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THE INFLUENCE PRISM IN SMEs: THE POWER OS CEOs' PERCEPTIONS ON TECHNOLOGY POLICY AND ITS ORGANIZATIONAL IMPACTS

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The Influence Prism in SMEs: The Power of CEOs' Perceptions on Technology Policy and Its Organizational Impacts

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Abstract / Résumé

This study examines a group of SMEs operating in the same industrial sector but with policies, strategies, and practices that differ significantly. An integrated framework is presented whose predictor variables comprise the Strategic Orientations of Business Enterprise (STROBE), structural characteristics and process, while the dependent variable relates to technology policy, the moderator variables to perceptions of the external environment, the predicted variables to realized innovative efforts (RIE), and the outcome variables to organizational performance. Analyses of data from 84 SMEs demonstrate substantial support for the framework and reveal the strong moderating influence of perceived environment on the relationship between predictor variables and technology policy and technology policy and RIE. The findings show a weak relationship between RIE and financial performance but a stronger relationship between RIE and export performance.

The results illustrate quite convincingly that perceived environment is a crucial aspect in determining technology policy and subsequent RIE, both of which represent important dimensions in the strategic management of technology. This paper therefore stresses the need for better knowledge of how managers and executives form their perceptions of the environment. This knowledge can be crucial to understanding how strategic management of technology is enacted in SMEs.

Cette étude examine la relation entre la politique technologique et l'orientation stratégique de l'entreprise en tenant compte de l'effet modérateur de la perception de l'environnement sur la performance ultime de l'entreprise. L'étude fut réalisée dans un échantillon contrôlé de 84 petites et moyennes entreprises.

Les résultats suggèrent que la perception des dirigeants d'entreprises de l'environnement dans lequel ils opèrent est une dimension essentielle de la stratégie technologique poursuivie par une firme.

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1. INTRODUCTION

Technology is considered one of the most powerful factors shaping the rules of competition (Tassey, 1992; Thurow, 1992). As a result, the strategic management of technology is a crucial concern for an increasing number of firms and also generates considerable academic interest (NRC, 1991). This paper investigates one central theme in the area of strategic management of technology, focusing on the determinants and outcomes of technology policy at the firm level (Ettlie and Bridges, 1987). More specifically, the study presented here is conducted in the context of small manufacturing enterprises (SMEs), where the CEO is known to play a crucial role (Harrison, 1992) and as a result where his/her perceptions of the external environment are likely to influence corporate directions and actions. In fact, it is argued that the CEOs' personal biases produce a prism effect through which data from the environment are interpreted differently, leading to a more or less aggressive technology policy and differing innovative actions, all of which affect organizational performance.

The basic thrust of this article is to demonstrate the power of environmental perceptions in moulding a firm's technological policy and to present evidence of its related impacts. Little empirical evidence exists with regard to the formulation or effects of technology policy in small firms (Zahra and Covin, 1993). This study attempts to fill this gap by addressing the following objectives within the specific context of SMEs:

(i) To determine the relative importance of different determinants of technology policy;

(ii) To assess the extent to which the relative importance of these determinants varies with the CEOs' perceptions of the external environment;

(iii) To evaluate the organizational impacts of technology policy in terms of realized innovative efforts for different perceived sub-environments;

(iv) To investigate the relationship between realized innovative efforts and firm performance.

2. RESEARCH FRAMEWORK

The proposed research framework builds on three key, and complementary premises. The first recognizes the importance of the external environment to the strategic management of technology. The second suggests that strategic coalignment with the external environment is essential. The third argues that perceptions of external environments vary because of the prism effect created by CEOs personal biases and that these perceptions override factual characteristics of the environment.

Firms operate in turbulent environments which can radically alter the bases of competition (Virany et al., 1992) and as a result need to make strategic choices that are adapted to their external environments (Harrison, 1992). As suggested by Pettigrew and Whipp (1991: 105), "the process of competition often begins from the understanding a firm develops of its environment". This is in line with the growing body of literature suggesting that organizations should become what Quinn (1992) has called "intelligent enterprises". In particular, in an open systems perspective, firms are continuously required to adapt to rapid technological changes.

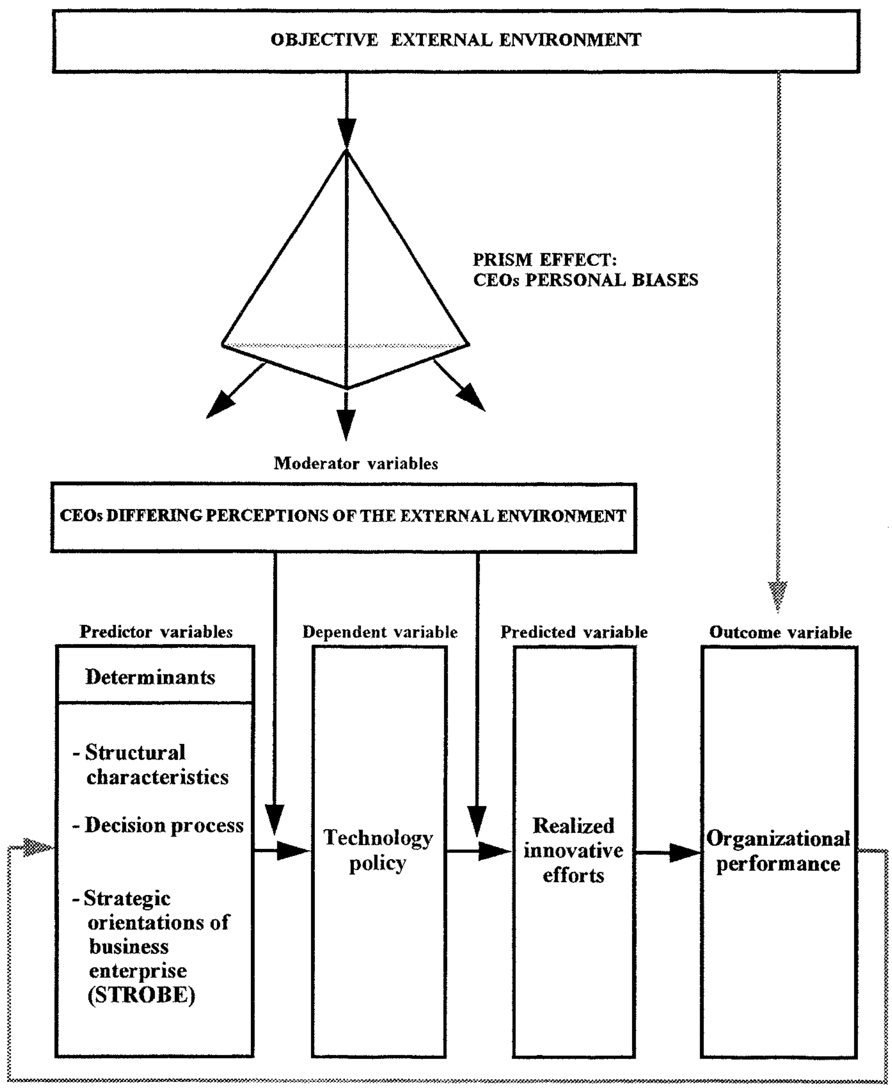
Considerable emphasis has been placed on contingency theories in a wide range of organizational studies. For contingency theorists, the notion of "fit", also called "coalignment" or "match", is an important concept, although it raises both conceptual and methodological difficulties (Venkatraman, 1989). In the literature on strategy, the required coalignment between strategy and its context has traditionally received a vast amount of attention from researchers (Ginsberg and Venkatraman, 1985). The appropriate match between organizational strategies and the external environment ("external fit") has been shown to have a positive impact on performance (Venkatraman and Prescott, 1990; Prescott, 1986). "Internal fit" can be viewed in terms of coalignment between strategy and organizational structure leading to increased performance (Rulmet, 1974; Chandler, 1962) or in terms of coalignment between technology and structure which also leads to increased effectiveness (Fry, 1982) and greater performance (Hoffman et al., 1992; Alexander and Randolf, 1985; Woodward, 1965). Achieving both external and internal fit may prove extremely difficult and Miller concludes that firms generally achieve either one or the other, although exceptionally they may attain both since, as the author reports, "internal and external fit are not always incompatible" (Miller, 1992: 159). Because of the inherent characteristics of SMEs such as their organic nature and the limited number of strategic decisions makers, internal fit might be easier to achieve than external fit. Further, in dealing with technology policy, external fit is extremely important since a firm's technology policy cannot be dissociated from the technological sophistication which characterizes a given industrial sector. As a result, this study focusses on external fit.

From the social constructionist perspective (Gergen, 1985), environmental pressures are socially determined (Mason, 1991). In Weick's view of the process of sense-making by an organization (Weick, 1979), action, knowledge, cognition, and communication are inseparable. In SMEs, the CEO is the "principal architect of corporate strategy" (Harrison, 1992) and his/her perceptions of the environment, no matter how biased they may appear, are predominant in determining the strategic direction of the firm. With respect to technology policy, the prism effect resulting from CEOs biases cannot be ignored as technological choices and investments are greatly influenced by managerial attitudes (Ginsberg and Venkatraman, 1992) and personal characteristics and personality traits (Lefebvre and Lefebvre, 1992).

Building on these three premises, the proposed research framework presented in Figure 1 focuses on external fit, namely the moderating effect of CEOs' differing perceptions of the external environment on technology policy and realized innovative efforts. The framework is extended to the overall impact on organizational performance.

Figure 1

RESEARCH FRAMEWORK



2.1 Technology policy (the dependent variable)

Technology policy is therefore defined as "the long-range strategy of the organization concerning the adoption of new process and material innovations and the orientation of new product or service innovations" (Ettlie and Bridges, 1987: 118).

Technology policy thus refers to the degree to which a firm aggressively pursues technological changes in terms of process innovation (i.e. up-to-date production technologies and equipment), product innovation, technological forecasting activities and recruitment of qualified human resources (Ettlie and Bridges, 1987). Administrative innovations are not included, yet it is becoming increasingly apparent that these forms of innovation are intricately intertwined with the new process innovations, which may be computer-based administrative or production applications.

2.2 Determinants of technology policy (the predictor variables)

As shown in figure 1, determinants of technology policy comprise structural characteristics of the firm, process, and strategic orientation (STROBE). Each of these is discussed in the following paragraphs.

Structural characteristics

The actual organizational structure provides the appropriate context for strategic choices (Burgelman, 1986) and for an aggressive technology policy (Ettlie and Bridges, 1987), although structure can also be viewed as being the result of strategic choices (Chandler, 1962). In particular, a concentration of technical and scientific knowledge, also termed technocratization, has been shown to be a crucial determinant of innovativeness (Collins et al., 1988) and a significant predictor of organizational technology policy (Ettlie and Bridges, 1987). On the other hand, a greater degree of centralization and formalization appears to hamper innovativeness (Cohn and Turyn, 1984; Hage and Aiken, 1970).

Process

Firms operate in unsettled environments which can radically alter the bases of competition (Virany et al., 1992). Therefore, strategic awareness of the competitive actions undertaken by direct competitors as well as the prevailing market conditions appears to be a crucial organizational process. This process promotes activities in the firm aimed at defining clients' opinions, conducting market studies, following competitors' strategies and predicting sales behavior and customer needs. The systematic use of scanning mechanisms aimed at identifying opportunities and threats from competitors or from emergent technologies is crucial (Weiss and Birnbaum, 1989) and must be viewed as a powerful determinant of technology policy.

Strategic orientations of business enterprise (STROBE)

Strategic orientation of the business enterprise or STROBE (Venkatraman, 1989) reflects the actual strategies pursued by a firm with respect to its competitors and involves a host of organizational activities, whether they be product related, price related, process related, or financially related. This measure characterizes a firm along six dimensions which correspond to traditional strategic orientations: aggressiveness, analysis, defensiveness, futurity, proactiveness and riskiness. The *aggressiveness* dimension reflects a firm's market share seeking behavior, and *analysis* captures the presence of formal planning and evaluation activities with respect to strategic alternatives. *Defensiveness* relates to the emphasis a firm places on performance monitoring and enhancement of core manufacturing competencies. The *futurity* dimension denotes the presence of a long-term view, supported by ongoing evaluation of significant trends, and of activities such as R&D which are designed to provide longer-term benefits for the firm. *Proactiveness* emphasizes opportunity seeking behavior, "first-to-market" innovativeness, and strategic acquisitions that support the preceding elements. Finally, the *riskiness* dimension relates to risk management in terms of resource allocation decisions, operations and choice of projects.

Given that policy can be defined as "the operationalized substance of strategy" (Adler, 1989: 54), specific corporate strategic orientations (Venkatraman, 1989) can determine a firm's technology policy. In this respect, higher values along each STROBE dimension should promote an aggressive technology policy. Further, the need for a stronger strategy technology connection has been suggested by a number of authors (Adam and Swamidass, 1989; Kotha and Orne, 1989) and explored empirically within the specific context of SMEs (Lefebvre et al., 1992).

This discussion on the determinants of technology policy leads to the following hypotheses:

H1a Structural characteristics are determinants of technology policy. In particular, technocratization is positively related to the degree of aggressiveness of technology policy in SMEs whereas centralization and formalization are negatively related to it.

H1b The systematic use of scanning mechanisms is positively related to the degree of aggressiveness of technology policy in SMEs.

H1c All dimensions of STROBE (aggressiveness, analysis, defensiveness, futurity, proactiveness, riskiness) are positively related to the degree of aggressiveness of technology policy in SMEs.

2.3 Perceived characteristics of the external environment (moderator variables)

As discussed by Venkatraman (1989), fit may be defined as moderation. That is, the relationship between a predictor variable and a dependent variable may vary with the level of a moderator variable. In the case of SMEs, the perception the CEO has of his/her environment may ultimately affect the relationship between the predictor variables and the technology policy (dependent variable). Environmental perceptions reflect two dimensions previously identified by Miller (1987) and more recently by Gupta and Chin (1993): hostility and dynamism. Environmental hostility captures the perceived threats to the very survival of the firm, namely increasingly tough competition on product prices, depleting markets, scarcity of qualified and specialized labor, difficulty of access to raw materials, components or parts from suppliers and government intervention. Obviously, these threats exist for all manufacturing firms but they may be more acute for SMEs since they do not have the financial leverage of larger firms. Hence, perceived hostility is considered as a key characteristic of the external environment in an SME context. As equally important, environmental dynamism, also called uncertainty (Khandwalla, 1977; Miller and Toulouse, 1986) reflects the perceived degree of unpredictability and rate of change of the external environment. In spite of their inherent inaccuracies (Tosi et al., 1973), these perceptions largely influence the direction and strength of the relationship between the determinants of technology policy and technology policy itself.

For this reason, we have formulated the following hypotheses:

H2a *The impact of the determinants of technology policy on the actual technology policy varies according to the CEOs' perceptions of environmental hostility in SMEs.*

H2b *The impact of the determinants of technology policy on the actual technology policy varies according to the CEOs' perceptions of environmental dynamism in SMEs.*

2.4 Realized innovative efforts (the predicted variables)

Realized innovative efforts in SMEs are usually of three types. The first is associated with traditional R&D investments which are mainly aimed at improving or modifying existing products, and, more rarely, developing new ones. The second concentrates on improving existing practices through the adoption of computer-based information and manufacturing technologies (Lefebvre and Lefebvre, 1993). Finally, the third represents the extent of external technological experience and know-how with respect to new technological developments, the commercial availability of new technologies and the comparative advantages which may be derived from the new technologies (Weiss and Birnbaum, 1989).

An aggressive technology policy should promote organizational innovativeness and success (Maidique and Patch, 1978). Empirical evidence provided by Ettlie and Bridges (1982) suggests that firms that have an aggressive and forward-looking technology policy are also more likely to innovate. Yet, all three types of realized innovative efforts require substantial financial and non-financial investments, which may be delayed or accelerated depending on the CEOs' perceptions of the external environment.

In dynamic environments, strategies of innovation seem more appropriate (Hambrick, 1983; Miller, 1988). The more hostile or dynamic the environment, the higher the need for innovation and, therefore, the higher the level of innovation. However, this argument is only partially supported, as empirical evidence with respect to product innovation has produced some conflicting results. Miller and Friesen (1982), for example, found a weak link between product innovation and environmental characteristics (in particular, dynamism and hostility) in the case of entrepreneurial firms, whereas Khan and Manopichetwattana (1989) observe a negative relationship between product innovation and environmental hostility. In this study, it is assumed that the relationship between a firm's technology policy and its realized innovative efforts may vary across different perceived sub-environments.

Hence, the following hypotheses will be tested:

H3a *An aggressive technology policy leads to greater realized innovative efforts in SMEs.*

H3b *The relationship between technology policy and realized innovative efforts varies depending on CEOs' perceptions of environmental hostility in SMEs.*

H3c *The relationship between technology policy and realized innovative efforts varies depending on CEOs' perceptions of environmental dynamism in SMEs.*

2.5 Organizational performance (the outcome variables)

We have seen that a firm's realized innovative efforts can be the result of multiple relationships between determinants of technology policy, the technology policy itself, and the

CEO's environmental perceptions. Obviously, this line of questioning is of interest if we can ultimately show that realized innovative efforts can enhance a firm's performance. This will be the subject of the last two hypotheses.

All three types of innovative efforts should contribute to a firm's performance. R&D activities have been associated with different types of firm performance such as profitability (Morbey and Reithner, 1990), productivity growth (Chakrabarti, 1990), and sales growth (Franko, 1989). As for computer-based process innovations, there is general agreement that the adoption of new technologies does improve a firm's competitiveness (Thurow, 1992) and is associated with competitive advantages derived from higher quality products, lower production costs or increased diversity. Ultimately, this could translate into improved firm performance. Finally, the level of external technological experience is of the utmost importance (Lefebvre et al., 1991) and gives firms a leading edge in terms of new market opportunities and new manufacturing or administrative processes. Again, this should have a positive impact on firm performance.

For SMEs, two types of performance are of critical importance. The first is financial performance, given the lack of financial resources in these firms. The second is export performance: with the opening up of new markets, SMEs are subjected to increased competition from new rivals and therefore must themselves broaden their reach by developing new markets (Baldwin et al., 1994).

Thus:

H4a Realized innovative efforts are positively associated with financial performance in SMEs.

H4b Realized innovative efforts are positively associated with export performance in SMEs.

3. METHODOLOGY

3.1 Population and data collection

To ensure a tight research design, and given the emphasis we place on differing environmental perceptions, efforts were made to target a population that was as homogeneous as possible. The following criteria were retained: all firms were independent, active in the same industrial sector (metal) and located in the same geographical region (province of Quebec); all belonged to the same size group (fewer than 200 employees). Furthermore, all had adopted at least one advanced manufacturing technology, which automatically excluded smaller artisanal firms and low level "job shops". From the list published by the Canadian Association of Manufacturers, 151 firms met all of the above criteria.

The CEOs of all these firms were contacted by phone: 86 CEOs agreed to schedule an interview. The principal reason CEOs of non-participating firms gave for not taking part in the study was lack of time. Two CEOs could not be reached in person during the four-month data collection period. Semi-structured interviews were conducted with the CEO's on the company sites and lasted between two and three hours. The principal investigators and two graduate students conducted the interviews using identical protocols. In the case of two firms, the CEO was not available at the time of the scheduled interview and close associates participated in the study: these two firms were discarded. The actual respondents in this study are therefore 84 CEOs, for a final response rate of 56%.

Analysis of non-respondents (goodness of fit tests) indicated that they did not differ from respondents with respect to firm size. However, the response rate was slightly higher outside the greater metropolitan area of Montreal (response rate = 62%).

3.2 Research variables

The variables are presented in Figure 2 along with their theoretical justification, Cronbach alpha coefficients when applicable, and descriptive statistics. All of the perceptual variables retained in this study were measured using previously tested multi-scale constructs. As operational measures for some variables were developed for larger firms, the Cronbach alpha coefficients from previous studies are shown, when available. The reliability of these constructs seems to hold up for the small firms involved in this study. The Cronbach alpha coefficients are within the guidelines set by Van de Ven and Ferry (1980), ranging from 0.50 to 0.85.

The structured interview guide is presented in Appendix 1. The measure of the degree of process innovativeness is a composite measure of the level of process innovativeness using data on computer-based administrative applications and computer-based manufacturing applications (see Appendix 2). This measure, inspired by the well-known Khandwalla Score (1977) is defined by using both the number of applications adopted by a firm and the weight attributed to each by a panel of experts who ranked each application on 7-point Likert scales according to its degree of radicalness (Lefebvre & Lefebvre, 1992; Dewar and Dutton, 1986). No distinction is made here between computer-based administrative and manufacturing applications since they are becoming more and more integrated in the manufacturing sector and are increasingly difficult to dissociate (Taylor et al., 1986; Goldhar and Jelinek, 1985).

One last comment pertains to the measure of performance. Financial performance is assessed using perceptual measures which have been used extensively by others (Robinson and Pearce, 1988; Woolridge and Floyd, 1990) and have been shown to correlate highly with objective measures such as ROA (return on assets). Subjective measures were also used because CEOs of small firms are often reluctant to provide hard financial data (Sapienza et al., 1988). For export performance, factual measures were used since these measures were not considered as sensitive information by the CEOs surveyed.

Figure 2
Research variables, operational measures and descriptive statistics

Variables	Operational measures	Construct reliability in previous studies	In this study		
			Construct reliability	Mean	S.D.
DEPENDENT VARIABLE		(Ettlie and Bridges 1987)[1]			
Technology Policy:[3]	nine items	0.79	0.85	4.02	1.39
PREDICTOR VARIABLES					
• **Structural characteristics:**					
Technocratization[3]	% of scientists, engineers, programmers and technicians	(Collins et al., 1988) N/A	N/A	5.97%	11.74%
Formalization[3]	three items	(Lefebvre & Lefebvre,1992) 0.89	0.51	4.05	1.53
Centralization[3]	six items	(Miller & Friesen, 1982) 0.79	0.70	6.56	0.46
• **Process:**					
Scanning mechanisms	four items	(Miller & Friesen, 1982) 0.74	0.72	3.91	1.36
• **Strategic orientation (STROBE):**		(Venkatraman, 1989)[2]			
Aggressiveness[3]	four items	0.68	0.71	2.79	1.27
Analysis[3]	six items	0.67	0.67	5.56	0.85
Defensiveness[3]	four items	0.53	0.71	5.50	1.09
Futurity[3]	five items	0.61	0.68	4.68	1.43
Proactiveness[3]	five items	0.64	0.51	3.30	1.63
Riskiness[3]	five items	0.53	0.52	3.40	1.27
MODERATOR VARIABLES					
• **Perceived environmental uncertainty:**		(Miller & Friesen, 1982)			
Hostility[3]	six items	0.55	0.50	3.96	1.43
Dynamism[3]	five items	0.74	0.58	3.06	1.24
PREDICTED VARIABLES					
• **R & D**	investments in R&D as a % of annual sales	N/A	N/A	1.83%	3.79%
• **Degree of process innovativeness:**					
Computer-based administrative technologies	see appendix 1 (composite measures)	N/A	N/A	56.02	36.43
Computer-based manufacturing technologies			N/A	53.40	39.60
• **External technological experience**[3]	three items	N/A derived from Weiss & Birnbaum (1989)	0.68	5.28	1.29
OUTCOME VARIABLES					
• **Financial performance**[3]	three items	(Collins et al. 1988)	0.73	4.59	0.89
• **Commercial performance**	level of export sales	N/A	N/A	17.17%	28.01%

(1) The 9 item construct is adapted from Ettlie et al. (1984) 7 item construct in which one the item was split into 2 separate items, and an additional item added from Ettlie (1983).
(2) Venkatraman used a composite measure of reliability developed by Werts, Linn and Joresborg, 1974; all other authors used the typical Cronbach α coefficient.
(3) Measured on 7 point Likert scales; the remaining variables are based on factual measures.

3.3 Data analysis

The data were analyzed in six consecutive steps. First, the relative contribution of organizational characteristics, process and strategic orientations (STROBE) to the explanation of the technology policy (dependent variable) was investigated by performing a hierarchical regression analysis (table 1). Second, in order to evaluate the interaction effects between the predictor variable and the environmental variables (hostility and dynamism), moderated regression analysis (Cohen and Cohen, 1983) was conducted (table 2). This corresponds to fit as moderation as described by Venkatraman (1989). Third, intercorrelations between the moderator variables and the dependent and predictor variables were performed in order to establish whether the moderator variables could be described as pure or quasi-moderators (Prescott, 1986). Fourth, subgroup analysis (Arnold, 1982; Sharma et al., 1981), where pairs of subgroups were formed using the median to reflect low and high scores on each of the moderator variables was carried out; this further confirmed the role of environmental variables as moderators (table 4). Fifth, the predictive or homological validity (Venkatraman and Grant, 1986) of the technology policy with respect to realized multiple innovative efforts was then verified (table 5). Finally, in order to address a recurrent question, the relationship between realized innovative efforts and performance was examined (table 6).

4. RESULTS AND DISCUSSION

4.1 Structural characteristics, process and STROBE as predictors of technology policy

The first three hypotheses (H1a, H1b, H1c) are tested using hierarchical regression analysis. In order to uncover problems of multicollinearity between the independent variables, the Pearson correlation matrix is presented in appendix 3. Since the strongest correlation coefficient occurs between defensiveness and analysis ($r = 0.49$), minimal redundancy exists between all independent variables. Results of the hierarchical regression analysis, in which the three blocks of variables (structural characteristics, process and strategic orientation) are entered one by one, are presented in table 1. It can be observed from model 1 that the variance explained by the effect of structural characteristics on technology policy accounts for slightly more than 6%. When entering the second block (process), we witness a significant change in the explained variance ($\Delta R^2 = 6.39\%$). Therefore, scanning mechanisms account for as much explained variance as do the structural characteristics. A significant and sharp increase in the variance is denoted as a result of the inclusion of the STROBE variables (model 3). In fact, explained variance in technology policy jumps to 48.93%, an increase of more than 36%. It therefore seems that organizational structure and scanning mechanisms have far less explanatory power than strategic orientation. The rather informal and ill-defined organizational structure found in SMEs as well as the apparent lack of formal scanning mechanisms largely explain this result.

The values of standardized betas in model 3 reveal interesting results. First, centralization, technocratization and formalization are all related positively and significantly to technology policy. With regard to *technocratization*, it comes as no surprise that the relative proportion of technically oriented personnel in a firm is related to a greater emphasis on technology policy, which is a natural extension of the degree of concern with technical issues in the firm. One surprising finding which contradicts the results of previous empirical studies on innovation (Cohn and Turyn, 1984) is the positive relationship between *formalization* and technology policy. This could be explained by the fact that the firms in this sample were all actively engaged in the new manufacturing technologies and were all "producers" of hard goods. These smaller firms require some structured procedures and guidelines in order to get things done and take advantage of the full benefits the new technologies provide; in any case, formalization does not equate to "bureaucratization", as our on-site observations enabled us to note. The unexpected positive impact of *centralization* could be explained by the fact that limiting the number of people in the policy making decisions may facilitate and accelerate the decision-making process. Second, as we turn to the contribution of the STROBE dimensions, proactiveness, futurity, aggressiveness and defensiveness are strong predictors of a more progressive technology policy. This again appears quite reasonable since the first three strategic orientations reveal an innovative and opportunistic market seeking behavior oriented towards the long term while the fourth, agressiveness, reflects a strong preoccupation with performance monitoring and enhancement of core manufacturing competencies. Finally, the negative beta coefficient for *analysis* is more intriguing. Although not significant, it raises the possibility that decision-making behavior in SMEs differs from that observed in larger organizations since it may rely more on intuition than on formal analysis.

In summary, strong support is found for hypothesis H1c and moderate support for H1b. Hypothesis H1a is only partially verified as all structural characteristics provide some explanatory power and the observed direction of the relationship for centralization and formalization is contrary to the one hypothesized.

Table 1
Results of hierarchical regression analysis:
technology policy as a function of structural characteristics, process and strategic orientation (n = 84)

INDEPENDENT VARIABLES	MODEL 1 $\beta^{(1)}$	MODEL 2 $\beta^{(1)}$	MODEL 3 $\beta^{(1)}$
Structural characteristics			
Formalization	0.23 ***	0.19 ***	0.17 **
Technocratization	0.08	0.11 *	0.09 *
Centralization	0.07	0.09 *	0.09 *
Process			
Scanning mechanisms		0.26 ***	0.04
Strategic orientations			
Aggressiveness			0.21 ***
Analysis			-0.08
Defensiveness			0.31 ***
Futurity			0.33 ***
Proactiveness			0.39 ****
Riskiness			0.01
R^2	6.24%(2) **	12.63%(2) ***	48.93%(2) ****
ΔR^2		6.39%(3) **	36.30%(3) ***

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

(1) Standardized betas reported
(2) Adjusted R^2
(3) Change in R^2 after each step of the hierarchical regression. F test is performed using the following formula:

$$F = \frac{\Delta R^2 / M}{(1 - R^2) / (n - k - 1)}$$

where M is the number of independent variables added from model 1 to model 2, n is number of respondents and k is the number variables in model 2. This is repeated for each subsequent models.

4.2 Environmental characteristics as moderators

Table 2 investigates the potential contribution of a third set of variables which were identified in figure 1 as moderator variables. Adding the environmental variables accounts for an increase of 2%. Our next step is therefore to investigate the interaction effects between environment and structural characteristics, process and strategic orientation. The interaction between environmental hostility and the main effects and interaction effects (model 5) accounts for a significant increase of more than 18% whereas environmental dynamism (model 6) provides a far less important and non significant increase of 8%. This strongly indicates that perceived environmental hostility is an important moderator for predicting technology policy in SME's. Model 7, which incorporates both hostility and dynamism, shows a cumulative R^2 of more than 73%.

Table 2
Results of moderated regression analysis:
Main effects and interaction terms
(n = 84)

	CUMULATIVE $R^{2(1)}$	$\Delta R^{2(2)}$
INDEPENDENT VARIABLES(3)		
Model 4: Main effects (Structural characteristics, decision process, strategic orientation and perceived environmental hostility and dynamism)	51.11% ****	2.18 % (model 4 vs model 3)
Model 5: Main effects and interaction effects with perceived environmental hostility	69.56 ***	18.45% *** (model 5 vs model 4)
Model 6: Main effects and interaction effects with perceived environmental dynamism	59.07 ***	7.96% (model 6 vs model 4)
Model 7: Main effects and interaction effects with both perceived environmental hostility and dynamism	73.25% **	22.14% ** (model 7 vs model 4)

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

(1) Adjusted R^2
(2) ΔR^2 = change in R^2; the F test is performed similarly as in table 1
(3) Although multicollinearity problems arise from the introduction of cross-product terms (interaction effects) for models 5, 6 and 7, moderated regression analysis is a valid tool when variables measured by Likert scales are used (Venkatraman, 1989). Further, stepwise regressions are also performed in order to reduce the number of terms in the regressions for models 5, 6 and 7.

Going a step further, table 3 shows how the environmental variables are related to structural characteristics, process, STROBE, and technology policy. Perceived environmental dynamism is significantly related to technology policy indicating that dynamism can be considered as a quasi-moderator, whereas perceived environmental hostility has a positive but not significant relationship with technology policy and hence can be termed as a pure moderator (Prescott, 1986). When examining the relationships between moderator and predictor variables, it is found that less than half of the correlation coefficients are significant. As a result, environmental perceptions cannot clearly be considered as an exogenous or predictor variable.

Table 3
Correlations between the moderator variables and predictor variables
(n = 84)

	HOSTILITY	DYNAMISM
DEPENDENT VARIABLES		
Technology Policy:	0.09	0.41 ****
PREDICTOR VARIABLES		
. Structural characteristics:		
Technocratization	0.00	0.23 **
Formalization	0.24 **	0.28 ***
Centralization	-0.05	-0.06
. Process:		
Scanning mechanisms	0.08	0.19 **
Strategic orientation (STROBE)		
Aggressiveness	0.18 **	0.00
Analysis	0.22 **	0.10
Defensiveness	0.12	0.15
Futurity	0.06	0.28 ***
Proactiveness	-0.06	0.25 **
Riskiness	0.13	-0.26 ***

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

In order to analyse in greater depth the moderating effects of the two environmental variables, the sample is divided according to perceived low versus high hostility and perceived low versus high dynamism. The median value is used to split the sample. The regression analysis is then repeated in each of the four subgroups or sub-environments (table 4). The results reveal a few important points. First, the technology policy is best explained by the predictor variables (structure and STROBE) in highly hostile environments and least explained in low dynamism environments. Second, proactiveness emerges as a significant predictor across all sub-environments. Third, all predictor variables relate significantly and positively to technology policy except for riskiness in the highly hostile sub-environment. This sheds some light on the non-significant standardized beta reported in table 1 for riskiness. CEOs of manufacturing SMEs do not invest in high-risk innovative projects when they perceive their environment as highly hostile. During the course of the interviews, CEOs were very concerned with the survival of their firm and as such reacted quite strongly to the threats brought upon by the competitors especially as it relates to price and scarcity of qualified manpower.

Finally, no consistent pattern seems to stand out across the first two sub-environments (low and high hostility): the Chow test (Chow, 1960), performed to uncover statistical differences in the size of the regression coefficients, confirms this finding ($F = 3.99$, $p < 0.01$). However, the Chow test is not significant for the last two sub-environments, namely low and high dynamism ($F = 1.34$, $p > 0.10$). These results strongly suggest that technology policy is particularly sensitive to perceived hostility in the environment. From the above discussion, H2a and H2b are verified: perceived environmental hostility can be considered a pure moderator whereas perceived dynamism acts as quasi-moderator.

Table 4
Results of regression analysis:
technology policy as a function of structural characteristics and process and strategic orientation accross sub-environments

INDEPENDENT VARIABLES	LOW HOSTILITY	HIGH HOSTILITY	LOW DYNAMISM	HIGH DYNAMISM
Structural characteristics				
V1 Formalization		0.27 ***	0.28 **	
V2 Technocratization		0.38 ***		
V3 Centralization	0.20 *	0.27 ***		0.29**
Process				
V4 Scanning mechanisms				
Strategic orientations				
V5 Aggressiveness		0.28 ***		
V6 Analysis				
V7 Defensiveness		0.36 ***		0.47 ***
V8 Futurity	0.62 ****		0.36 **	
V9 Proactiveness	0.29 ***	0.71 ****	0.39 ***	0.34 ***
V10 Riskiness	0.36 ***	-0.17 *		
R^2	60.09% ****	79.54% ****	43.71% ***	62.17 ****

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

4.3 Technology policy and realized innovative efforts

Table 5 reveals positive and significant relationships between all three types of realized innovative efforts and technology policy, thus supporting H3a. Depending on the CEOs' perceptions of their external environment, varying degrees of emphasis may be placed on different types of innovative efforts.

Table 5
Predictive validity of technology policy:
Intercorrelations between technology policy and realized innovative efforts

Predicted variables	All firms (n = 84)	Sub-environments			
		Low hostility	High hostility	Low dynamism	High dynamism
Realized innovative efforts:					
R&D	0.34 ****	0.47 ****	0.25 *	0.20 *	0.38 ***
Score of innovativeness for computer-based applications	0.29 ***	0.19 *	0.34 ***	0.15	0.34 ***
External technological experience	0.37 ****	0.25 **	0.50 ****	0.30 **	0.47 ***

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

The last four columns of table 5 suggest that this is certainly the case, thus supporting hypotheses H3b and H3c. For instance, if we consider the first type of innovative effort, high environmental dynamism should lead to increased efforts in R&D activities, corresponding to a strategy of differentiation (Miles and Snow, 1978). This assumption appears to be supported here ($r = 0.38$, $p < 0.01$ for high dynamism compared to $r = 0.20$, $p < 0.10$ for low dynamism). A relatively stronger correlation coefficient for the low hostility environment implies that an aggressive technology policy promotes higher R&D investments when perceived external threats to the survival of the firm are considered to be of manageable proportion. The fact that CEOs of smaller firms may indeed expend a great deal of their efforts in reducing risk may also partially explain this result. More emphasis is placed on the adoption of computer-based applications in the high hostility and high dynamism sub-environments either to maintain or to improve competitive posture. It could be argued here that in these types of perceived environments, CEOs tend to rely on innovative efforts which provide faster pay off than would be the case with R&D activities. A similar pattern also emerges for the third kind of innovative effort: greater emphasis is placed on external technological experience when facing either highly hostile or highly dynamic environments. Obviously, the possibility of reciprocal causality can be recognized: greater technological experience generates a deeper knowledge of technological discontinuities and change, which in turn modifies CEOs' assessment of their external environment. This would certainly merit further investigation.

4.4 Realized innovative efforts and performance

Table 6 does not convincingly demonstrate any link between financial performance and innovative efforts and H4a is therefore rejected. Only the degree of process innovativeness shows a significant correlation coefficient. Hard economic times for North American manufacturing firms at the time of this survey (early 1990s) may partially explain the lack of significant findings. The negative coefficients observed for R&D may well be sector-specific: in the metal industry, R&D activities are somewhat lower than in high technology sectors such as biotechnologies and, surprisingly, additional analysis reveals that in our sample, R&D investments are not correlated with the degree of process innovativeness ($r = 0.01$, $p = 0.91$). Further, the link between R&D investment and subsequent performance at the firm level is not obvious (Morbey and Reithner, 1990; Oakey et al., 1988) due in part to the lag effect reported by Brockoff (1986).

Support for hypothesis H4b is more evident as the link between export- generated sales and innovative efforts appears to be stronger: all correlation coefficients are positive and the scores for innovativeness and external technological experience are significantly related to export performance ($r = 0.21$, $p < 0.05$ and $r = 0.18$ $p < 0.05$).

Table 6
Intercorrelations between realized innovative efforts and performance
(n = 84)

Realized innovative efforts	Financial performance (n = 84)	Export performance
R&D	-0.05	0.09
Score of innovativeness for computer-based applications	0.14 *	0.21 **
External technological experience	0.11	0.18 **

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

The lack of support for H4a and the somewhat stronger support for H4b may be explained by the fact that small firms sacrifice short term benefits for the longer term benefits which may accrue from the opening-up of new markets. This is confirmed by the positive yet not significant correlation coefficient between financial performance and export performance ($r = 0.11$) and supports results from previous studies suggesting that the market share-profitability relationship is not necessarily positive and in fact is context specific (Prescott et al. (1986).

5. RESEARCH LIMITATIONS

This study's findings should be interpreted in the light of certain limitations. First, the sample is rather small (n = 84) and homogeneous. This might preclude our making comprehensive generalizations: the results may be context-specific since both industrial sector and organizational size have a definite impact. Second, caution must be exercised, as reciprocal causality may exist among certain variables. Third, each firm's results are based on data given by a single informant (the CEO) at a given point in time.

On the other hand, some of these limitations can also be viewed as providing benefits. Considerable efforts were made to identify a rather homogeneous and tight sample within a well defined geographical area where firms share a common political, social, and fiscal environment and where the availability and cost of production factors are to a large extent similar. Furthermore, concentrating on firms of similar size within a single industry allows to examine contingency perspectives within a similar context which according to Ginsberg and Venkatraman (1985) constitutes a first step prior to generalization. Yet this does not imply that no difference exists since variations could be attributed to the specificity of the activity which firms perform within the overall metal sector. The small sample size further allows one to conduct two-to three-hour long structured interviews on site: the data collected is probably more accurate and richer than it would be otherwise. Researchers also noticed that the timing of this survey influenced the results. All the CEOs we talked to were deeply concerned with the recession. This suggests that the results of this study, or of other studies, for that matter, should be considered in the light of the economic context. The fact that only CEOs were interviewed, no matter how difficult it might have been to reach them, is also a strength in any research on strategic orientations and activities in SMEs. In these smaller firms, strategy tends to be intuitively derived (Mintzberg, 1988), essentially driven by CEOs (Harrison, 1992) and difficult to detach from the characteristics of its founders (Adler, 1989).

6. CONCLUSION

Given the above limitations and strengths, this study yields some important results. In general, structural characteristics and process are less important predictors of technology policy than strategic orientation in SMEs while perceived environmental characteristics moderate the relationship between technology policy and the predictor variables. Added perspective was gained by distinguishing between two characteristics of the perceived environment, namely hostility and dynamism. Hostility proved to be a much stronger moderator than dynamism in SME's. The conceptual framework was extended to include the organizational outcome of an aggressive technology policy: all realized innovative efforts are positively linked with an aggressive policy but different emphasis is placed on each type of effort depending on the CEOs perceptions of the external environment. Finally, the relationship between realized innovative efforts and financial performance is rather weak but the relationship with another form of performance, namely export-generated sales, is much stronger.

Environment has long been considered an important contingency variable by researchers. The results contribute to past research efforts by demonstrating empirically the power of perception. Hence, perceptions of external environments created through the prism effect of CEOs' personal biases rather than objective measures of these environments are significant issues to consider in the strategy process of SMEs. Consequently, considerable emphasis will need to be placed on the cognitive schemas of CEOs and their relationship with strategy formulation. The practical implications are obvious as mis-read and/or mis-interpreted environments would probably translate into sub-optimal allocation of resources which could be detrimental to the overall performance or survival of a firm. This is indeed a critical issue for all firms, especially for SMEs, which face limited and scarce human and financial resources. In our industrial economies, these firms are increasingly important as they are known to provide a significant number of new job creation opportunities as well as being an important structural mechanism for innovation.

Future research should therefore concentrate on providing a better understanding of the prism effect and its impact on other organizational settings and industrial environments. Furthermore, it would be interesting to extend the study reported here to include the dynamic nature of the model which is assumed in the framework. Future research on the feedback loop from the outcome variables to the predictor variables, which implies the evolutive nature of the model, is needed. Longitudinal case studies would be appropriate to explore the dynamic aspects of the framework.

As a concluding remark, it has been stressed that strategic management of technology is a prime concern for firms in today's highly changing commercial and technological environments. Firms' technology policy and realized innovative efforts are at the core of this preoccupation, which, from our results, cannot be dissociated from the important moderating effects of CEOs' perceptions. Research on fit should be able to take into account this added dimension given the impact it may ultimately have on organizational performance.

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APPENDIX 1
STRUCTURED INTERVIEW GUIDE

DEPENDENT VARIABLE

TECHNOLOGY POLICY

1. The policy of this firm has always been to explore the most up-to-date production (operations) technology.	1 – 2 – 3 – 4 – 5 – 6 – 7
2. We are going ahead with plans to evaluate new processing equipment.	1 – 2 – 3 – 4 – 5 – 6 – 7
3. We have a long tradition and reputation in our industry for attempting to be first to try out new methods and equipment.	1 – 2 – 3 – 4 – 5 – 6 – 7
4. We plan to increase our R&D spending over the next 5 years.	1 – 2 – 3 – 4 – 5 – 6 – 7
5. We spend more than most firms in our industry on new product development.	1 – 2 – 3 – 4 – 5 – 6 – 7
6. We are actively engaged in a campaign to recruit the best qualified technical personnel available (engineering and production).	1 – 2 – 3 – 4 – 5 – 6 – 7
7. We are actively engaged in a campaign to recruit the best qualified marketing personnel available.	1 – 2 – 3 – 4 – 5 – 6 – 7
8. We are one of the few firms in our industry that does technological forecasting for products.	1 – 2 – 3 – 4 – 5 – 6 – 7
9. We are one of the few firms in our industry that does technological forecasting for production processes.	1 – 2 – 3 – 4 – 5 – 6 – 7

PREDICTOR VARIABLES

STRUCTURAL CHARACTERISTICS

- **Technocratization:** number of scientists, engineers, programmers and technicians divided by the total number of employees.
- **Formalisation**

1. There are no written job descriptions.	1 – 2 – 3 – 4 – 5 – 6 – 7	There are complete written job descriptions for all jobs.
2. Our employees make their own rules on the job.	1 – 2 – 3 – 4 – 5 – 6 – 7	Our employees must strictly abide by company rules on the job.
3. We always have arguments about job overlap among our managers.	1 – 2 – 3 – 4 – 5 – 6 – 7	We never have any arguments about job overlap among our managers.

- **Centralisation**

Which levels of management are usually responsible for making decisions of the following types?

	Lower levels of management	Middle levels of management	Senior levels of management
1. Capital budgeting	1 – 2 – 3 – 4 – 5 – 6 – 7		
2. Introduction of new products	1 – 2 – 3 – 4 – 5 – 6 – 7		
3. Acquisition of other companies	1 – 2 – 3 – 4 – 5 – 6 – 7		
4. Pricing of major product lines	1 – 2 – 3 – 4 – 5 – 6 – 7		
5. Entry into major new markets	1 – 2 – 3 – 4 – 5 – 6 – 7		
6. Hiring and firing senior personnel	1 – 2 – 3 – 4 – 5 – 6 – 7		

PROCESS

- **Scanning**

Rate the extent to which the following scanning methods are used by your firm to gather information about its environment.

	Never used	Used extremely frequently
1. Routine gathering of opinions from clients	1 – 2 – 3 – 4 – 5 – 6 – 7	
2. Explicit tracking of policies and tactics of competitors	1 – 2 – 3 – 4 – 5 – 6 – 7	
3. Forecasting sales and customer preferences	1 – 2 – 3 – 4 – 5 – 6 – 7	
4. Special market research studies	1 – 2 – 3 – 4 – 5 – 6 – 7	

STRATEGIC ORIENTATION (STROBE)

	Strongly disagree	Strongly agree
• **Aggressiveness Dimension**		
1. We sacrifice profitability to gain market share.	1 – 2 – 3 – 4 – 5 – 6 – 7	
2. We cut prices to increase market share.	1 – 2 – 3 – 4 – 5 – 6 – 7	
3. We set prices below competition.	1 – 2 – 3 – 4 – 5 – 6 – 7	
4. We seek a market share position at the expense of cash flow and profitability.	1 – 2 – 3 – 4 – 5 – 6 – 7	
• **Analysis Dimension**		
1. We emphasize effective coordination among different functional areas.	1 – 2 – 3 – 4 – 5 – 6 – 7	
2. We believe that information systems provide support for decision making.	1 – 2 – 3 – 4 – 5 – 6 – 7	
3. When confronted with a major decision, we usually try to develop a thorough analysis.	1 – 2 – 3 – 4 – 5 – 6 – 7	
4. We encourage the use of planning techniques.	1 – 2 – 3 – 4 – 5 – 6 – 7	
5. We encourage the use of the output of management information and control systems.	1 – 2 – 3 – 4 – 5 – 6 – 7	
6. We encourage manpower planning and performance appraisal of senior managers.	1 – 2 – 3 – 4 – 5 – 6 – 7	

- **Defensiveness Dimension**

1. We have brought significant modifications to the manufacturing technology.	1 – 2 – 3 – 4 – 5 – 6 – 7
2. We encourage the use of cost control systems for monitoring performance.	1 – 2 – 3 – 4 – 5 – 6 – 7
3. We encourage the use of production management techniques.	1 – 2 – 3 – 4 – 5 – 6 – 7
4. We emphase product quality (e.g. through the use of quality circles).	1 – 2 – 3 – 4 – 5 – 6 – 7

- **Futurity Dimension**

1. Our criteria for resource allocation generally reflect short-term considerations (reversed scale).	1 – 2 – 3 – 4 – 5 – 6 – 7
2. We emphasize basic research to provide us with a future competitive edge.	1 – 2 – 3 – 4 – 5 – 6 – 7
3. We forecast key indicators of operations.	1 – 2 – 3 – 4 – 5 – 6 – 7
4. We try to obtain a formal tracking of general trends.	1 – 2 – 3 – 4 – 5 – 6 – 7
5. We analyse critical issues with "what if".	1 – 2 – 3 – 4 – 5 – 6 – 7

- **Proactiveness Dimension**

1. We are constantly seeking new opportunities related to present operations.	1 – 2 – 3 – 4 – 5 – 6 – 7
2. We are usually the first ones to introduce new brands or products in the market.	1 – 2 – 3 – 4 – 5 – 6 – 7
3. We are constantly on the look out for business that can be acquired.	1 – 2 – 3 – 4 – 5 – 6 – 7
4. Competitors generally pre-empt us by expanding capacity (reversed scale)	1 – 2 – 3 – 4 – 5 – 6 – 7
5. Our operations in larger stages of life cycle are strategically diminuted	1 – 2 – 3 – 4 – 5 – 6 – 7

- **Riskiness Dimension**

1. Our activities can be generally characterized as high-risk.	1 – 2 – 3 – 4 – 5 – 6 – 7
2. We adopt a rather conservative view when making major decisions (reversed scale).	1 – 2 – 3 – 4 – 5 – 6 – 7
3. Our new projects are approved on a "stage by stage" basis rather than with "blanket" approval (reversed scale).	1 – 2 – 3 – 4 – 5 – 6 – 7
4. We tend to support projects where the expected returns are certain (reversed scale).	1 – 2 – 3 – 4 – 5 – 6 – 7
5. Our operations have generally followed the "tried and true" paths (reversed scale).	1 – 2 – 3 – 4 – 5 – 6 – 7

MODERATOR VARIABLES

- **Environmental hostility (economic, politic and commercial)**

(Please circle the appropriate number on the scale)

1. The environment poses very little threat to the survival of our firm.	1 – 2 – 3 – 4 – 5 – 6 – 7	The environment poses a great threat to the survival of our firm.

How severe are the following challenges at the present:

	This is not a substantial threat — This is a very substantial threat
2. Tough price competition	1 — 2 — 3 — 4 — 5 — 6 — 7
3. Competition in product quality or novelty	1 — 2 — 3 — 4 — 5 — 6 — 7
4. Dwindling markets for products	1 — 2 — 3 — 4 — 5 — 6 — 7
5. Scarce supply of labour and/or material	1 — 2 — 3 — 4 — 5 — 6 — 7
6. Government interference	1 — 2 — 3 — 4 — 5 — 6 — 7

- **Environmental dynamism**

1. Our firm must rarely change its marketing practices to keep up with the market and with competitors.	1 — 2 — 3 — 4 — 5 — 6 — 7	Our firm must change its marketing practices very frequently to keep up with the market and with competitors (e.g. semi-annually).
2. The rate at which products or services become obsolete in this industry is very slow (e.g. basic metal like copper).	1 — 2 — 3 — 4 — 5 — 6 — 7	The rate at which products or services become obsolete in this industry is very fast (as in fashion goods and semi-conductor).
3. Actions of competitors are quite easy to predict (as in some primary industries).	1 — 2 — 3 — 4 — 5 — 6 — 7	Actions of competitors are unpredictable.
4. Demand and consumer tastes are fairly easy to forecast (e.g. for milk companies).	1 — 2 — 3 — 4 — 5 — 6 — 7	Demand and consumer tastes are almost unpredictable (e.g. high fashion goods).
5. The production/service technology is not subject to significant change and is well-established (e.g. in steel production).	1 — 2 — 3 — 4 — 5 — 6 — 7	The modes of production / serviec change often and in major way (e.g. advanced electronic components).

PREDICTED VARIABLES

- **R & D** investments in R & D as a % of annual sales.
- **Degree of process innovativeness** (see appendix 2).
- **External technological experience.**

	Minimally — Somewhat — Very
1. Are you aware of the most recent technological developments?	1 — 2 — 3 — 4 — 5 — 6 — 7
2. Are you up to date on the availability of the most recent technological developments in the market?	1 — 2 — 3 — 4 — 5 — 6 — 7
3. Are you aware of the comparative advantages that you can get from these most recent developments?	1 — 2 — 3 — 4 — 5 — 6 — 7

- **Financial performance compared to industry**

	Below average	Average compared to industry	Above average
Annual rate of growth measured in percentage of total assets in the last 5 years.	1 — 2 — 3 — 4 — 5 — 6 — 7		
Annual rate of growth of sales in the last 5 years.	1 — 2 — 3 — 4 — 5 — 6 — 7		
Average return on investment during the last 5 years.	1 — 2 — 3 — 4 — 5 — 6 — 7		

- **Export performance:** export sales divided by total sales.

APPENDIX 2
Measuring the degree of process innovativeness of a manufacturing firm

Degree of process innovativeness for computer-based administrative applications = $\sum_{i=1}^{21} i_j \times r_j$ where i_j = 0 or 1 depending on the adoption of innovation j, and r_j = degree of radicalness of innovation j as established by a panel of experts who ranked each innovation on 7 point Likert scales.

Computer-based applications: *

Degree of process innovativeness for Computer-based administrative applications:

Innovation i_j:

i_1 Accounts payable/accounts receivable
i_2 Inventory management
i_3 Sales analysis
i_4 Payroll
i_5 Billing
i_6 Cost accounting
i_7 Operations management
i_8 Word processing
i_9 Electronic mail/electronic filing

Computer-based production applications

Production Technology

i_{10} Computer-assisted design (CAD) and/or Computer-assisted engineering (CAE)
i_{11} CAD output used to control manufacturing machines (CAD/CAM)

Fabrication and Assembly

i_{12} Flexible manufacturing cells (FMC) or systems (FMS)
i_{13} Numerical control machines (NC)
i_{14} Pick and place robots
i_{15} Other robots

Automated Material Handling

i_{16} Automated storage and retrieval system (AS/RS)
i_{17} Automated guided vehicle system (AGVS)

Automated Sensor-Based Inspection and/or Test Equipment

i_{18} Performed on incoming or in-process materials
i_{19} Performed on final product

Communications and Control

i_{20} Inter company computer network linking plant to subcontractors

Manufacturing Information Systems

i_{21} MRPI or MRPII

* Adapted from a typology produced by Statistics Canada (1989)

APPENDIX 3

MATRIX OF INTERCORRELATIONS AMONG THE INDEPENDENT VARIABLES
(n=84)

Variables	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1 Formalization	1.00									
V2 Technocratization	0.00	1.00								
V3 Centralization	-0.00	-0.06	1.00							
V4 Scanning	0.15	-0.13	-0.07	1.00						
V5 Aggressiveness	-0.07	0.20*	-0.15	-0.03	1.00					
V6 Analysis	0.29***	0.00	-0.07	0.38****	-0.01	1.00				
V7 Defensiveness	0.28***	0.00	0.05	0.24**	-0.14	0.49****	1.00			
V8 Futurity	0.14	0.05	-0.07	0.55***	-0.13	0.40***	0.44***	1.00		
V9 Proactiveness	-0.12	0.03	-0.03	0.13	-0.05	0.13	-0.02	0.37***	1.00	
V10 Riskness	-0.21*	-0.03	0.04	-0.16	0.36**	-0.12	-0.22*	-0.24**	0.04	1.00

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

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