R&D – STRATEGIC ELEMENTS FOR INNOVATION AND MARKET SUCCESS

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Abstract. *Innovation management in SMEs means not only the operational control of processes, but also the strategic management of the company. A fundamental component of strategic innovation management is the long-term decision to innovate, which is accompanied by the need to establish structures and to provide resources for the acquisition of technology. Therefore, continuous research and development (R&D) is decisive in driving the success of the innovation process onto the market.*
The empirical analyses of R&D management and innovation success in SMEs uses data from the Third and Fourth Community Innovation Survey (CIS3 and CIS4), and discusses the following topics: firstly, some descriptive statistics on R&D in European SME's, and in this context a brief discussion of R&D as a core business competence; secondly, the determining factors of R&D in SME's; finally, the influence of R&D on market success.

Keywords: innovation management; small business strategies; strategic management; research and development (R&D).

1. R&D in small and medium sized enterprises

In 2000, one out of four manufacturing firms, and one out of three firms in knowledge-intensive business services (KIBS)[1] were engaged in R&D activities. Since almost all enterprises are small or medium-sized (SMEs, i.e. having less than 250 employees), these figures are representative for the group of SMEs. The Third Community Innovation Survey (CIS3), from which these data are taken, reveals that five countries show above-average shares of R&D performing SMEs in both sector groups: Germany, Belgium, Finland, Sweden and Austria. Manufacturing SMEs in the Netherlands and Switzerland show a high share of firms being active in R&D, too, while the share of SMEs in the KIBS is slightly below EU average.

[1] Banking and insurance, computer-related services and software, research and development services, engineering activities and technical consultancy, technical testing and analyses.

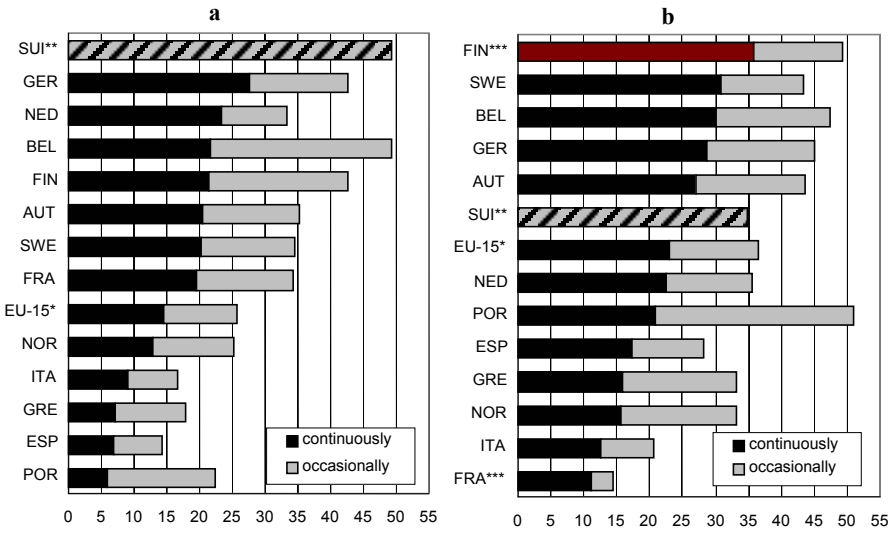


Figure 1. Share of enterprises with R&D activities in Europe in 2000.
a. Manufacturing;b. Knowledge-intensive business services [a)]

Enterprises with 10 or more employees that performed R&D during 1998 and 2000 either continuously or occasionally, as a percentage of the total number of enterprises.
a) Knowledge-intensive business services except business/tax/legal consultancy and advertising. * EU-15: excluding Denmark Ireland, Luxembourg, Great Britain, including Norway. ** Switzerland: Enterprises with 5 or more employees, reference period: 2000-2002, no distinction possibly by continuous and occasional R&D activities. *** Finland and France: knowledge-intensive business services except banks/insurances. Source: EU and Norway: Eurostat - CIS3 (New Cronos).

The CIS3 results also highlight that only a part of the enterprises perform R&D in-house on a continuous base. In manufacturing, only 15% of all enterprises are researching continuously, while 10% do R&D only occasionally. In the KIBS, the share of enterprises with continuous R&D is clearly higher, reaching 23% at the EU level, and 15% are performing R&D occasionally. In some countries, a high proportion of enterprises engage in R&D only from time to time: this is especially true for Portugal and Greece, and hold for Belgium in case of manufacturing.

A high share of SMEs that conduct R&D is an important element for a wealthy innovation system.[2] These enterprises are often pioneers in developing and implementing fundamentally new technologies. They are often more flexible than large enterprises helping them to detect and utilise new demands for technologies and open up new markets. In many countries, R&D oriented SMEs are an important source for technology-driven structural change and economic growth. Their particular relevance for

[2] See for a general discussion of the phenomena innovation: Dodgson, Rothwell (1995), Fagerberg, Mowery, Nelson (2005), Freeman, Soete (1997), Stonemann (1995), Tidd, Bessant und Pavitt (2005).

a country's technological performance rests on three features:[3] Firstly, SMEs are often at the forefront in the development of fundamentally new technologies that are expected to grow significantly in future years, such as biotechnology, computer and software, measurement and controlling instruments. Secondly, SMEs are key innovators in the early stages of new market development, when absolute demand is still low, uncertainty about the future technological development is high, and many innovation designs compete with each other. Such market and technology environments are often little attractive for large companies. And at least, SMEs are a major performer of R&D in the service sector, a sector which is increasingly relevant to a nations technological performance.[4] In services, entry barriers to R&D are rather low due to small project sizes, short project lengths, and less technological complexity. Services are a major source for growth today, and international competition in services increases steadily. A high number of innovative SMEs in this sector may thus increase international competitiveness and the prospects for economic growth.

While there are many good reasons for SMEs to engage in R&D, a number of obstacles may deter them from doing so. These refer to specific economic characteristics of R&D. While these characteristics apply to all enterprises, there are several reasons why they distract SMEs from R&D more likely than large enterprises:

(a) R&D implies a variety of specific costs, e.g. fix costs, entry costs, and sunk costs:[5] R&D is often only practicable when a certain minimum commitment of resources is exceeded. In order to start R&D activities, one-time investment such as laboratory equipment, specialised staff and changes in a firm's internal organisation are needed. When decided to stop R&D at a later point in time, this investment is likely to be of little use for other activities and will thus constitute sunk costs. A number of resources needed for R&D are fixed costs, i.e. they cannot be reduced significantly in case of downsizing R&D activities. Furthermore, the nature of research projects is not such that they cannot simply be shortened or reduced in scope. In consequence, the decision to carry out R&D can tie up a significant proportion of capacities in small firms. Given the high risk exposure of R&D (see below), this may lead them to decide not to conduct R&D.

(b) R&D is an investment for the future: Conducting R&D means allocating a part of current expenditure to activities that, if successful, will not create revenue until later periods. Since most of this investment is in current expenditure (salaries, material, external services), financing of R&D activities drains the current operating profit and can severely restrict an enterprise's liquidity.[6] These negative cash-flow effects tend to effect SMEs more seriously since they typically have less opportunities to gain extra-profits from which to fund R&D. Furthermore, minimum project sizes

[3] See for R&D in SME's Acs, Audretsch (1988), (1990), Harhoff, Licht et al. (1996), Hoffmann, Parejo, Bessant (1998), Kleinknecht (1987), Rothwell (1991), Scherer (1991).
[4] See for innovation in services: Hauknes, Miles (1996), Miles (1994), Czarnitzki, Spielkamp (2003)
[5] See Sutton (1991).
[6] See Hall (2006).

and indivisibility of particular R&D activities result in a high share of R&D costs to total sales in SMEs, which aggravates the financing of R&D.

(c) R&D bears risks and uncertainty: R&D is always associated with uncertainty. At the start of a research project it is not clear on the one hand whether the idea will be able to be implemented in practice (technological risk) and, on the other hand, whether the new products that result from R&D will be accepted by their potential users (market acceptance risk). Since SMEs perform a smaller number of R&D projects at the same time compared to large enterprises, they are less able to share risks among a portfolio of different projects.[7] The failure of one project may thus have serious drawbacks on an SME and may jeopardise the enterprise's existence.

(d) R&D output is immaterial and difficult to protect: Results from R&D are predominantly new knowledge and are thus immaterial in nature while only a small fraction of R&D directly yields into material products such as prototypes. Knowledge is difficult to protect, however, and the outflow of knowledge to others will significantly reduce the returns from R&D efforts. Protecting new knowledge is therefore key for obtaining economic gains from R&D.[8] Formal protection methods such as patents, industrial designs or trade marks are costly, however, especially when it comes to monitoring potential infringements and entering into legal disputes. This may hinder SMEs from extensively using such protection methods. New knowledge that cannot be codified can only be protected by strategic measures such as secrecy. Since such measures tend to be effective only partially, SMEs may fear to loose their R&D investment and refrain from engaging in R&D.

2. Determining factors of continuous R&D

On the basis of economic considerations, SMEs often decide (consciously or otherwise) against establishing an R&D department and carrying out R&D continuously. They rely on the notion that they can be innovative even without long-term research and development, since they have comparative advantages in other areas of the innovation process.[9] Various factors play a role in an SME's decision to carry out R&D on a continuous basis and thereby to introduce a suitable organisational structure and take on the additional fixed costs entailed.[10]

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[7] See Scherer et al. (2000).

[8] See Cohen et al. (2000), Levin et al. (1987), Lanjouw, Lerner (1997).

[9] Less than a fifth of very small firms (with fewer than 50 employees) carry out R&D. This proportion increases among the small-medium firms (50-99 employees) and the medium firms (100-499 employees), standing at 30 percent and 39 percent respectively. However this is still far below large firms' innovation participation of 70 percent. This gap remains even if we only consider the product innovators, for whom R&D activities are of particular significance: a good third of very small product innovators carry out R&D regularly. This proportion increases steadily with firm size, reaching 76 percent for large firms. See Rammer, Spielkamp (2006).

[10] See Cohen (1995), Gottschalk, Janz (2003).

We have analysed the determinants of an SME's decision to engage in continuous R&D activities using enterprise data from the German CIS4 survey, conducted by the ZEW (see Annex for a short description of the data base). The econometric investigation yields the following main results (see table 1):

(a) Firm size is of central importance: As employee numbers increase, more possibilities open to introduce an organisational structure for R&D and assign specific individuals to the task. This also reflects the fact that the fixed cost burden from R&D tends to decrease as firm size increases, since the resources necessary for carrying out continuous R&D in a small firm are limited and do not increase in a linear relationship with firm size. The proportional cost of these minimal resources makes a large difference to small firms but would hardly be noticed by larger SMEs.

(b) Age of a company: The inclination to carry out continuous R&D decreases as a firm gets older. Firstly, many older firms have an established programme of products that they offer to regular customers. In particular, firms that sell on a niche market or a narrowly-defined regional market, with only few direct competitors, abandon R&D and concentrate on further developing products in accordance with their customers' wishes. Secondly, younger companies must try to establish themselves in the face of established firms by bringing out new products. R&D is often necessary to achieve this.

(c) Knowledge: Sufficient human capital is virtually a prerequisite for internal R&D. The influence of the proportion of employees who are graduates on this strategic decision is accordingly large.

(d) Export activities and product range: A significantly greater proportion of SMEs that are active on export markets carry out R&D. The first reason for this is that SMEs are more likely to achieve unique selling propositions on their markets; these can also be used for entry into foreign markets. Secondly, in order to find success on foreign markets, an offer must differ from what locally active firms already sell. Therefore, fresh ideas and new technologies (R&D) are needed. Firms with limited diversity in their range of products – measured by the largest proportion of turnover for a single product group – are less likely to carry out R&D in comparision to firms whose main product only accounts for a comparatively small proportion of turnover.

(e) The market environment: SMEs conduct continuous R&D to a significantly large extent in markets where technologies change rapidly and the life-cycle of product is extremly short. In contrast, if demand does not follow a clear trend, this unequivocally brakes the strategic decision to invest in R&D. On markets where price competition plays a central role and markets where service and flexibility are decisive for competitive success, SMEs carry out R&D less often than in other competitive conditions. In circumstances where market success is determined by technological progress, there is virtually no way to get around R&D; this environmental factor therefore has an accordingly high influence on the level of R&D. SMEs that are only faced with a small number of competitors carry out more internal R&D than SMEs who have a large number of competitors. Conversely, the first group of SMEs also carry out more R&D than SMEs in a monopolistic position.

Table 1

Factors for continuous R&D activities in SMEs in Germany 2004
(Marginal effects from a probit model with robust standard errors)

	Marginal effect	(z value)
ln(number of employees)	0,060	7,91***
ln(age in years)	-0,032	-3,24***
Proportion of graduates	0,003	7,79***
Export activity	0,217	9,82***
ln(previous year's labour productivity)	0,017	1,24
Largest share of turnover from a single product group	-0,001	-2,16**
Part of a national group of companies	0,023	1,22
Market environment:		
Technology changes rapidly	0,095	4,36***
Products become dated rapidly	0,077	3,44***
Development of demand difficult to predict	-0,061	-2,93***
Price of great importance as competitive factor	-0,081	-3,72***
Service/flexibility of great importance as competitive factor	-0,032	-1,70*
Technological advantage of great importance as competitive factor	0,128	5,96***
Number of main competitors between 1 und 5	0,043	2,29**
Sector (Reference: mechanical engineering):		
Food/tobacco	-0,165	-3,26***
Textiles/clothing/leather	-0,089	-1,84*
Wood/paper/printing/publishing	-0,194	-5,15***
Chemical/pharmaceutical/mineral oil	0,142	2,78***
Processing of rubber/plastics	-0,109	-2,42**
Glass/ceramics/stone	-0,053	-0,83
Manufacture and working of metals	-0,107	-2,94***
Electronics	0,030	0,66
Manufacture of instruments	0,100	2,20**
Manufacture of vehicles	-0,139	-2,77***
Furniture/jewellery/musical instruments/sports equip./toys	-0,139	-2,90***
Banking/insurance	-0,133	-2,62***
IT and telecommunications	-0,053	-1,12
R&D service providers	0,238	3,27***
Engineering offices and technical laboratories	-0,146	-3,55***
Consultancy and advertising	-0,137	-2,71***
Radio/film production/cinemas	-0,172	-2,69***
Constant	-1,291	-5,43***
Number of observations	2.936	
Pseudo R^2	0,270	
Wald Chi^2	683,29***	

Source: ZEW, Mannheim Innovation Panel – 2005 survey.

(f) In addition to these factors related to the market environment, the sector to which a firm belongs has a decisive influence on R&D activity. This general sector effect is, in particular, a reflection of the importance R&D has for performance in these sectors. It therefore measures the different technological conditions for production and the stage of maturity a sector has reached. Research is less prevalent in service sectors (excluding R&D service providers) than in mechanical engineering – which is the reference sector in our model. The greatest inclination towards R&D can be observed in the electronics industry, the manufacture of instruments and the chemical and pharmaceutical industries; the lowest – outside services – was in the sectors of wood/ paper/ printing/ publishing, food/ tobacco, furniture/ sports equipment/toys and manufacture of vehicles.

3. Continuous R&D and innovation success

Successful R&D not only assures technological capability, but also promises more success for the firm in the long-term. This is particularly true in cases where R&D results in marketable products that set themselves apart from what competitors have on offer. Firms are able to win market share and even sell to completely new customer groups. Such high potential for growth and profit can be put down to "radical innovations" in particular (i.e. market novelties that, at the same time, open new fields of business).

The influence of continuous R&D activity on innovation success was estimated for different firm sizes with the help of multivariate analysis models (see table 2):

(a) For one thing, R&D has a decisive positive effect on the success of complex innovation activities. Firms that continuously carry out research are better placed to introduce product and process innovations simultaneously, i.e. to implement change processes both in production and in the areas of distribution, marketing and customer relations. We can assume that the presence of a dedicated R&D department – or, in the case of very small companies, a responsible member of staff – makes it easier to carry out necessary organisational and technological changes while also aiding in the acquisition of new knowledge, which often means recruiting new staff.

(b) Also worthy of notice is the large effect of R&D activity on the income small firms can gain with innovations. Firms that have fewer than 50 employees and carry out R&D regularly achieve a 22-percentage-point higher share of turnover with market novelties and 11 percentage points higher with product range novelties. Clear positive influences of this sort can also be found among small-medium firms (50-99 employees), although to a lesser extent (10 and 5 percentage points respectively). Medium-large companies only achieve an "R&D success premium" when it comes to turnover from market novelties, while for large companies no significant effects can be observed for market novelties or product range novelties.

Table 2

The effect of continuous R&D activity on the success of innovation
(by company size category)

		up to 49 employees	50 to 99 employees	100 to 499 employees	500 and more employees
Innovator	Introduction of new products and processes	+14 % ***	n.s.	+16 % ***	+22 % ***
	Introduction of new products only	n.s.	+13 % *	n.s.	-22 % ***
	Introduction of new processes only	-14 % *	n.s.	-11 % *	n.s.
Product innovator	Share of turnover from new products	+10 % ***	n.s.	n.s.	-7 % *
	Share of turnover from market novelties	+22 % ***	+10 % **	+5 % *	n.s.
	Share of turnover from product range novelties	+11 % ***	+5 % *	n.s.	n.s.
	Share of turnover from product imitations	n.s.	n.s.	n.s.	n.s.

Note: marginal effects on the medians of coefficients estimated using multinominal logit models (for the introduction of innovations) and tobit models (for the shares of turnover).
^, *, **, ***: estimated coefficients statistically significant at the 15%, 10%, 5% and 1% levels respectively Guide to understanding: the probability of an innovating firm with up to 49 employees introducing product and process innovations simultaneously increases by 14 percentage points compared to the median value for the sample, if the firm conducts continuous R&D. The probability of introducing process innovations only decreases by the same amount. The share of total turnover realised through market novelties for product innovators in this size category increases by 22 percentage points in the case of continuous R&D activities.
Source: ZEW, Mannheim Innovation Panel – 2005 survey.

(c) Regardless of company size, there is no evidence that R&D influences the share of turnover from product imitations. This indicates that companies do not need to carry out research of their own in order to progressively improve their existing product range and adapt it to new technical possibilities and customer demands. As a rule, such incremental innovations can be realised with the technical knowledge and market know-how already available within the firm.

4. Final remarks

Successful small and medium-sized enterprises consider the secret to their success the fact that they are in the position to combine technological competence

(R&D) and market know-how effectively and create an innovative atmosphere within the company. They work directly together with clients, constantly observe the market and make active efforts to access all available information. These capabilities are reflected in a readiness to change.

R&D plays an essential role in promoting the success of complex innovation activities. Companies that carry out research on a continuous basis are in a far better position to introduce product and process innovations simultaneously, i.e. make changes to the good itself and to how it is distributed and marketed, as well as to customer communications.

Furthermore, firms that carry out research have much higher success rates with new products that constitute original offerings on the market, i.e. "objective" innovations which, at the same time, imply entering a new market segment or selling to a new customer group. Crossing the technology and market thresholds leads to profits from the window of opportunity and rents from innovation. That states that R&D matters in SMEs.

Annex

The analysis of the determinants of engaging in continuous R&D activities, and the effects of theses activities on innovation success, rest on the German Community Innovation Survey CIS4 data. The German CIS4 has been conducted by the ZEW in 2005 and was a voluntary mail survey using a standardised written questionnaire. Out of a stratified random sample of about 28,000 enterprises (strata referring to sector, size class and region), almost 5,500 enterprises provided information on their innovation activities.

References

Acs, Z. J., Audretsch D.B. (1988). *Innovation in Large and Small Firms: An Empirical Analysis,* American Economic Review, Vol. 78, No. 4, pg. 678-690.

Acs, Z. J., Audretsch D.B. (1990). *Innovation and Small Firms*, Cambridge, MIT Press.

Cohen, W.M., *Empirical Studies of Innovative Activity*, Stoneman, P. (Ed.) (1995). *Handbook of the Economics of Innovation and Technological Change*, Oxford, Oxford University Press, 182-264.

Cohen, W.M., Nelson, R., Walsh, J. (2000). *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent or Not*, NBER Working Paper 7552.

Czarnitzki, D., Spielkamp, A. (2003). *Business Services in Germany: Bridges for Innovation*, The Service Journal, Vol. 23, No. 2, pg. 1-30.

Dodgson, M., Rothwell, R. (Eds.) (1995). *The Handbook of Industrial Innovation*, London, Edward Elgar.

Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.) (2005). *The Oxford Handbook of Innovation*, Oxford, Oxford University Press.

Freeman, C., Soete, L. (1997). *The Economics of Industrial Innovation*, 3. Ed., Cambridge MA.
Gottschalk, S., Janz, N. (2003). *Bestimmungsfaktoren der Innovationstätigkeit*, Janz, N., Licht, G. (Eds.), Innovationsforschung heute. Die Mannheimer Innovationspanels, Baden-Baden, Nomos (= ZEW Wirtschaftsanalysen Band 63), 17-40.
Hall, B.B. (2006). *The Financing of Innovation*, Shane, S. (Ed.), Blackwell Handbook of Technology and Innovation Management, Oxford, Blackwell.
Harhoff, D., Licht, G. et al. (1996). *Innovationsaktivitäten kleiner und mittlerer Unternehmen*, Baden-Baden, Nomos.
Hauknes, J., Miles, I. (1996). *Services in European Innovation Systems – A Review of Issues*, Step Report, Oslo, 1996.
Hoffmann, K., Parejo, M., Bessant, J. (1998). *Small Firms, R&D, technology and innovation: a literature review*, Technovation, Vol. 18, pg. 39-52.
Kleinknecht, A. (1987). *Measuring R&D in Small Firms: How Much Are We Missing?*, Journal of Industrial Economics, Vol. 36, No. 2, pg. 253-256.
Lanjouw, J.L., Lerner, J. (1997). *The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature*, NBER Working Papers 6296.
Levin, R.C., Klevorik, A.K., Nelson, R.R., Winter, S.G. (1987). *Appropriating the Returns from Industrial Research and Development*, Brookings Papers on Economic Activity, Vol. 3, pg. 783-820.
Miles, I. (1994). *Innovation in Services*, Dodgson, M., Rothwell, R. (eds.), The Handbook of Industrial Innovation, Cheltenham.
OECD, Eurostat (1997). *Oslo-Manual. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, OECD Paris.
Rammer, Ch., Spielkamp, A. (2006). *FuE-Verhalten von kleinen und mittleren Unternehmen*, Legler, H., Grenzmann, Ch. (Eds.), FuE-Aktivitäten der deutschen Wirtschaft - Analysen auf der Basis von FuE-Erhebungen, Essen, Wissenschaftsstatistik im Stifterverband für die Deutsche Wissenschaft.
Rammer, Ch., Aschhoff, B., Doherr, T., Peters, B., Schmidt, T. (2005). *Innovationen in der deutschen Wirtschaft. Bericht zur Innovationserhebung 2004*, Mannheim.
Rothwell, R. (1989). *Small Firms, Innovation and Industrial Change*, Small Business Economics, Vol. 1, No. 1, pg. 51-64.
Scherer, F.M. (1991). *Changing Perspectives on the Firm Size Problem*, Acs, Z.J., Audretsch, D.B. (Eds.), Innovation and Technological Change: An International Comparison, Ann Arbor, University of Michigan Press, pg. 24-38.
Scherer, F.M., Harhoff, D., Kukies, J. (2000). *Uncertainty and the Size Distribution of Rewards from Innovation*, Journal of Evolutionary Economics, Vol. 10, pg. 175-200.
Stonemann, P. (1995). *Handbook of the Economics of Innovation and Technological Change*, Oxford.
Sutton, J. (1991). *Sunk Costs and Market Structure, Price Competition, Advertising and the Evolution of Concentration*, Cambridge, MIT Press.
Tidd, J., Bessant, J., Pavitt, K. (2005). *Managing Innovation*, 3 Ed., Chichester, Wiley.

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