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Management control related to research performance and effectiveness: a comparative study of biomedical and pharmaceutical laboratories in universities, institutes and companies

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Abstract

In this paper the influence of management control on research performance and effectiveness is analyzed in biomedical and pharmaceutical laboratories in universities, institutes and companies. Management control is defined broadly as 'any way of directed influence' and is divided into personnel, resources, process and external control. In universities and institutes, research performance and effectiveness are measured by the number of publications in scientific journals and in journals for physicians and the citation score; in industry by the number of patents, the length of the development-process and the operating profit margin. The study consisted of questionnaires, sent to the senior scientific staff of 40 university departments and 17 departments of 5 health research institutes in the Netherlands and 10 European research laboratories of leading pharmaceutical companies, combined with structured interviews, which were held with the chaired professors and the research directors. Given the limitations of a cross-sectional design and a relatively small study population, the following tentative conclusions are drawn. Firstly, the strength of most management control variables proves to be highest in the relative certain environment of industrial R&D. Secondly, process control is only positively associated with innovative performance in industry. Thirdly, clear contrast has been found in the efficacy of personnel, resources and external control, dividing the more than average from the less than average performers, regardless of the organizational setting. Fourthly, in light of this finding it should be a matter of major concern for research policy makers, that efficacy of personnel and administrative control is judged so negatively in universities.

Keywords: Management control, Research, Performance, Effectiveness.

INTRODUCTION

Technological innovation has become one of the main drivers of competition, propelling new firms to the forefront and eroding the competitive advantage of well-established firms (Porter, 1985). Especially in the 'science based' industries (Pavitt, 1984), like the pharmaceutical industry, innovation has become essential for long term survival. As MacKenzie and Wajcman (1985) and Biemans (1992) indicate, the process of technological innovation is not done in a single company, but in a whole network with other companies (e.g. suppliers and distributors), universities, institutes, contract laboratories and user and political groups. In this paper attention will be paid to those organizations in the network, which concentrate on research and development.

There is considerable literature covering the managerial aspects of innovation in industry (for a selected overview, see Tushman and Moore, 1988). These studies mainly concentrate on the strategic and operational aspects, like project selection and evaluation, project planning, human resources management and staffing and interfaces with marketing and production. In academia and institutes comparably less (but still considerable) attention has been paid to the managerial aspects of research (e.g. Mason, 1979; Maintz, 1985 and Spangenberg, 1989). There is also some literature focusing on research in individual laboratories in universities and institutes (e.g. Knorr-Cetina, 1981; Latour and Woolgar, 1979). Two large European surveys (Andrews ed., 1979 and Franklin, 1988), have been done into research management, including universities, institutes and company laboratories in the study population. In these studies, however, no emphasis was laid on the possible differences, deriving from the organizational setting. Only at the level of the individual researcher, studies are done to evaluate these differences (e.g. Fisscher, 1986). It is the aim of this paper to analyze the influence of management control on research performance and effectiveness in different R&D-environments: the biomedical and pharmaceutical research departments in

universities and health research institutes and the R&D-laboratories of pharmaceutical companies.

Definition of variables

In the present study the systems theoretic approach of the double unity cell (van Engelen, 1989), a combination of a control situation (de Leeuw, 1979) and a value chain (Porter, 1985), has been used to model the relevant entities and the relations between them. In this model the research process is considered to be a value chain in which research input (information and chemical compounds) is converted into output (scientific publications in universities and institutes and a patent or a registrated drug in pharmaceutical companies).

In universities and institutes, the output is divided, auditorium dependent, into *'research and user performance'*. While research performance refers to the output directed to the scientific auditorium, measured by the number of papers in international scientific journals, the user performance refers to the output directed to physicians, measured by the number of papers in journals for physicians. For effectiveness and management control the definitions of Anthony (1965) are used. *Organizational effectiveness relates to the accomplishment of the cooperative purpose. (..) When a desired end is attained we shall say that the action is effective* (Anthony 1965, p. 27). In universities and institutes the effectiveness is reflected by the use of the results of the research department by the scientific auditorium (*effective scientific output*, Hazeu, 1989), measured by the citation score (Moed et al., 1985). In industry the length of the development-process and the operating profit margin are used to reflect R&D- and industrial effectiveness.

Management control is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives (Anthony, 1965, p. 27). Anthony conceives management control as the planning and control level between strategic planning (goal formulation) and operational control (assuring that specific tasks are carried out). In the present study management control is divided into system, process and external control. System control refers to the control over the personnel and material resources of the system (the research laboratory). Personnel control is measured by the assessed efficacy of the human resources management, and resources control by the estimated pace of the administrative procedures. Process control describes the control over the research process (the cycle: ideation, planning and design, resource acquisition, organizing, producing and output evaluation, Mason, 1979). It is assessed by the frequency of the research meetings and the attendancy mix. External control refers to the control over the environment (Pfeffer and Salancik 1978), assessed by international and contractor communication[1].

[1] Ashby's law of requisite variety (1956) has been used to decide whether the control variables, used in this study, are sufficient to cover the concept of control. Ashby's law can be summarized as follows: 'For effective control the controller must define a goal for the system and have a model of the system or at least a good understanding of the system to be controlled, must have sufficient information about the system and the environment, and must have enough measures of control at its disposal.' In this study goal setting and having a model are described as coordination. System information is described as research process communication and environmental information as external control. The measures of control are described as personnel and resources control. So it can be concluded that the control variables used in this study cover the concept of control, as proposed by Ashby, sufficiently.

Hypotheses

Two important differences between universities, institutes and companies, influencing management control, can be distinguished. Firstly, the missions are different: in universities it is basic research, in institutes it is applied research, and in industry it is applied research and development. In the sequence: basic research, applied research and development, the environmental and task uncertainty is assumed to decrease (Cohen and March 1974, Zeldenrust, 1989). Especially in basic research the research activities are rather uncertain, in the sense that task outcomes are not repetitious and predictable. It is hypothesized that international communication and process control will be most intensive in universities, in order to reduce the environmental and task uncertainties, and least intensive in company laboratories. Regarding international communication, the differences might be slight, because in a 'science based industry', like pharmaceuticals, the building of an international network with scientists and physicians, is essential for attaining innovative ideas (Biemans, 1992). Because the institutes are heavily involved in contract research, it is hypothesized that the contacts with outside contractors will be most intense here. The difference with universities might be slight, because of the recent increase in importance of external funding in university research.

Secondly, there are differences originating from the profit or non (not for)-profit background. It is assumed that managers in non-profit organizations are more restricted in handling organizational problems than managers in profit organizations (Hofstede, 1981). Lifetime appointment, combined with a strong legal status, limits the possibilities of decisive intervention in situations of conflict. Also reallocation and job rotation are more difficult to implement. Furthermore, in profit organizations the feedback on dropping results is very direct. The operating profit margin is very compelling because of the permanent threat of being overreached by a competitor. Therefore, it is expected that the scientific staff in pharmaceutical companies will set higher value upon system control and planning by higher management, than the staff in universities and institutes. In table 1 the predicted differences are summarized.

Table 1. The predicted differences in the strength of the different management control variables between the strata: universities, institutes and companies.

	Universities	Institutes	Companies
System control	-	±	+
Process control			
Planning	-	±	+
Frequency/att. mix	+	±	-
External control			
International comm.	+	±	±
Contractor comm.	±	+	*

+ comparatively highest strength of the management control variable;
± moderate strength; - lowest strength; * not measured

It is hypothesized that for most of the management control variables, the more than average performers will show higher scores than the less than average ones (median split). It is expected that this difference will be the most distinct for those performance and effectiveness variables, which are a reflection of the mission of the organization.

METHODS

The study consisted of structured interviews, about research management and control, with a selected sample of chaired professors in biomedical and pharmaceutical university departments and with one or two of the Research Directors of the large health research institutes in the Netherlands. In industry, one or two of the Directors of the Research, Development and Clinical Research Divisions (mostly members of the Board) of leading pharmaceutical companies, were interviewed. This was combined with questionnaires about personnel, budget and research policy, submitted to the chaired professors and their senior scientific staff in universities and to the senior scientific staff of the different research departments in institutes. In the company laboratories they were sent to the heads of the different research departments.

For the assessment of the different management control variables, Likert 5-point scales were used. After the data-collection a factor analysis was performed. Cronbach's α (1970) was calculated for the individual sub-scales, to find out, whether they corresponded with the variables defined, and to check for the internal consistency of the items, supposed to measure a single concept. In all cases Cronbach's α was sufficiently high ($> .75$), to warrant confidence in the internal consistency. In four cases the answers on particular questions loaded on different variables along the three strata (universities, institutes and companies). These questions were omitted from the analysis. To correct its influence on research performance, size was entered first in the multivariate analyses, and before the management control variables were entered. In order to warrant objectivity the performance variables were measured by use of bibliometric measures and public information (year reports etc.) and checked by the research management concerned. Also size has been included as an independent variable, because it has a major impact on research performance. For a more detailed description of the variables, the reader is referred to table 2.

For the clarity of presentation all univariate relationships are presented using Spearman rank correlation and Oneway Anova. Non-parametric analysis of group means, using the Kruskal Wallis test, did not alter the conclusions. The multivariate associations are measured on the ranking numbers with a neural network. The neural network uses the iterative steepest descent technique, with exponential sum formula, based upon series expansion, to approach the minimum error solution. It is developed for usage in cases in which other numerical modelling methods (like multiple regression) perform poorly, due to insufficient or singular data (Hoptroff, 1991). The neural network divides the data into two groups: a model set of 80% and a test set of the remaining 20%. First, the neural network builds a model on the data of the model set, then this model is tested on the data of the test set. Because of their general use in multivariate analyses, in this paper the terms explained variance and F-value are used. Strictly spoken, they only relate to predicted (mostly linear or transformed to linear) relationships. The neural network, however, is designed to model all kinds of linear and non-linear relationships. In the present study, only linear and curvi-linear relationships are measured, because of the relatively small study population.

Table 2. The definition of size, management control, performance and effectiveness.

Size	
Research staff	Total number of scientists working in research departments (uni. and inst.) or on the R&D-process (industry), in full time equivalents
System control (personnel and resources control)	
Efficacy	Subjective assessment by the chaired professors and the senior scientific staff (in universities and institutes), or the heads of the different research departments (in company laboratories) of the efficacy of personnel policy, appointment, promotion and career planning (Likert 5-point scales, higher values indicate a more positive assessment)
Adequacy	Subjective assessment of the adequacy of the size of the research budget and the laboratory equipment (Likert scales, higher values indicate a more positive assessment)
Administrative control	Rapidity of administrative procedures, regarding appointment and procurement of equipment {US$ 5,000 in universities and institutes and $ 50,000 in industry, Likert scales, 1 = (more than) a year; 5 = (less than) a month}
Process control	
Planning	Subjective assessment of the importance of short and middle range planning by higher management (for instance research committees in universities and institutes or the main office in industry, Likert scales, higher values indicate a more positive perception)
Frequency	Frequency of research meetings {Likert scales, 1 = (less than) once in six month; 5 = (more than) once a week, research process comm.}
Attendancy mix	Attendancy of research meetings: only scientific staff or also technical and analytical support staff, researchers of other laboratories etc. (Likert scales, higher values indicate more diversity in attendancy, research process communication)
External control	
International comm.	Frequency of international contacts with scientists and physicians, for instance on congresses and workshops {Likert-scales, 1 = (less than) once a year; 5 = (more than) once a month}
Contractor communication	Frequency of contacts (industrial and governmental) contractors {universities and institutes only, Likert-scales 1 = (less than) once a year; 5 = (more than) once a month}
Research and user performance and effectiveness (universities and institutes only)	
Research performance	The average number of papers, published annually by scientists of the research department, in international scientific journals (1988-1991)
User performance	The average number of papers, published annually by scientists of the research department, in (national and international) journals for physicians (1988-1991)
Citation score	The average number of citations per paper, published in 1985 till 1987, in the three years following the publication, weighed for the average number of citations of papers which were published in the same (sub)-disciplines
R&D and industrial performance and effectiveness (companies only)	
Number of patents	The number of patents for lead's (new chemical compounds with assumed therapeutic efficacy), submitted world wide (1985-1991, first priority date)
Length of development	Length of the development-process (from the discovery of the lead until registration as a drug, $years^{-1}$)
Operating profit margin	Operating result / revenues. Operating result = result after deduction of normal operating charges and before financial income and expenses, taxes etc. Revenues = net turnover including other operating revenues, change in stocks and capitalized costs

RESULTS

Data collection and response

The data were collected in 1991 and 1992. In total 84 university departments, 7 health research institutes and 20 pharmaceutical companies were approached for the study. 49 University departments (response rate 58%), 5 institutes (response rate 71%) and 14 companies (response rate 70%) entered the study. The information of 40 university departments, 17 departments of 5 health research institutes, and 10 research laboratories of leading pharmaceutical companies (average world wide sales of ethical drugs in 1991: 3.7 ± 2.1 billion US$) could be used in the comparative analyses, presented in this paper. In total 47 interviews were held: 16 with chaired professors, 9 with Directors of institutes and 22 with R&D-Directors in companies. 49 Questionnaires were sent to the chaired professors and 184 to their senior scientific staff. 46 Questionnaires were returned by the chaired professors (individual response rate 94%) and 96 by their senior scientific staff (individual response rate 52%). 72 Questionnaires were sent to the senior scientific staff of the institute, of which 40 were returned (individual response rate 56%). 59 Questionnaires were sent to the heads of the research departments in the company laboratories, of which 38 were returned (individual response rate 64%). So the figures presented in this paper, are based upon 3 to 4 questionnaires per university department, institute department or company laboratory.

Comparison between the strata

In table 3 a comparison of management control between universities, institutes and companies, is presented.

Table 3. A comparison of management control in biomedical and pharmaceutical research departments in universities, institutes and pharmaceutical R&D-laboratories {mean and (SD)}.

	Universities n=40	Institutes n=17	Companies n=10	F-value
Personnel control				
Efficacy	2.52 (.77)	3.12 (.82)	3.33 (1.02)	6.96***
Resources control				
Adequacy	2.69 (1.08)	2.95 (.90)	3.56 (.63)	3.65*
Administrative control	2.00 (.99)	2.41 (1.03)	3.48 (1.26)	8.96***
Process control				
Planning	3.62 (1.17)	3.64 (1.17)	3.78 (1.57)	.06
Frequency	4.25 (.78)	4.49 (.96)	3.07 (.88)	10.50***
Attendancy mix	2.81 (.44)	2.80 (.65)	2.37 (.51)	3.37*
External control				
International comm.	2.54 (.97)	2.89 (1.14)	3.46 (1.31)	3.64*
Contractor communication	2.84 (1.04)	2.59 (1.26)	*	.09

Scales from 1 to 5, 1 = weakest control and 5 = maximum control; * = not measured
$F_{\text{one way anova}}$: *** $p < .001$, ** $p < .01$, * $p < .05$

Table 3 shows that the scientists express a negative opinion on the efficacy of the personnel and resources control situation in universities. the mean values of their answers, measured at a 5-point scale, are below 3. In comparison the scientific staff in pharmaceutical companies is much more positive. Both regarding personnel and resources control the mean values of their answers are above 3. The estimated pace of the administrative procedures is nearly twice as high as in universities. Also the participation in international congresses is significantly higher in industry. The researchers in the institutes take an intermediate position. Research process communication, both in terms of frequency and attendancy mix, is more intense in universities and institutes than in companies. All these differences prove to be statistically significant. No difference is found in the assessed importance of planning. In all three strata the scientific staff is positive about the importance of short and middle range planning, by higher management. Also no difference is found in the level of contractor communication between universities and institutes.

Performance and effectiveness

In table 4 the Spearman rank correlations of size and management control with performance and effectiveness, are presented.

Table 4. The Spearman rank correlations between the size and mangement control variables and the size, performance and effectiveness variables in universities, institutes and companies.

	Universities				Institutes				Companies			
	size	perform.	citation		size	perform.	citation		size	patent	devel.	profit
	research	user score			research	user score			number	length		margin
	n=40				n=17				n=10			
Size												
Research staff	x	.76	.40	.26	x	.53	.69	.05	x	.66	.74	.65
Personnel control												
Efficacy	.50	.42	.18	.33	.49	.48	.68	.41	.56	.39	.43	.71
Resources control												
Adequacy	.12	.22	-.21	-.30	-.03	.01	-.07	-.15	.73	.24	.54	.51
Adm. control	.13	.23	-.07	.24	.34	.25	.47	.15	.14	.17	.42	.39
Process control												
Planning	-.25	-.15	.01	.05	.36	-.24	.10	.03	.36	.06	.62	.42
Frequency	.06	.10	-.09	-.16	.28	.06	.30	.08	.44	.75	.30	.08
Attendancy mix	.04	.01	.12	.22	.01	-.33	.20	.28	.18	.13	.66	.18
External control												
International comm.	.11	.42	.04	.16	-.05	.11	.43	.32	.25	-.02	-.26	.73
Contractor comm.	.23	.35	.18	.19	.21	.12	.67	.45	*	*	*	*

The underlined numbers are statistically significant ($p < .1$, 2-tailed test); * = not measured

The management control variables are hardly mutually correlated (data not shown). Size, however, is significantly correlations with different management control variables. Namely, with efficacy of personnel control in all three strata, with adequacy of resources in industry and with frequency of research meetings in institutes and (although not significant) in industry. As could be expected, the size of the scientific staff is highly correlated with performance in all three strata. More interesting is the observation, that strength of personnel control is also positively associated with research performance and citation score in universities; research and user performance in institutes and the operating profit margin in industry. Concerning resources control, adequacy of resources is negatively associated with citation score in universities, while administrative control is positively associated with user performance in institutes. Concerning process control, the frequency of research meetings is positively associated with the number of patents, whereas planning and the attendancy mix are positively associated with the length of the development process. Concerning external control, international and contractor communication are both positively associated with research performance in universities and user performance in institutes. Contractor communication is also positively correlated with citation score in institutes. International communication is positively associated with the operating profit margin in industry.

In table 5 the multivariate models of the associations of management control with performance and effectiveness are presented. The strength of the models differed considerable. Relatively weaker models are found for user performance and citation score in universities and research performance and citation score in institutes, with a total percentage of explained variance of less than 40%. Also lower F-values and test set fits are measured (except for user performance in universities). Contrary to this, relatively strong models are found for research performance in universities, user performance in institutes and all the performance and effectiveness variables in industry, with a total explained variance of more than 60%. Also the F-values (taking into account the differences in sample size between the strata), and the test set fits (except for research performance in universities) are higher. As could be expected, also in the multivariate models, size contributed most, 50 to 85% of the explained variance. Only for the citation score no significant association with size is found. The control variables contribute less: 15 to 50% of the explained variance. Personnel control, administrative control and external control associate significantly with research performance in universities, user performance in institutes and operating profit margin in industry. Comparatively, adequacy of resources and process control seem to be of less importance. Elements of process control enter the multivariate models only in industry, while adequacy of resources is only negatively associated with user performance and citation score in universities.

CONCLUSIONS AND DISCUSSION

The results provide a clear confirmation for the thesis that the differences in the level of management control are most distinct for those performance and effectiveness variables, which reflect the mission of the organization. Three of the management control variables, together with size, prove to give a good prediction for those performance and effectiveness variables, which reflect the primary research goals of the management: (basic) research performance in universities and (applied) user performance in institutes. Whereas, management control is only weakly associated with the secondary management goals: user performance in universities and research performance in institutes. In industry the best multivariate model of size and management control is formed with the parameter of industrial effectiveness, the operating profit margin. Apparently, this measure provides the best reflection of the

Table 5. Percentage explained variance of the performance and effectiveness variables by the different management control variables in universities, institutes and companies.

	Universities performance citation research user score n=40			Institutes performance citation research user score n=17			Companies patent devel. profit number length margin n=10		
Size									
Research staff	46%	30%[1]	-	33%	37%	-	44%	52%	43%
Personnel control									
Efficacy	5%	-	9%	5%	14%	2%	18%	4%	17%
Resources control									
Adequacy	-	5%(-)	6%(-)	-	-	-	-	-	-
Adm. control	3%	-	10%	-	10%	-	-	-	11%
Process control									
Planning	-	-	-	-	-	-	-	2%	-
Frequency	-	-	-	-	-	-	14%	-	-
Attendancy mix	-	-	-	-	-	-	-	5%	-
External control									
International comm.	3%	-	-	-	7%	-	-	-	10%
Contractor comm.	8%	-	-	-	9%	10%	*	*	*
Total	65%	35%	25%	38%	77%	12%	76%	63%	81%
R^2 model set	69%	34%	31%	68%	80%	11%	79%	59%	80%
R^2 test set	27%	42%	8%	15%	64%	15%	53%	85%	82%
F-value	12.69***	6.51**	4.00*	4.33*	22.29***	2.41	6.44*	4.89*	5.19*

[1] = incl. clinical practice; - = variable does not associate significantly with performance and effectiveness in the multivariate analysis; (-) = variable is negatively associated with performance or effectiveness; F-value: *** $p < .001$, ** $p < .01$, * $p < .05$

management situation in R&D. This result is in accordance with the conclusion of van Engelen (1989) for the marketing sector. This implicates that in all strata the same three management control variables: personnel, administrative and external control, are closely associated with performance and effectiveness. This provides strong confirmation for the thesis, that there is a fundamental association between management control and performance and effectiveness, dividing the more than average from the less than average performers, regardless of the organizational setting.

However, these finding should be interpreted with some caution, whereas with a cross-sectional design no cause-effect relations can be identified with certainty. The relationships might be, and partly will be, inverse. For instance concerning the efficacy of personnel policy, the researchers in the better research groups might have responded more positively than their colleagues in the less performing ones, whereas the 'objective' situation was the same. Furthermore, researchers in better research groups in universities and institutes might get

more possibilities to present papers in international congresses as key note speaker, with the expenses paid by the organizing committee. Also contractors will try to select the best research groups. However, keeping this in mind, the results can be used as a comprehensive list of features of the better research laboratories.

Probably just as interesting is the observation that in universities and institutes process control proves to be relatively unimportant as a discriminating factor between less and more than average performers. Although larger differences could be established in the way and manner research was supervised (relatively tight versus loose control), those differences were not retrieved in the multivariate analyses with any of the performance variables. Apparently, performance in universities and institutes is primarily related to system control and external control and not closely related to process control. Systems designers and research policy makers could profit from this knowledge, by especially concentrating their efforts on the first two aspects.

In the light of the above findings, another striking result is the negative judgement of the personnel and resources control situation in universities and, although to a lesser extent, in institutes (table 3). This finding should also be interpreted with some caution. In a professional bureaucracy, like a Medical Faculty or a research institute, there is always a certain tension between professionals and the administrative staff (Mintzberg, 1979, 1983). This tension might have resulted in a negative attitude towards personnel and resources control. Also Slootman (1991) found a negative judgement of the human resources management in academia. However, the results in this study are more profound. Slootman found that the higher scientific ranks were clearly more positive than the lower ones. In this study, however, only the higher scientific ranks are questioned. Therefore, this negative judgement should be a point of concern for research policy makers.

Size had a major impact, not only on output, but also on personnel control. This is not surprising, size enlarges the management tools considerably: in terms of career planning, remuneration, and possibilities for replacement in situations of conflict. Interestingly, only in industry a clear association of size and adequacy of resources is found. This finding is in agreement with the observation of Spangenberg (1989), that 'objective' and 'subjective' size are hardly associated in academia. The negative association of 'subjective' size with citation score in universities, could indicate that the scientists in the better research groups are more difficult to satisfy than there colleagues in the less than average ones, being more eager to get the best equipment possible. This difference in the assessment of the adequacy of the resources might be considered as a reflection of a difference in competitive orientation between universities and industry (Fisscher, 1986). A further confirmation could be, that in a subgroup of the sample it is established that researchers in universities are much more competitively oriented than those in industry.

In industry the level of process control associates positively with the R&D-parameters. In the, in comparison to development, uncertain environment of industrial discovery, higher frequency of research meetings proves to be a dividing parameter. Contrary to the discovery phase, the research in the development phase is well defined, and can be planned according to strict schedules. In accordance with this, a positive association with planning was found. The association of attendancy mix with performance might be regarded as a reflection of the success of the project teams, established in the middle of the 1980s. In the project team meetings, researchers of the different phases of the R&D-process, and staff members of marketing and production, discuss the ongoing research projects on a regular basis. Nevertheless, in the structured interviews, some R&D-Directors expressed there concern that, despite the

fact that the project teams had clearly speeded up the R&D-process, the frequency of meetings, with all the organization necessary, on the long run would reduce the positive effects.

Most of the theses, concerning the differences between the strata, are confirmed by the results. Respondents in companies are clearly more positive about the strength of system control than those in universities and institutes. So it may be concluded that the fundamental differences as reflected by management control between profit and non-profit research organizations, still exist. In accordance with the hypothesis the frequency of research meetings and the attendancy mix are higher in universities and institutes (table 3). It must be considered, however, that at least part of this difference, must be contributed to the larger size of the R&D-process in industry. In accordance with the expectation, the assessed importance of planning by higher management is the highest in industry, but the differences are far from significant. Especially for universities this result is unexpected. Apparently colleague control is more accepted than assumed in literature (Weick, 1984). Contrary to expectations, international communication proves to be most intense in industry and lowest in universities. This contradictory finding can probably be explained, by the differences in available travelling budgets.

Given the inherent limitations of a cross-sectional design and a relatively small study population the following more general conclusions are tentatively drawn. Although larger differences in management control could be demonstrated between the strata, for instance the strength of administrative control being larger in the weakly performing research laboratories in industry, than in the best performing ones in universities and institutes, if we compare the less with the more than average performers, in all the strata the same factors were identified. A successful research laboratory can be characterized by the following features: 1. much attention is paid to human resources management; 2. the administrative procedures are carried out quickly; 3. there is a flexible adjustment to changing situations; 4. much attention is paid to the building and maintaining of an (international) network; 5. comparatively process control is not a discriminating factor in universities and industry. Of course, these findings are not new. Numerous researchers have pointed on the importance of the human factor in research (e.g. Allen, 1976, Twiss, 1974, and Pelz and Andrews, 1976). Also the importance of flexible procedures and networking are stressed in many studies (e.g. Volberda, 1992 and Biemans, 1992). This is the first time, however, that the contribution of these factors has been proved in a comparative study in different R&D-environments, demonstrating their crucial role in successful research management.

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REFERENCES

Allen, Th. 1977, *Managing the Flow of Technology,* MIT Press, Boston.

Andrews, F.M. (ed.) 1979, *Scientific Productivity. The Effectiveness of Research Groups in Six Countries*, Cambridge University Press/UNESCO, Cambridge and Paris.

Anthony, R.N. 1965, *Planning and Control Systems. A Framework for Analysis*, Harvard University, Boston.

Ashby, W.R. 1956, *Introduction to cybernetics*, Chapmann and Hall, London.

Biemans, W.G. 1992, *Managing innovation within networks*, Routledge, London, New York.

Cohen, M.D. and March, J.G. 1974, *Leadership and Ambiguity: the American College President*, McGraw-Hill, New York.

Cronbach, L.J. 1970, *Essentials of psychological testing*, Harper & Row, New York, Evanston, London.

Engelen, J.M.L. van 1991, The Role of Information Systems in Marketing Success, in *Bussiness Strategy and Information Technology*, eds. Sutherland, E.,Morieux, Y. pp. 72-85, Routledge, London, New York.

Fisscher, O.A.M. 1986, Onderzoek in drie Research instellingen naar de sturing en motivatie in samenhang met de gerichtheid van het Researchwerk, Ph.D.-thesis, Erven van der Kamp BV, Groningen.

Franklin, M.N. 1988, *The Community of Science in Europe. Preconditions for Research Effectiveness in European Community Countries*, University of Strathclyde, Gower/EC Aldershot.

Hazeu, C.A. 1989, *Systeem en gedrag in het wetenschappelijk onderzoek. Een model voor toedeling van taken en verantwoordelijkheden in een multi-niveau systeem, toegepist op het universitaire onderzoek* , VUGA Uitg., 's Gravenhage.

Hofstede, G.H. 1981, Management Control of Public and Not-for-Profit Activities, Accounting, Organizations and Society 3, pp.193-211.

Hoptroff, R.G., Bramson, M.J. and Hall, T.J. 1991, Forecisting economic turning points with neural nets, *IEEE* 1 pp. 347-353.

Knorr-Cetina, K.D. 1981, The Manufacture of Knowledge. An essay on the Constructivist and Contextual Nature of Science, Pergamon Press, Oxford, New York, Toronto, Sydney, Paris, Frankfurt.

Latour, B. and Woolgar, S. 1979, Laboratory Life. The Social Construction of Scientific Facts, Sage Publications, Beverley Hills, London.

Leeuw, A.C.J. de 1979, The control paradigm is an aid for understanding and designing organizations, Progr. in Cyb. and Syst. Res. 5, pp. 93-100.

MacKenzie, D. and Wajcman, J. 1985, *The Social Shaping of Technology*, Open University Press, Milton Keynes, Philadelphia.

Mason, R.O. 1979, The Role of Management in Science, Publ Adm. Review, pp. 112-116.

Mayntz, R. 1985, *Forschungsmanagement: Steuerungsversuche zwischen Scylla und Charybdis; Problem der Organisation und Leitung von Hochschulfreien öffentlich finanzierten Forschungsinstituten* Westdeutscher Verlag, Opladen.

Mintzberg, H. 1979, *The Structuring of Organizations: a synthesis of the Research*, Prentice-Hall, Englewood Cliffs.

Mintzberg, H. 1983, *Power In and Around Organizations* Prentice-Hall, Englewood Cliffs.

Moed, H.F., Burger, W.J.M., Frankfort, J.G. and van Raan, A.F.J. 1985, The application of bibliometric indicators: important factors to be considered, *Scientometrics* 8 pp. 177-203.

Pavitt, K. 1984, Sectoral patterns of technical change: Towards a taxonomy and a theory, Research policy 13 pp. 343-373.

Pelz, D. and Andrews, F.M. 1976, *Scientists in Organizations. Productive Climates for Research and Development*, 2end ext. ed. John Wiley and Sons Inc., New York, London and Sydney.

Pfeffer, J. and Salancik, G.R. 1978, *The External Control of Organizations*, Harper and Row, New York

Porter, M.E. 1985, *Competitive advantage, creating and sustaining superior performance*, Free Press, New York.

Slootman, A.W. 1991, *Arbeidsbeleving van universitair wetenschappelijk personeel*, Ph.D.-thesis, CSHOB, University Twente, Enschede.

Spangenberg, J.F.A. 1989, *Economies of Atmosphere. The Joint Impact of Scale, Scope, and Atmosphere on Scientific Performance in Clinical Medicine and Economics* Van Gorcum, Issen/Maistricht.

Tushman, M. and Moore, W., 1988, *Readings in the Management of Innovation*, Balling Publ. Co., Cambridge.

Twiss, B.C. 1974, *Managing technological innovation*, Longman, London.

Volberda, H.W. 1992, *Organizational Flexibility. Change and Preservation*, Ph.D.-thesis, Wolters Noordhof, Groningen.

Weick, K.E. 1984, Contradictions in a community of scholars: the cohesion-accuracy trade off, in J.L. Bess (ed.), College and university organization, New York University Press, New York, London, pp. 15-30.

Zeldenrust, S. 1989, *Ambiguity, Choice and Control in Research*, Ph.D.-thesis., Amsterdam