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Auteurs: Louis André Lefebvre, Élisabeth Lefebvre, & Jean Harvey
Authors:

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ORGANIZATIONAL ASSETS AS DETERMINANTS

OF ADVANCED MANUFACTURING TECHNOLOGY

ADOPTION IN SME'S

Dr. Louis A. Lefebvre
Professor
Ecole Polytechnique
University of Montreal

Dr. Elisabeth Lefebvre
Assistant Professor
Ecole Polytechnique
University of Montreal

Dr. Jean Harvey
Professor
Department of Administrative Sciences
University of Quebec at Montreal

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**ORGANIZATIONAL ASSETS AS DETERMINANTS OF ADVANCED
MANUFACTURING TECHNOLOGY ADOPTION IN SME'S**

The new rules of competition imposed by the increased globalization of markets and the rapid technological changes are among the realities with which organizations must comply. This obviously creates strain on the capacity of organizations to adapt to both external and internal pressures and, as a result, their capacity to manage change. In a recent article, Adler and Shenbar (1990) noted quite rightly that skills remained a key element that needed to be dealt with when technological change is sought and the one which most directly affects the attainment of an organization's goals. In fact, Rogers (1983) long ago documented the fact that the innovation adoption process is a social one. Since then, much work has been done to investigate the individual roles (Maidique, 1980; Dean, 1987), the critical functions (Roberts and Fusfeld, 1981), and the networks (Adler, 1989; Weiss & Birnbaum, 1989) which must be present to sustain the innovative capacity of organizations, all of which points to the importance of mobilizing human capital to ensure successful change in organizations.

This study focuses on advanced computer-based manufacturing technology (AMT) adoption in 116 manufacturing firms with more than 50 and less than 200 employees. It is hypothesized that the technological strategy pursued by a firm is largely influenced by employee involvement in the process of strategy formulation, available technological skills in the organization and the presence of external networks. Further, this technology strategy would itself be a determinant of the level of technological penetration attained

by the firm. This is in line with the evolutive model proposed by Burgelman and Rosenbloom (1989), according to which the rationale for technology adoption cannot be dissociated from a firm's previously acquired capabilities.

Theoretical considerations

In the technology adoption literature, previous research work has largely concentrated on the various factors which may ultimately affect adoption (see for example, Pennings, 1987; Dean, 1987a). There is, however, growing empirical evidence that such factors may be subject to a firm's prior experience with technology (Lefebvre et al. 1991), thus suggesting that organizational knowledge and skills may ultimately be a major determinant of the technology adoption rationale (Burgelman and Rosenbloom, 1989). Thus, strategy can be viewed essentially as a "social learning process" through which technology strategy emerges from acquired technical capabilities, which themselves are shaped by past technological experience. More recently, Adler and Shenbar (1990) have shown that the characteristics of a firm's technological base may alter organizational strategies. If such is the case, it could reasonably be assumed that technology strategy would also be largely influenced by this technological base, in the sense of both the "technological" know-how and the organizational levers for effectively building and deploying that know-how (Adler and Shenbar, 1990:25). Among the elements composing the technological base, the authors emphasize the importance of

organizational assets, of which management and employee skills may constitute the single most important element. Itami (1987) also discusses the dominant role of these "invisible assets" in a organization's development. Going a step further, Aaker (1989) sees the fit between skills and strategy as essential in order to derive the full benefits of technology. Thus, the conclusion that human resources play a central role in a successful technology strategy is inescapable. This research has therefore focused on the study of capabilities of employees in an organization, on how these capabilities may affect the motivations behind the technology strategy and, ultimately, the organization's technological strategy itself and therefore its distinctive competencies.

While we do agree with the relative importance of employee skills, recent research conducted by Dean (1987b) also suggests that the justification process for new technology adoption is largely dominated by the influence of its proponents. In fact, influences on adoption may come from individuals or groups internal or external to the organization (Pennings, 1987). Decision participants usually considered as influential proponents in past research include both internal actors (CEO, production and marketing managers) and external actors (consultants, technology suppliers, and customers). The argument presented here is that the strategies pursued, as well as the actual technology adoption decisions, are to a large extent moulded by the internal proponents. Yet one cannot deny the role of external parties, which in many instances have a great influence on a firm's strategy. This network of relations constitutes the basis of an organization's

external assets (Adler and Shenbar, 1990) and is considered to be of major importance in determining the outcome of a firm's technology strategy.

While considering adoption of advanced manufacturing technologies, a firm may investigate different strategic options which should be embedded within the overall strategic process (Adam and Swamidass, 1989; Kotha and Orne, 1989). Key factors identified as important priorities for a manufacturing strategy formulation include cost, productivity, quality, flexibility, and reliability (Leong et al., 1990). These same criteria are also found to be pertinent in the case of decisions regarding the adoption of manufacturing technology (Meredith, 1987a).

Insert Figure 1 here

In this paper, the suggested relationship between employee skills, influences, strategic motivations, and AMT adoption (See figure 1) is investigated in the particular context of small manufacturing enterprises or firms (SME's). The economic importance of these smaller firms, their propensity to be innovative (Acs and Audretsch, 1988; Rothwell, 1978), and the fact that they are rather accessible sites for the observation of complex phenomena justify this choice. Meredith's studies on the technology adoption behavior of smaller firms have demonstrated that SME's tend to seek different competitive advantages from new technology than larger firms.

Rothwell and Zegveld (1982) have also stressed the importance of employee participation in SME's and their impact on the outcome of the decision-making process. Although participative in nature, the decision-making process is undoubtedly subject to the CEO's strong influence, especially in the smaller SME's. Similarly, employee know-how and experience would certainly have an impact on the strategic orientation. Finally, it must be recognized that small firms may be more outward oriented (Meredith, 1987b) and therefore sensitive to external networks, since in a large number of situations, they lack the internal expertise to address correctly the problem or opportunity at hand.

The next section outlines the model on which this work is based, the research variables used, and the overall methodological approach.

Methodological issues

The dimensions retained in this study are presented in Figure 1. The model builds on previous work done by Burgelman (1988), and Burgelman and Rosenbloom (1989), who have suggested the general nature of both the model and the relationships involved.

The actual variables used to portray the different dimensions of the model are listed in Figure 2 along with their theoretical justifications.

Insert Figure 2 here

The sample studied here comprised 116 small and medium-sized firms, drawn from a government directory of manufacturing firms operating in Quebec. Selection was carried out using systematic sampling procedures. All of the firms involved had more than 50 and fewer than 200 employees. The lower limit was arbitrarily set to allow for representation of the different employee categories, while the upper limit corresponds to one of the accepted definitions of SME's (Stanworth et al. 1982). All had adopted at least one computer-based information and/or production technology.¹

The top manager or CEO of each of the firms chosen received a pre-tested questionnaire which he/she had to fill in. His/her overall knowledge of the characteristics of the organization and of its strategy and performance makes him/her an ideal source of information (Hambrick, 1981), especially in SME's (Miller & Toulouse, 1986).

Factor analysis with varimax rotation was first conducted on each of the three sets of variables in order to uncover the relationships within each set and ultimately reduce the number of variables to a limited number of orthogonal factors. These factors were

¹ Computer-based information technologies: accounts payable/receivable; inventory control; sales analysis; payroll; billing; cost accounting; management of operations; word processing; electronic mail/filing; teleconferencing.

Computer-based manufacturing technologies: CAD (computer-assisted design); CAM (Computer assisted manufacturing); automated numerical control; automated storage and retrieval system; automated quality-control system.

considered as independent variables in a multiple regression analysis. The technique of hierarchical regression analysis was retained since it enabled us to test the joint effects of control variables and independent variable sets on the dependent variable. Furthermore, hierarchical regression analysis allows us to determine whether strategic motivations mediate the effects of the control variable, of technical capabilities and of the internal and external influences on AMT adoption (Cohen and Cohen, 1983).

Results and discussion

Results of the principal component analysis performed on each of the three sets of variables are shown in tables 1, 2 and 3 respectively. All loadings greater than .60 were considered as statistically significant (Dillon and Goldstein, 1984).

The underlying dimensions revealed in Table 1 could clearly be labelled as "technical capabilities of white-collar workers" (FC1) and "technical capabilities of blue-collar workers" (FC2). Both factors together accounted for 66% of the variance explained. As should be noted from the means presented in this table, the greatest users of computer-based technologies are clerical and secretarial workers, who are usually the first groups involved in the use of information technologies such as word processing and basic accounting applications. As information technologies get more sophisticated and move away from transactional purposes, professionals and managers start using them.

These findings implicitly support the well-known stage hypothesis model of Nolan (1979). The low percentage of blue-collar workers exposed to computer-based technologies reflects the current low penetration of AMT's in the smaller manufacturing firms.

Insert table 1 here

Results from table 2 do not present any interpretational difficulties. The first factor is clearly dominated by the influence of consultants and suppliers of technologies (FI1). These external influences are indeed known to be crucial for the smaller firms. The second factor (FI2) relates to the influence of functional groups, whereas the last factor (FI3) points to the influence of the CEO. The three factors, which together explain 76.1% of the variance, were labelled respectively "influence of external networks", "influence of functional groups" and "influence of CEO". From the means shown in table 2, it should be noted that the strongest single influence is that of the CEO. Although this is largely supported by the literature, some caution should be exercised since it is the CEO who is actually doing the reporting. The internal functional groups appear to be more influential than external groups.

Insert table 2 here

Table 3 outlines the strategic motivations for AMT adoption. For all 116 firms, increase in overall productivity received the highest ranking mean followed by increase in the quality of customer services. It appears that cost reductions (labor costs and cost of finished products), although quite important, are not the primary concern. As Meredith (1987b) has indicated, smaller manufacturing firms rarely compete on cost leadership alone but rather tend to exploit other competitive advantages such as greater customization and higher quality of the products and services offered. Two factors (FS1 and FS2) are derived from the factorial analysis. The first reflects a number of expectations of technology adoption that are more internally oriented such as an increase in the flexibility of the manufacturing process, reduction in labor costs and reduction in cost of finished products. The second factor denotes a more outward orientation: image of the firm and quality of customer services. These two factors, labelled respectively "inward oriented strategic motivations", and "outward oriented strategic motivations", accounted for 65% of the variance explained.

Insert table 3 here

A first set of multiple regressions was conducted in order to evaluate the extent to which technology strategy motivations (block 4) can be explained by firm size (block 1), technical capabilities (block 2), and influences (block 3). Results presented in table 4 reveal that while firm size is an important determinant of inward oriented strategies, influence of functional groups is the major explanatory factor of both inward and

outward oriented technology strategies. In other words, the influence of both the marketing group and the engineering production group is prevalent in shaping the technology strategy of a firm.

Insert table 4 here

Results of a second multiple hierarchical regression analysis conducted on all four blocks of variables are presented in table 5. Blocks of variables were entered progressively starting with the control variable (block 1) and followed by blocks 2, 3 and 4 which represent, respectively, the technical capabilities, influences and strategic motivations. The dependent variable in this case is the level of AMT penetration.

Our results first indicate that the control variable, firm size has a positive relationship to AMT adoption, but only, accounts for only 3% of variance [$R = 0.029$, $p < 0.05$] which is not overly surprising given that firms considered for this research were restricted to SME's of more than 50 and less than 200 employees. Obviously, this restriction moderated the effect of firm size, which had been identified by a number of authors (see for example Noori, 1990) as an important predictor of AMT adoption.

When entering the second block, we witness a sharp increase in the explained variance. The technical capabilities of blue-collar workers are related significantly and positively to the level of AMT penetration. This could correspond to Adler and Clark's

"experiential learning-by-doing, or first order learning" (Alder and Clark, 1991, p. 270). In fact it could reasonably be assumed that the smaller manufacturing firm relies mostly on this form of learning. Indeed, skilled blue-collar workers already experienced with the functioning and operation of AMT's are a rare commodity; acquiring and retaining such skilled workers, if this is indeed possible, constitutes a formidable challenge for the smaller manufacturing firms. In most cases, SME's must invest heavily in on-the-job learning whereby blue collar workers acquire skills and capabilities with technology through ongoing exposure and use of the more sophisticated machinery.

Yet this does not always translate into longer term benefits for the smaller firms since a significant percentage of these skilled blue collar workers prefer to leave for better paying jobs and improved working conditions offered by the larger firms.

Insert table 5 here

The effect of white-collar workers is far less significant. Although one might speculate that technical capabilities of white-collar workers would be positively related to AMT adoption, this is not supported by our data. Could white-collar workers be experienced with information technologies without having any link with manufacturing technologies? Could it be that the integration of information and production technologies is not yet a reality in smaller firms?

Introducing block 3 increases the total explained variance to 47.6%. External influences are undoubtedly important determinants of AMT adoption. Consultants and suppliers of technology seem to carry substantial weight when it comes to acquisitions of new technology. These external parties provide the expertise and competencies which smaller firms often lack. Furthermore, market pressures to become more productive may make these outside experts more attractive to smaller firms that are hoping to improve their operations. Although the CEO's influence is predominant, this influence does not appear to vary with the level of technological penetration of the firm. The functional groups' influence is positively but not significantly associated with the level of AMT adoption. This only partially supports previous study results indicating that the influence of the engineering production groups was a major discriminant factor between adopters and non-adopters of AMT's (Lefebvre et al., 1991). It would appear that the first inroads of factory automation require heavy involvement on the part of certain internal groups such as engineering and production, which may act as major proponents. As the firm moves in the direction of acquiring additional AMT's, other factors come into account, namely, the technical capabilities of blue-collar workers and the presence of external networks.

When adding block 4 to the regression equation, the total explained variance increases to more than 53% and substantial reductions in the regression coefficients of the technical capabilities and influences may be observed. This leads us to believe that strategic motivations play a mediating role (Cohen and Cohen, 1983). Outward oriented

strategic motivations are stronger determinants of AMT adoption than internal motivations although both are positively related. Previous studies have shown that while cost considerations prevailed during the first steps into automation, in the later stages firms tended to broaden their expectations to include both operational efficiency and market effectiveness in the form of the quality of customer services and the superior image of the firm (Lefebvre and Lefebvre, 1991).

A number of limitations should be taken into account when interpreting the study results. This research was conducted in a very specific context, that of smaller manufacturing firms. Even so, although firm size was controlled for by limiting the range to more than 50 and fewer than 200 employees, it was shown that size still played a certain role (table 5). This suggests that close attention needs to be paid to this variable, which has been shown to be a proxy for other structural variables, such as complexity and technocratization (Collins *et al.*, 1988). The fact that the CEO acted as respondent may have introduced a bias in some cases, but most authors agree that he or she is the most qualified "interlocuter", especially in smaller firms. The major limitation is probably in the operational definition of the dependent variable. The operational measure of the level of AMT penetration, in this case the cumulative count of AMTs adopted, does not assess the actual degree of integration of technologies. This would have required on-site studies with a smaller number of participating firms.

CONCLUSION

Results of this study generally support the model presented in Figure 1. It does appear that strategic motivations mediate the effect of other organizational assets, namely, technical capabilities and influences, which implies that the relationship between the different variables representing organizational assets is a complex one even in smaller firms. It was also shown that the strongest determinants of the level of AMT adoption are the technical capabilities of the blue-collar workers ($B = .48$, $p < 0.01$), outwardly oriented strategic motivations ($B = .28$, $p < 0.05$), which are highly related to the influence of functional groups (see table 4), and to a lesser extent, the presence of external networks ($B = .20$, p not significant). Thus, capabilities acquired by blue-collar workers with the use of new technologies, a strong preoccupation for the less tangible benefits such as quality of customer services and image of the firm, and external networking with consultants and suppliers of technology constitute essential ingredients of the smaller firm hoping to progressively acquire AMT's.

The implications of these findings cannot be dissociated from some of the harsh realities small firms have to deal with. One such reality is the growing preoccupation with the availability of a skilled workforce. Obviously, this is one of the major competitive factors in today's global economy. Skilled blue-collar workers experienced with computer-based manufacturing technologies are a rare commodity. Yet, as was shown here, they are essential if a firm chooses to invest in the adoption of new

technologies. Short-term considerations are often dominant in smaller firms, which are not as strategically articulate and long-term oriented as their larger counterparts. Thus the presence of qualified personnel and specialized outside expertise appear essential since time is a factor, and a return on the investment must be realized within a reasonable time frame.

While results of this study present interesting insights into the determinants of AMT penetration in smaller manufacturing firms, additional research is required to better understand the interactions between the different elements which comprise organizational assets. Longitudinal studies would constitute a next step that would allow one to uncover some of the intricate relationships that might exist between the type and level of organizational assets and the adoption of AMT's in SME's. This certainly represents a potentially rich line of research which could profit policy-makers, practitioners and academics willing to investigate correlates of technology adoption in SME's as well as the contributing role of these smaller firms in the overall competitive process.

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FIGURE 1

ORGANIZATIONAL ASSETS AND TECHNOLOGY STRATEGY IN SME'S

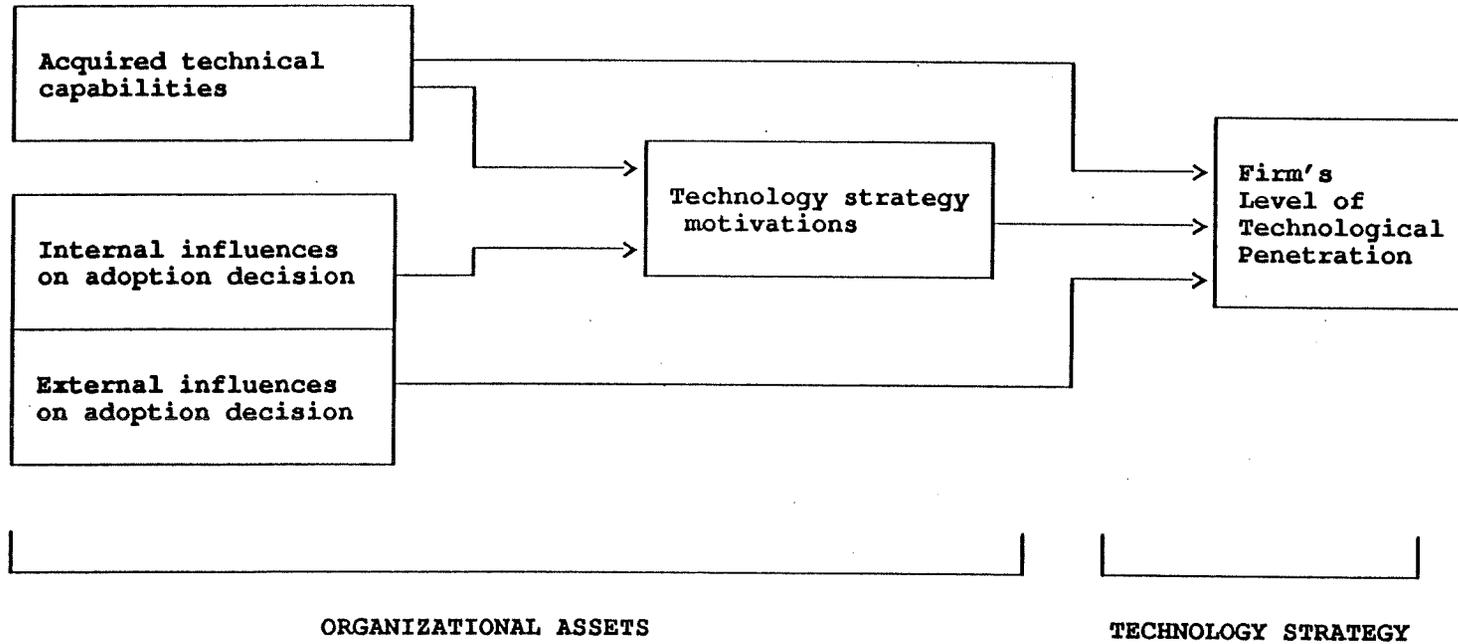


FIGURE 2
RESEARCH DIMENSIONS AND VARIABLES

Dimensions	Variables	Theoretical Justification ¹
ORGANIZATIONAL ASSETS:		
ACQUIRED TECHNICAL CAPABILITIES	Extent of actual use of technology by: clerical employees (factual) secretaries (factual) managers (factual) professionals (factual) blue-collar workers (factual)	Rosenbloom and Burgelman 1989
INTERNAL INFLUENCES ON ADOPTION DECISION	Influence of the chief executive officer (perceived) Influence of engineering and production group (perceived) Influence of marketing group (perceived)	Brown and Karagozogu 1989, Dean 1987, Miller and Toulouse 1986, Skinner 1985 Adler 1989, Ettlle et al. 1984, Bigoness and Perrault 1981, Cohn 1980. Ettlle and Bridges 1987, Robertson and Gatignon 1987
EXTERNAL INFLUENCES ON ADOPTION DECISION	Influence of consultant (perceived) Influence of suppliers of technologies (perceived) Influence of customers (perceived)	Cohn 1980 Weiss and Birnbaum 1989, Robertson and Gatignon 1987, Hall 1987 Weiss and Birnbaum 1989, Ettlle and Bridges 1982
STRATEGIC MOTIVATIONS WITH RESPECT TO TECHNOLOGY		
- cost	Reduction in cost of finished product (perceived)	Farley et al. 1987, Swamidass and Newell 1987, Wheelwright 1985
- productivity	Reduction in labor costs (perceived)	Hayes et Wheelwright 1984
- quality	Increase in overall productivity (perceived) Increase in the quality of product(s) (perceived) Increase in the quality of customer services (perceived)	Goldhar 1986, Kimberly 1986 Farley et al. 1987, Swamidass and Newell 1987, Buffa 1985, Meredith 1987, Wheelwright 1984. Meredith 1987
- flexibility	Superior image of the firm (perceived) Increase in the flexibility of the manufacturing process (perceived)	Geistants and Eschenbach 1990, Meredith 1987. Nemetz and Fry 1988, Swamidass and Newell 1987, Buffa 1985, Wheelwright 1984
TECHNOLOGY STRATEGY		
Level of technological penetration	Number of simultaneous advanced manufacturing technologies adopted by a firm (actual)	Lefebvre et al. 1991.

1. Refers to authors who have identified one or more of the variables as associated with the adoption of one form of innovations

TABLE 1

RESULTS OF VARIMAX ROTATED PRINCIPAL COMPONENTS
ANALYSIS FOR TECHNICAL CAPABILITIES

	Mean percentage (n=116)	Factor 1 (FC1)	Factor 2 (FC2)
Technical capabilities of:			
Clerical employees	70.97	0.78	-0.03
Secretaries	72.39	0.53	0.41
Managers	56.63	0.77	0.30
Professionals	57.78	0.78	0.16
Blue-collar workers	14.03	0.10	0.95
Cumulative percentage of total variance explained		48.8%	66.0%

TABLE 2
RESULTS OF VARIMAX ROTATED PRINCIPAL COMPONENTS
ANALYSIS¹ FOR INFLUENCES

	Mean (n=116)	Factor 1 (FI1)	Factor 2 (FI2)	Factor 3 (FI3)
Internal influences on AMT adoption decision				
Influence of chief executive officer	4.32	-0.03	-0.01	0.98
Influence of engineering and production group	3.47	0.18	0.80	0.10
Influence of marketing group	2.24	0.00	0.88	-0.20
External influences on AMT adoption decision				
Influence of consultants	2.64	0.88	0.04	0.02
Influence of suppliers of technologies	2.43	0.86	0.20	-0.08
Influence of customers	2.46	0.45	0.54	0.22
Cumulative percentage of total variance explained		39.0%	58.5%	76.1%

¹ All variables are measured on a 5 point likert scale (1 = very low influence, 5 = very high influence).

TABLE 3
RESULTS OF VARIMAX ROTATED PRINCIPAL
COMPONENTS ANALYSIS¹ FOR STRATEGIC MOTIVATIONS

	Mean (n=116)	Factor 1 (FC1)	Factor 2 (FC2)
Strategic motivations			
Reduction in cost of finished product(s)	3.63	0.77	0.23
Reduction in labor costs	3.86	0.78	-0.08
Increase in overall productivity	4.36	0.64	0.42
Increase in the quality of product(s)	3.85	0.65	0.43
Increase in the quality of customer services	4.15	0.41	0.69
Superior image of the firm	3.58	-0.01	0.88
Increase in the flexibility of the manufacturing process	3.71	0.79	0.19
Cumulative percentage of total variance explained		49.8%	65.1%

¹ All variables are measured on a 5 point likert scale (1 = very low influence, 5 = very high influence).

TABLE 4

MULTIPLE REGRESSION ANALYSIS¹ PREDICTING
TECHNOLOGY STRATEGY MOTIVATIONS

	FSI inward oriented strategic motivations Beta coefficients	FS2 outward oriented strategic motivations Beta coefficients
Block 1: Control variables		
Ln of annual sales	0.26*	0.04*
Block 2: Technical capabilities		
FC1: White-collar employees	0.09	0.07
FC2: Blue-collar workers	0.18	0.09
Block 3: Influences		
FI1: External networks	0.06	0.10
FI2: Functional groups	0.27*	0.42***
FI3: CEO	0.00	0.02
R ²	26.6%	23.6%

* p < 0.10
 ** p < 0.05
 *** p < 0.01
 **** p < 0.001

¹ Basic assumptions for conducting regression analysis are met: because of large sample size, the assumption of multivariate normality is not rejected; the Pearson correlation matrix presented in table 6 (Appendix 1) indicates that the independent variables are not highly correlated; finally, analysis of residues indicated no violation of basic assumptions.

TABLE 5
HIERARCHICAL MULTIPLE REGRESSION ANALYSIS¹

Betas coefficients				
	Block 1	Block 2	Block 3	Block 4
Block 1: Control variables				
Ln of annual sales	0.17**	0.15*	0.19	0.19
Block 2: Technical capabilities				
FC1: White-collar employees		0.08	-0.03	-0.06
FC2: Blue-collar workers		0.52****	0.52****	0.48***
Block 3: Influences				
FI1: External networks			0.23*	0.20
FI2: Functional groups			0.15	0.02
FI3: CEO			0.01	0.02
Block 4: Strategic motivations				
FS1: Outward oriented				0.28**
FS2: Inward oriented				0.05
R ²	2.9%	32.7%	47.6%	53.3%
ΔR ²	2.9%	29.8%	14.9%	5.7%

* p < 0.10
 ** p < 0.05
 *** p < 0.01
 **** p < 0.001

¹ Basic assumptions for conducting regression analysis are met: because of large sample size, the assumption of multivariate normality is not rejected; the Pearson correlation matrix presented in table 6 (Appendix 1) indicates that the independent variables are not highly correlated; finally, analysis of residues indicated no violation of basic assumptions.

APPENDIX 1

TABLE 6

MATRIX OF PEARSON CORRELATION
COEFFICIENTS FOR ALL INDEPENDENT VARIABLES

	1	2	3	4	5	6	7	8
Block 1: Control variables								
1. Ln of annual sales	1.0000							
Block 2: Technical capabilities								
2. FC1: White-collar employees	0.2571**	1.0000						
3. FC2: Blue collar-workers	0.1357	0.0000	1.000					
Block 3: Influences								
4. FI1: External networks	-0.1133	0.1292	0.2450	1.000				
5. FI2: Functional groups	0.3313**	0.3620**	0.1156	0.0000	1.0000			
6. FI3: CEO	0.0713	-0.0058	0.0416	0.0000	0.0000	1.0000		
Block 4: Strategic motivations								
7. FS1: Inward oriented	0.2610**	-0.0886	0.2029	0.2029	0.3142**	0.4592***	1.000	
8. FS2: Outward oriented	-0.0588	0.0527	0.1352	0.1616	0.1838	0.3079	0.0000	1.0000

Correlation coefficients between factors derived from each factorial analysis are, of course, equal to zero, since factors are orthogonal.

* p < 0.10
 ** p < 0.05
 *** p < 0.01
 **** p < 0.001

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