Drivers and Effects of Patterns in Innovation Activities

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1 Overview

We explore firm innovation activities that go beyond internal R&D activities. Our broader conceptualization of innovation activities also includes investments into new equipment enabling innovative products and services as well as investments primarily directed at the market/client interface. We argue conceptually that complementary as well as substitutive relationships can be envisioned between these elements of firm's innovation activities. We test these relationships for a broad sample of more than 4,600 firms in Germany by applying latent class cluster estimation techniques. We identify actual innovation patterns based on these estimations. In a subsequent step of the analysis we relate these patterns to innovation success to derive best practices. These patterns should allow us to investigate interrelationships between different forms of innovation expenditures which could lead to the derivation of weights within the COINVEST macro framework.

2 Approach

Theoretical framework

We review major literature on linear, non-linear and modes of innovation (e.g. Freeman and Soete, 1997; Jensen et al., 2007; Lundvall, 1992). We want to extend these discussions by connecting them to two other streams of literature. On the one hand, this is the role that suppliers can play as enablers of innovation through new equipment or materials (e.g. Pavitt, 1984) as well as innovation partners (e.g. Dyer, 1996). On the other hand, we focus on the market orientation of firm's innovation activities which has received much attention in marketing literature (e.g. Day, 1994; Menguc and Auh, 2006). We plan to synthesize the arguments in the literature for complementary and substitutive relationships between in-house R&D, supply-driven and market-oriented elements of a firm's innovation activities.

Data and methods

For the empirical part of this analysis we use data from a survey on the innovation activities of German enterprises called the “Mannheim Innovation Panel” (MIP). It is the German contribution to the Community Innovation Survey (CIS) of the European Union. Thus, the methodology and questionnaire used fully comply with CIS standards and follow the OECD Oslo manual. For our analysis we use surveys conducted in 1997, 2001 and 2005 in which data was collected on the innovation activities of enterprises during the preceding three-year periods. A relatively small minority of the firms in our dataset has responded in all of the surveys. A panel approach is therefore not feasible. We opt for a pooled sample instead. The survey targets the heads of R&D departments or innovation management of firms with at least five employees. Hence, we can obtain direct information on innovation investments other than R&D. Heads of R&D departments are asked to estimate the expenditures in the reporting year on:

- Intramural (in-house) R&D
- Acquisition of R&D (extramural R&D)
- Acquisition of machinery, equipment and software
- Acquisition of other external knowledge
- Training, product/service design, market research etc. for market introduction

Based on these estimates, the share of expenditures and hence importance of the particular activity for a firm’s innovation activity can be calculated. We restrict the sample to firms with positive overall innovation expenditures. This provides us with a sample of 4,631 observations.

We use these variables to estimate patterns or homogeneous subpopulations within our sample with regard to their innovation activities by using latent class cluster estimation techniques. This method addresses some weaknesses of traditional cluster analytical methods (for example, K-Means). It is based on a formal statistical model which allows probability based classifications and variables of mixed scale type (Jensen et al., 2007; for a detailed discussion see Hagenaars and McCutcheon, 2002). It also provides criteria for determining the appropriate number of classes which tends to be challenging with conventional cluster techniques. Each additional cluster provides a better fitting solution (in its extreme form, each observation would be in its own cluster) but too many clusters make it hard to identify and interpret meaningful structures. Hence, a parsimonious solution is required. Due to the underlying statistical model the latent class cluster analysis provides quantitative indicators for choosing an appropriate number of clusters. This decision is typically based upon the Bayesian information criteria (BIC). It compares the exploratory power of models with one additional cluster to the number of parameters required to estimate it. Hence, these criteria should be minimized to indicate an appropriate number of clusters.

Latent class cluster methods also allow us to include and simultaneously estimate logit models on structural features of a firm (e.g. its size, industry) which influence the probability of being part of such a cluster. Subsequently, probabilities for cluster membership can be predicted for each firm. We add these variables to an additional effect estimation on the performance effects of the individual patterns. These performance effects are observed in the subsequent time period to avoid potential deficits in interpretability from simultaneity.

3 Preliminary results

Table 1 shows descriptive statistics for the share of different types of innovation expenditures of sales. It suggests that intramural R&D as well as expenditures on machinery and equipment are the most important elements of innovation expenditures. They account for roughly 2.9% of sales each. Market related innovation expenditures follow with 1.5% and the remaining elements appear to be of minor importance.

Table 1: Share of different types of innovation expenditures of sales

Variable	Mean	Std. Dev.
Intramural R&D	0.029	0.076
Extramural R&D	0.004	0.027
Machinery	0.029	0.381
Other techn. knowl.	0.001	0.009
Market related	0.015	0.099

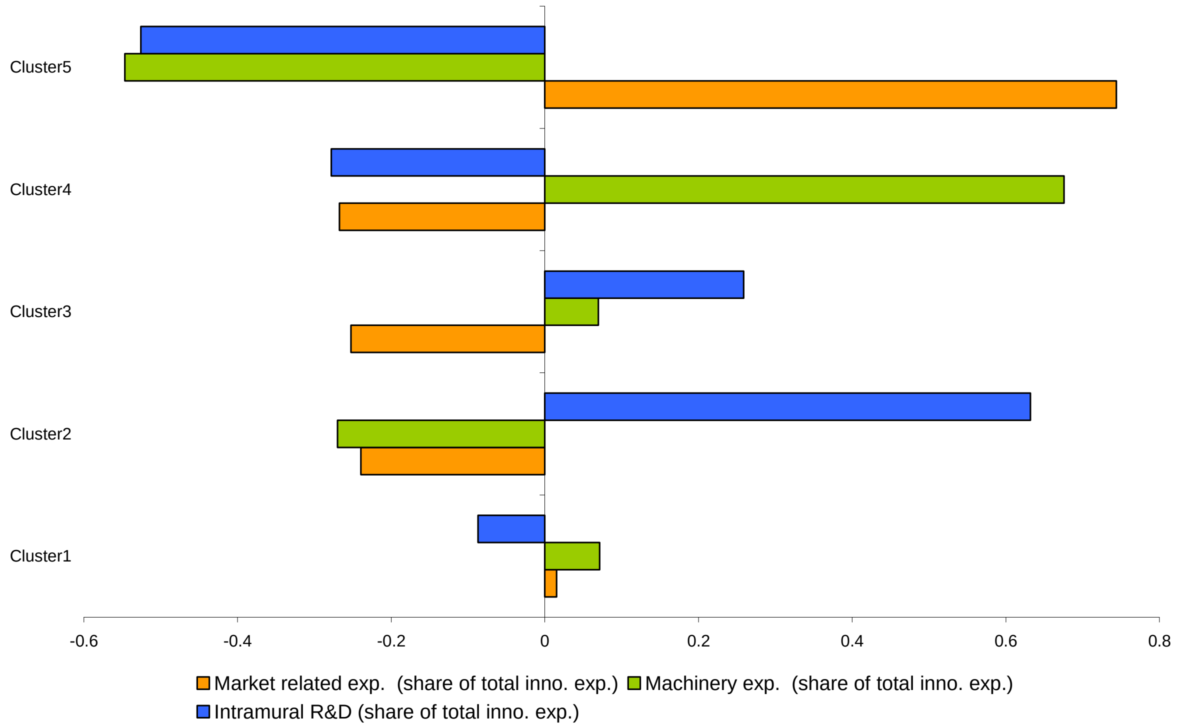
Table 2 provides a different perspective. It illustrates the share of different types of innovation expenditures on its total. Besides, these statistics are also split up by industries. These statistics suggest some trade-offs between different innovation activities. First, firms in low-tech manufacturing and low knowledge-intensive services rely predominantly on expenditures for machinery and equipment. Lower intramural R&D expenditures appear to be the compensation for this. Secondly, intramural R&D expenditures are mostly relevant in medium- and high-tech manufacturing sectors. Third, market related innovation expenditures are most relevant in service sectors as well as low-tech manufacturing.

Table 2: Share of different types of innovation expenditures of total by industry

Industry	Intramural R&D	Extramural R&D	Machinery	Other techn. knowl.	Market related
Low-tech manuf.	25%	5%	43%	4%	24%
Medium-tech manuf.	42%	6%	33%	2%	17%
High-tech manuf.	53%	8%	22%	3%	15%
Low knowl.-int. sevices	14%	6%	50%	3%	27%
Knowl.-int. services	30%	5%	32%	5%	27%
Total	34%	6%	35%	3%	22%

With these descriptive findings in mind we conduct a latent class cluster estimation. We choose the two types of innovation expenditures with the lowest importance, expenditures on extramural R&D and other technological knowledge, as the control group. The Baysian Information Criteria (BIC) reaches its minimum for a five cluster solution. Appendix A provides full estimation details. Figure 1 highlights the central findings on cluster membership.

Figure 1: Probabilities for cluster membership



See Appendix A for full details

Clusters 1 (1,794 observations) and 3 (711 observations) represent combinations of innovation activities. Cluster 1 combines purchases of machinery and equipment with market related expenditures. We will refer to this innovation pattern as “machinery-market balance”. In contrast, firms in cluster 3 have high probabilities for combining intramural R&D with the purchase of machinery and equipment. Hence, we refer to this innovation pattern as “R&D-machinery balance”.

The remaining 3 clusters show a clear concentration in innovation activities. Cluster 2 (1,226 observations) is primarily focussed with intramural R&D (“R&D focus”), cluster 4 (490 observations) with purchasing machinery and equipment (“machinery focus”) while the firms in the smallest cluster 5 (410 observations) concentrate on market related innovation activities (“market focus”).

Each of these innovation patterns can be traced back to firm specific (e.g. innovation budget, age, size), industry specific or regional factors (East Germany). Appendix A provides an early overview of these findings.

4 Next steps

- Fostering the breadth and depth of the theoretical framework

- Quality management and consistency checks on the cluster estimation
- Linking the cluster estimation to performance effects (i.e. different dimensions of innovation success) in the subsequent time periods (1998, 2002, 2006)

5 References

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6 Appendix

Appendix A: Results of latent class cluster estimation, coefficients and standard errors for probability of cluster membership

	Cluster1		Cluster2		Cluster3		Cluster4		Cluster5	
Indicators	Machinery-market balance		R&D focus		R&D-machinery balance		Machinery focus		Market focus	
Intramural R&D (share of total inno. exp.)	-0.09	**	0.63	***	0.26	***	-0.28	***	-0.53	***
	0.05		0.05		0.05		0.05		0.19	
Machinery exp. (share of total inno. exp.)	0.07	***	-0.27	***	0.07	***	0.68	***	-0.55	***
	0.02		0.02		0.03		0.02		0.08	
Market related exp. (share of total inno. exp.)	0.02	***	-0.24	***	-0.25	***	-0.27	***	0.74	***
	0.01		0.00		0.00		0.00		0.00	
Covariates										
Innovation exp. (as share of sales)	-1.53	***	0.24		2.30	***	2.20	***	-3.21	***
	0.36		0.34		0.52		0.41		0.73	
Share of emply. w/ college educ. (ratio)	0.19		2.07	***	0.47	*	-2.76	***	0.02	
	0.18		0.20		0.35		0.32		0.24	
Company age (years, logs)	-0.03		-0.07	*	0.05		0.04		0.00	
	0.04		0.05		0.07		0.05		0.06	
No of empl. (logs)	-0.15	***	-0.06	**	0.48	***	-0.09	***	-0.18	***
	0.02		0.03		0.05		0.03		0.03	
Group w/ foreign HQ (d)	-0.20	**	-0.06		0.20		0.07		-0.02	
	0.12		0.14		0.19		0.18		0.18	
Group w/ domestic HQ (d)	-0.06		-0.23	***	0.46	***	-0.21	**	0.04	
	0.07		0.09		0.13		0.11		0.11	
Export share of sales (ratio)	0.18		0.97	***	0.33		-1.50	***	0.01	
	0.16		0.17		0.26		0.30		0.25	

Indicators	Cluster1 Machinery-market balance		Cluster2 R&D focus		Cluster3 R&D-machinery balance		Cluster4 Machinery focus		Cluster5 Market focus	
Governm. R&D subsidy (d)	-0.16	**	0.80	***	0.52	***	-0.35	***	-0.81	***
	0.08		0.09		0.13		0.12		0.14	
Location East Germany (d)	-0.08		-0.31	***	-0.13		0.38	***	0.14	*
	0.07		0.09		0.14		0.10		0.10	
R&D industry tech. Lead (index)	0.25	***	0.19	***	-0.09		-0.43	**	0.09	
	0.08		0.08		0.12		0.19		0.12	
Medium-tech manuf. (d)	-0.16	**	0.59	***	0.25	*	-0.21	*	-0.46	***
	0.10		0.13		0.15		0.14		0.14	
High-tech manuf. (d)	-0.06		1.04	***	0.24		-0.92	***	-0.30	*
	0.14		0.16		0.22		0.27		0.22	
Knowl.-int. services (d)	0.32	***	0.21	*	-0.94	***	0.08		0.32	**
	0.11		0.15		0.21		0.14		0.14	
Low. knowl.-int. services (d)	0.26	**	-0.34	**	-0.92	***	0.64	***	0.36	**
	0.12		0.20		0.23		0.14		0.16	
Year 1997 (d)	-0.93	***	-0.53	***	2.00	***	0.43	***	-0.98	***
	0.09		0.11		0.16		0.11		0.12	
Year 2001 (d)	0.54	***	0.08		-0.70	***	0.43	***	-0.35	***
	0.09		0.11		0.24		0.13		0.13	
Constant	2.06	***	0.13		-3.64	***	0.34	*	1.12	***
	0.17		0.23		0.38		0.24		0.24	

* p<0.10, ** p<0.05, *** p<0.01, (d) Dummy variable