italics: close to significant).

intention to highlight this distinction. Further research is needed to find out whether product delivering and capability delivering companies show the same innovation profile and whether their innovation policies are identical. The implication is that innovativeness can at least partially be controlled by management, policy-directed action.

A special point of interest is the variable "payback period", one of the three variables that were near to significance in this study. The role of this variable is mentioned in a report on a global survey on innovation from a leading consultant firm specialised in technological innovation (Little, 1997). The survey reveals that "increasing the number of new products" and "reducing the payback period of these new products" is seen as a much more critical business success factor by innovating companies than it used to be 5 years before. The negative sign of key variable 13 (applying a shorter payback period) in our study is consistent with the general findings made by Little (1997). If a company is heading for sequential new products, they note that a short payback period for each new product is required.

A delicate problem in this paper is the role of the manager's educational level. We found a weak but not significant negative relationship with innovation activities. This does not sound reasonable. We suggest two possible solutions. First, there is no relationship at all. Both the weak overall positive correlation under pairwise deletion and the weakly negative correlations under listwise deletion (neither of them significant in this paper) really have no meaning. Secondly, there is a weakly positive relationship. However, as we described earlier, an accidentally strong positive association in the groups of respondents that are excluded from the analysis in our paper, suppresses this. As a complement, negative correlations appear in Table A3. Further research is needed to clear up this issue.

Another question concerns the robustness of the results. It was our ambition to find out which variables really matter to innovativeness. The choice was made to gather data through telephone interviews. The advantage was that the data could be collected in a short time and that the response would probably be higher than could have been achieved with a mailed questionnaire. A disadvantage was that the items in the questionnaire had to be formulated according to the prerequisites of a survey by telephone. We decided on two simultaneous approaches.

Logistic regression is statistically healthy but it does not allow for causal interpretations. Linear regression, however, is appropriate in this respect, but in our case it is limited by severe violations of its model assumptions. In retrospect, this concurrent design was nevertheless fruitful because both approaches could be used complementarily. Our analysis could even have been refined by first selecting input variables that hold, controlling for the remaining input variables, and secondly, examining which throughput variables hold, together with the selected input variables. We believe that this would be more appropriate in a project that is explicitly designed for this purpose, and in which no assumptions of the linear regression model are violated.

The agreement between the results can be understood, starting from their fundamentally common objective. Apart from all differences in symbols, values and probabilities, both methods aim at the identification of variables that cause systematic, significant changes in a dependent variable.

Finally, there is a relevant question concerning the effectiveness of the innovation efforts. To what extent may innovation activities undertaken by a specific SME be considered successful or not? In this study, the involvement in innovation projects was taken as the output variable of innovative efforts. The study did not focus on the success rate (the percentage of products meeting the firm's innovation criteria) of these efforts. In an extensive analysis of 195 new product cases from 125 industrial product firms, Kleinschmidt and Cooper (1991) investigated the relationship between product innovativeness and success rate. According to the level of market newness and technological newness, Kleinschmidt and Cooper divided the product cases into three categories: highly innovative products, moderately innovative products, and low innovativeness products.

A U-shaped relationship between product innovativeness and success rate became evident. The success rate was greatest for highly innovative products (78% successful), and almost as high for low innovative products (68%), but dropped dramatically to 51% for the middle group.

In our survey, no classification was used to categorise the type of innovation efforts. An exploratory policy study of the Dutch Ministry of Economic Affairs, to uncover the number and nature of product innovations in The Netherlands (Kleinknecht et al., 1992), showed that 43.9% of all product innovations may be classified as low innovative, 52.3% as moderate and only 3.8% as highly innovative products.

If the findings of Kleinschmidt and Cooper are projected on the classification data of the Dutch Ministry of Economic Affairs, one may assume that a lot of innovative efforts in The Netherlands are focused on product innovations with a relatively lower chance of succeeding in the market.

Several studies have been carried out to find out which variables are associated with innovative efforts of SMEs. The aim of this study was to find which variables suffice to "explain" the differences between SMEs carrying out innovation projects and others that do not, within the total domain of variables reported in the literature as being important for innovation. Finally, four variables remained as independent predictors of innovation activities.

We would like to remind the reader that our exploratory study is based on a relatively small sample of one kind of firm, within a particular geographic area of The Netherlands. Further research is needed to determine whether the outcomes hold for innovative efforts in other sectors of industry.

Appendix A. Terminology and Tables A1–A5

A.1. Statistical terms and procedures

A *correlation* describes the strength of the association between two variables from −1 to +1.

A *partial correlation* describes the strength of the association between two variables, controlling for others. In a causal interpretation, it is a measure of the amount of variation explained by one independent variable after the others have explained all they could.

Multiple regression, and multiple correlation and its square (the coefficient of multiple determination R^2), describe the degree of predictability of a dependent variable by a set of independent variables.

Standardised regression coefficients (or beta-weights) describe the amount of change in standard deviation units in a dependent variable for one standard deviation change in an independent variable, controlling for the other variables.

An *F-statistic* tests the hypothesis of independence for correlations, partial correlations and multiple regression coefficients. A small p-value suggests that independence is not likely; p, therefore, indicates the probability of a statistic deviating from zero by chance. Conventionally, $p \leq 0.05$ suggests significance. One can also evaluate the difference between complete and reduced nested regression models by an F-statistic.

For binary dependent variables, the *logistic regression* model describes how the probability of a particular category depends on the values of independent variables. Logistic coefficients can roughly be interpreted as the change in the probability that an event will occur for a one-unit change in an independent variable.[1]

Listwise deletion excludes all respondents from the analysis who have a missing value on one or more variables in the analysis. (*Pairwise deletion* is listwise deletion for two variables).

The footnotes in Tables A1–A5 include explanations on statistical details.

Refer to Agresti and Finlay (1997); SPSS Base 9.0 (Application Guide), ISBN 0-13-020401-3, ch. 11, 12; SPSS Regression Models 9.0, ISBN 0-13-020-404-8, ch. 2, 8.

[1] We are grateful to Dr Jan G.M. Lammers, Associate Professor of Research Methodology at the University of Nijmegen, Department of Research Methodology, for his friendly help in applying logistic regression and for his comments on an earlier draft.

Table A1
Bivariate correlations and logistic regression between innovation efforts (dependent variable) and successive independent variables (predictors) 2–15

		Correlation		Logistic regression	
1 Innovation efforts predictor	N[a]	r[b]	$F_{1,N-2}$[c]	R^{2}[d]	p model[e]
2 Innovation subs.	147	0.436	34.002	0.267	0.0000
3 Knowledge C's	151	0.338	19.191	0.171	0.0002
4 Knowledge subs.	140	0.160	3.617	0.038	0.0470
5 Collaboration	151	0.177	4.804	0.042	0.0292
6 Collaboration subs.	148	0.044	0.277	0.003	0.5911
7 Finances	137	0.055	0.415	0.004	0.5109
8 Empl. h./ac. educ.	151	0.155	3.647	0.039	0.0376
9 Empl. mdl. educ.	148	0.022	0.071	0.001	0.7878
10 Manager educ.	151	0.099	1.482	0.022	0.2897
11 Prod. eqmt. val.	127	0.141	2.537	0.027	0.1085
12 Prod. eqmt. inv.	120	0.028	0.090	0.001	0.7607
13 Payback period	133	−0.176	4.202	0.041	0.0422
14 Autom. Inform.	148	0.191	5.506	0.060	0.0361
15 R&D	123	0.273	9.713	0.133	0.0004

[a] N: number of valid cases; pairwise deletion of missing values.
[b] r: correlation.
[c] F: $F_{1,118 \text{ or over}} > 3.92$ corresponds to $p < 0.05$.
[d] R^2: Nagelkerke goodness-of-fit statistic, quantifying explained “variation”; range 0–1. Similar in intent to explained variance in a regression model.
[e] p: tests the null hypothesis that the coefficients in the current bivariate model, except the constant, are 0.

Table A2
Correlations; listwise deletion. Left off diagonal: all variables; *N*=83. Right off diagonal: remaining variables after partial analysis (see Table A3); *N*=107

Variables:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.Innnovation efforts		0.48	0.29		0.16					−0.07			−0.14		0.26
2. Innovation subs.	0.54		0.29		0.08					0.04			−0.02		0.16
3. Knowledge C's	0.23	0.26			−0.05					0.15			−0.14		0.03
4. Knowledge subs.	0.12	0.19	0.20												
5. Collaboration	0.16	0.06	−0.09	0.03						0.03			0.00		0.12
6. Collaboration subs.	0.09	0.24	−0.05	0.15	0.24										
7. Finances	0.07	0.15	0.22	−0.01	−0.08	0.00									
8. Empl.h./ac. educ.	0.18	0.27	0.01	−0.06	0.07	0.06	−0.15								
9. Empl. mdl. educ.	0.08	0.16	0.18	−0.20	0.27	0.06	0.07	0.18							
10. Manager educ.	−0.12	−0.05	0.10	−0.02	0.07	−0.04	0.13	0.27	0.04				−0.14		0.12
11. Prod. eqmt. val.	0.08	0.12	0.06	0.22	0.02	−0.05	0.03	0.02	0.09	0.02					
12. Prod. eqmt. inv.	−0.09	0.26	0.04	−0.04	−0.19	−0.07	−0.07	−0.13	−0.15	−0.13	−0.19				
13. Payback period	−0.12	−0.01	−0.14	0.09	0.06	0.12	−0.03	−0.20	−0.03	−0.14	−0.06	−0.12			−0.07
14. Autom. Inform.	0.16	0.06	0.12	0.17	0.24	0.06	0.09	0.08	0.10	0.08	0.19	0.00	0.08		
15. R&D	0.32	0.15	0.01	0.09	0.16	0.12	0.02	0.23	−0.04	0.15	−0.15	−0.14	−0.09	0.12	

Table A3
Partial correlations and corresponding F values for dependent variable (1) and successive independent variables (i), controlling for remaining independent variables ($j-m$). Listwise deletion of missing values. First run (N=83) based on Table A2, including all variables; second run (N=107) only including significant or promising predictors after the first run

	N=83		N=107	
1 Innovation efforts predictor	$r_{1i\cdot j-m}$	$F_{1,N-k-1}$[a]	$r_{1i\cdot j-m}$	$F_{1,N-k-1}$[b]
2 Innovation subs.	0.467	18.922	0.405	19.631
3 Knowledge C's	0.145	1.451	0.210	4.619
4 Knowledge subs.	−0.057	0.222		
5 Collaboration	0.157	1.726	0.140	1.999
6 Collaboration subs.	−0.078	0.421		
7 Finances	−0.007	0.003		
8 Empl. h./ac. educ.	0.029	0.058		
9 Empl. mdl. educ.	−0.065	0.285		
10 Manager educ.	−0.207	3.035	−0.182	3.426
11 Prod. eqmt. val.	0.069	0.323		
12 Prod. eqmt. inv.	0.067	0.306		
13 Payback period	−0.104	0.748	−0.137	1.919
14 Autom. Inform.	0.091	0.566		
15 R&D	0.290	6.261	0.226	5.394

[a] $F_{1,68}>4.00$ corresponds to $p<0.05$.
[b] $F_{1,100}>4.00$ corresponds to $p<0.05$.

Table A4
Multiple regression: standardized beta-weights, explained variance and F values for complete (1) and reduced (2–9) models after partial correlation analysis (N=107)

	Beta-weights for models 1–9								
	1	2	3	4	5	6	7	8	9
2 Innovation subs.	0.384	–	0.440	0.394	0.388	0.381	0.414	0.398	0.395
3 Knowledge centres	0.187	0.302	–	0.178	0.165	0.202	0.181	0.157	0.170
5 Collaboration	0.117	0.146	0.104	–	0.113	0.116	0.138	–	–
10 Manager education	−0.155	−0.165	−0.130	−0.152	–	−0.142	−0.134	–	–
13 Payback period	−0.115	−0.106	−0.136	−0.114	−0.097	–	−0.126	−0.097	–
15 R&D	0.195	0.205	0.189	0.208	0.178	0.201	–	0.190	0.197
Explained variance	0.334	0.203	0.303	0.321	0.311	0.321	0.298	0.299	0.290
$F_{k1-k2,N-k1-1}$[d]		19.631	4.618	1.999[a]	3.426	1.919	5.394	2.641[b]	2.221[c]

[a] $F_{1,100}>4.00$ corresponds to $p<0.05$.
[b] $F_{2,100}>3.15$ corresponds to $p<0.05$.
[c] $F_{3,100}>2.76$ corresponds to $p<0.05$.
[d] The statistics $F_{k1-k2,N-k1-1}$ in this table and $F_{1,N-k-1}$ in Table A3 are equivalent for the regression models 2–7. The statistics, however, are computed by different algorithms. This can be argued as follows. Suppose that regression models A and B are identical, except for predictor X, which is absent in model B ("B is nested in A"). Now one can demonstrate that the F-statistic of the difference between the explained variances of models A and B (expressing the effect of X) is equivalent to the F-statistic of the partial correlation between the dependent variable and X.

Table A5
Selected logistic regression models. Dependent variable: innovation efforts

		Predictor(s) included				If removed	
Model	Predictor(s)	−2LL[a]	R^{2b}	Chi-square	Sign.[c]	−2LL[a]	Sign.[c]
1	2 Inn. subs.	82.391	0.392	28.283	0.0000	32.290	0.0000
2	2 Inn. subs.	74.407	0.481	36.268	0.0000	25.896	0.0000
	15 R&D					8.110	0.0044
3	2 Inn. subs.	111.969	0.446	47.792	0.0000	23.435	0.0000
	3 Knowl. C's					4.990	0.0255
	15 R&D					7.067	0.0079

[a] −2LL ("−2 log likelihood") is a measure of how well the estimated model fits the data. A good model translates to a small value for −2LL. If a model fits perfectly, the likelihood is 1 and −2LL is 0.

[b] R^2 Nagelkerke goodness-of-fit statistic, quantifying explained "variation"; range 0–1. Similar in intent to explained variance in a regression model.

[c] Sign. is the probability of a statistic differing from zero by chance. Conventionally, a 5% extreme area marks significance.

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