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Technological Capability and Productivity Growth: An Industrialized / Industrializing Country Comparison

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Technological Capability and Productivity Growth: An Industrialized / Industrializing Country Comparison.*

Pierre J. Tremblay†

Résumé / Abstract

L'importance des changements techniques comme éléments clés expliquant les différences entre pays quant aux niveaux et aux taux de productivité industrielle est de plus en plus reconnue. En conséquence, il y a un intérêt croissant quant au développement des capacités nécessaires à de tels changements. Cependant, la nature de cette capacité (dite capacité technologique) et ses liens avec la croissance de productivité est encore peu comprise. Cet article explore empiriquement les liens entre (i) la capacité technologique (variable causale) (ii) la génération de changements techniques (variable intermédiaire) et (iii) la croissance de productivité (variable résultante). En particulier, il examine les dimensions organisationnelles de la capacité technologique.

The importance of technical change as a crucial element explaining inter-country differences in levels and rates of change in industrial productivity has been increasingly acknowledged. Hence, growing significance has been attached to developing the capability to generate such change. However, the perceived nature of that capability (described here as "technological capability") and its links to productivity growth are still poorly understood. This paper empirically explores the links between (i) technological capability (the causal variable) (ii) the generation of technical changes (the intermediate variable) and (iii) productivity growth (the end-result variable). In particular, it examines organizational dimensions of technological capability.

Mots Clés : capacité technologique, systèmes organisationnels, changement technique, croissance de productivité, pâtes et papiers, Inde, Canada

Keywords : technological capability, organizational systems, technical change, productivity growth, pulp and paper, India, Canada

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1. Introduction

In recent years, interest in the investigation of inter-country differences in levels and rates of change in industrial productivity has grown considerably. Although previous studies have generally focused on macro economic issues such as trade policies, the importance of technical change as a crucial element explaining these differences has been increasingly acknowledged. Hence, growing significance has been attached to developing the capability to generate such change. However, the perceived nature of that capability (described here as "technological capability") and its links to productivity growth are still poorly understood. This, as suggested by Nelson (1981, p.1037), may be due to the fact that "economists have not engaged in much empirical research on the determinants of the productivity of individual firms."

A wide range of expressions exist in the economic literature to describe the "capabilities" related to technical and technological change generation. Terms such as technological "effort", "search", "learning", "capacity", and "capabilities" are frequently used. (See for example, Bell *et al.*, 1984; Dahlman *et al*, 1987; Enos, 1991; UNCTAD, 1996; more exhaustive taxonomies have been devised by Lall, 1987, 1992). The definition of *technological capability* used in this paper is similar to the one given by Bell and Pavitt (1993a, b): *Technological capabilities* embody the resources required to manage and actualize the **generation of technical change**. These resources are accumulated and embodied in people (skills, knowledge and experience) and organizational systems. In order to emphasize the importance of these consequential capabilities, one needs to differentiate them from other basic capacities referred to as *Production capacity*: It "incorporates the resources used to produce industrial goods at given levels of efficiency and given input combinations: equipment (capital-embodied technology), labour skills (operating and managerial know-how and experience), product and input specifications and the organizational methods and systems used" (Bell and Pavitt, 1993b, p.163).

Although technological capability is said to be embodied in people **and** in **organizational systems**, few studies have examined the organizational dimensions of technological capability in conjunction with technical change and productivity growth. Therefore, the aim of this paper is to empirically explore this issue. This is the central paper of a large research program (Tremblay, 1994) which addressed three main questions:

1. Is there a systematic relationship between technological capability and productivity performance of firms?
2. What is the nature of that technological capability? And in particular, what are its organizational dimensions and how important are they?
3. Are there any significant differences between firms in industrialized and industrializing countries regarding their productivity performance, the nature of their technological capabilities, and the relationship between the two?

The present paper integrates data and conclusions from previous papers written by the author (Tremblay, 1997, 1998a, b) and focuses specifically on the organizational and managerial factors that drive change-generating activities in firms and their impact on economic performance.

The research is based on first hand empirical data gathered at the mill level. The data were obtained through direct observation, interviews and questionnaires as well as from mills' records (over a period of five to seven years, between 1984 and 1991). The mills surveyed are situated in two countries that have a well-established pulp and paper industry: an industrialized country, Canada, and an industrializing country, India. Inter-firm comparisons are therefore made at both national and international levels.

The paper is divided into five sections. Following a review of the literature in section two, the third section describes the framework and methodology of the research. The fourth section presents results regarding the technological capabilities embodied in organizational systems. It focuses on key features of the organization within which the firms' human resources are deployed. It analyses a wide spectrum of organizational and managerial characteristics such as, decision-making, interaction-influence, supportive relationships, etc. The relationship between these characteristics and productivity rates is examined. The conclusion provides a review of the entire evidence and highlights the importance of technological capabilities embodied in organizational systems as a source of productivity growth.

2. Background

Numerous studies have examined the indigenous development of technological capabilities (at the firm level) in industrializing countries (see UNCTAD, 1996 for a literature review). Researchers in this field have demonstrated that significant technological capabilities are present within some firms (e.g., in Latin America: Katz[1] 1984, 1987; Herbert-Copley, 1990; in India: Lall, 1985, 1987). There is also evidence that firms (in Korea and in Taiwan (China)) have the capabilities to generate continuous incremental change built upon technologies that were originally imported (e.g., Westphal *et al*, 1985; Enos and Park, 1988). The latter studies attribute such dynamism to capabilities accumulated earlier in human resources (e.g., engineering competencies). Furthermore, Romijn's (1997) recent quantitative study revealed similar results in that positive correlations were obtained between measures of product manufacturing complexity and external search, external assistance and human capital. In contrast, other studies have shown that the development of technological capability is either absent or very limited (e.g., Bell *et al* 1982; Herbert-Copley, 1992), and that the majority of firms remain "static" in terms of economic performance. Although only a few studies have investigated these issues in the case of the particular industry examined in this research, the pulp and paper industry (Scott-Kemmis, 1988; Quazi, 1984; Chantramonklasri, 1986, de Marquez, 1979), similar differences between firms have been found. Most of this literature has emphasized that technological capability is a crucial element in generating technical change and (occasionally) improvement performance. There are, however, three particularly important limitations to these studies.

First, very few authors have systematically analyzed the link between technological capability and productivity growth. This is partly due to the fact that it is difficult to generate adequate productivity data over time. Furthermore, very little of the work involves adequate elements of comparative analysis. As Pack (1992) noted, much of the research consists only of case studies of individual firms, while inter-country comparisons (industrialized versus industrializing) are rare, if not almost totally absent.

Second, most of the literature has adopted a rather narrow perspective regarding the composition of technological capabilities. Only the importance of technological capabilities embodied in human resources has been emphasized. More specifically, in treating human resources as assets, the focus has primarily been on the stock of individuals within the firm rather than

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[1] The studies by Katz and his collaborators, as part of the "Programa BID/CEPAL/PNUD de Investigaciones en Temas de Ciencia y Technología en América Latina" (1975-1982) (partly summarized in Katz, 1984, 1987; and in other independent sources such as Dahlman and Cortes, 1984; Sercovich, 1984; and Teitel, 1981) are of particular interest.

on the structure of groups and of the overall organization within which individuals work.

Finally, definitions of technological capability differ across authors and the distinction between production capacity and technological capability is rarely made. For example, Romijn's (1997, p.361) study on "technological capability" acquisition clearly refers to "production capacity" as defined earlier in this paper: "For measuring the technological capability of the sample firms it therefore made sense to concentrate on the development of an indicator of production capability rather than innovation or investment capability." The study did not include generative capabilities, measurements of change generation (innovation) and performance growth indicators[2]. It is therefore not surprising to find that the variable measuring in-firm technological efforts (number of people involved in activities aimed at assimilating and improving products) did not perform well in the correlation analysis and could not be used for the regression analysis. As with most studies in this field, the determinants of internal capability focused narrowly on human capital, assuming that "latent" capabilities are a guarantor of success. However, if one wants to generate innovation, a recognized engine of national economic growth, studies on technological capability building that address development issues must concentrate on crucial generative capabilities.

In a recent study[3], Tremblay (1997) found that the technological capabilities embodied in human resources ("latent" capabilities), assessed by level of education, do not provide a clear explanation of inter-mill differences in productivity growth. These results contradict the common assumption that an increase in academic knowledge of staff increases productivity. On the other hand, an explicit relationship between productivity growth and the organizational commitment of human resources in performing change-generating activities was found. Four variables were used in the semi-quantitative analysis: *scale* (ratio of the number individuals committed to change-generating activities), *intensity* (frequency at which change-generating activities are performed), *responsibility* (amount of responsibility felt by each member of the organization to commit himself to change) and *role* (types of

[2] This major limitation is recognized by Romijn (1997). The determinants that induce firms to engage in technological learning was outside the scope of the study.

[3] This study is part of the main research (Tremblay, 1994)

activities performed). The empirical analysis demonstrated that technological capabilities embodied in organizational systems are important. For example, the responsibility and intensity variables showed a near linear relationship with a total productivity growth index (Refer to Table A.1 in the Appendix for a summary of the findings). Yet, "what are the determinants or organizational capabilities that contribute to organizational commitment to change and its resulting productivity?" remains a central question that will be addressed in the present paper.

The importance of organizational dimensions for the industry is not a new subject. In the past decade or so, dramatic changes have occurred in our socioeconomic systems. New technologies (such as the information and telecommunication technologies) have emerged, market structures have been continually changing and finally, the organization of production and management methods have been questioned, reassessed, "revitalized" and "reinvented". These trends have induced academic researchers and management consultants to generate various hypothesis about the origin of such phenomena and to carry out research that could benefit the development of the industrial sector. However, empirical investigations linking organizational dimensions with economic performance indicators are limited (e.g., Burns and Stalker, 1961; Likert, 1961, 1967; Covin and Slevin, 1990; Denison, 1990; see Tremblay, 1994 for a selected review).

Although these organizational issues have recently been addressed in industrializing countries on an empirical basis, the studies carried out thus far have a number of important limitations[4] (e.g., Meyer-Stamer *et al*., 1991; Mody et al, 1992; Kaplinsky and Posthuma, 1993; Kaplinsky, 1994, 1995, Bessant and Kaplinsky, 1995; Carrillo, 1995; Meyer-Stamer, 1995). First, they have often focused on organizational "techniques" (such as JIT, RMP, TQC, TQM, etc.) rather than on underlying or wider aspects of organization and management (not only in terms of human capital). Yet, many authors argue that organizational "techniques" are not sufficient by themselves to generate substantial change. For example, it has been suggested that the techniques must be introduced either in a systemic manner (Kaplinsky, 1995) or in combination with "social innovations" (Posthuma, 1995; Meyer-Stamer *et al*., 1991). Second, the studies have focused almost exclusively (if not totally) on industries using discrete processes. Case studies of firms in industrializing

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[4] There were previously few studies demontrating the impact of IT related technologies for industrializing countries however, only in general terms (e.g. Hoffman, 1989).

countries that use complex continuous processes are lacking[5]. Third, comparative analyses between industrialized and industrializing countries have not been carried out. And finally, productivity growth data linked to both technological capabilities and the generation of technical change are absent.

In conclusion, although management and/or organizational capability is said to be an important element in increasing the performance of a firm, few studies have examined this crucial point in conjunction with technical change and productivity growth.

3. Framework and Methodology

The framework of the present research is fairly straightforward. At the core of the research are technological capabilities (the causal or independent variables). The actualization of these capabilities via the generation of technical change (the functional linkage or "intermediate" variable) results in performance growth (the "end-result" or dependent variable). Three types of indicators were used and/or created to measure these variables:

1. Performance indicators (Tremblay, 1998a)
2. Technical change generation pattern indicators (Tremblay, 1998a, b)
3. Technological capability indicators:
    a) Human resources' competencies (Tremblay, 1997, 1998a)
    b) Organizational commitment to change (Tremblay, 1997, 1998a)
    c) Wider organizational dimensions

3.1 End-result Variables: Productivity and Performance Growth

A total productivity (TP) index was calculated for the purpose of this study. Other performance indicators were also used such as, physical performance indices specific to the pulp and paper manufacturing industry as well as and partial productivity indicators. However, they could provide only a partial indication of production efficiency and were used mainly to ascertain the validity of the aggregated measures of partial and total productivity growth. The approach used to measure total productivity at the firm level consists of an elementary, additive model and is similar to the approaches developed by

[5] "Japanese" techniques for continuous processes also have fewer successful stories in the industrialized countries.

the American Productivity Center (Kendrick and Creamer, 1965; Kendrick, 1984) and by other practitioners (e.g., Craig and Harris 1973, Kraus 1978, Hayes 1982).

$$TP_i = \frac{\sum_i Ouput}{\sum_i Material + \sum_i Energy + \sum_i Labour + \sum_i Capital}$$

Given that this research examines a *dynamic* process of technical change generation, a total productivity growth index (TPG) is computed (linear regression) from the yearly (*i*) TP indices and is presented throughout this paper as percent of growth. The measurements, indicators and methods are described in Tremblay (1994, 1998a).

3.2 Intermediate Variables: Technical Changes

Technical changes constitute the functional linkage between firms' technological capabilities and the ensuing changes in productivity trends. Special attention has been given to all forms of technical changes[6] (recorded and unrecorded as annual capital expenditure), their size, types, and contribution toward productivity growth. The analysis of these underlying patterns of technical change has been covered in Tremblay (1994, 1997, 1998a, b). A summary of the findings is provided in Table A.1 of the Appendix.

3.3 Causal Variables: Technological Capabilities

A central argument of this paper and others (e.g., Tremblay, 1997) is that technological capabilities should not be seen only in terms of human resources – particular types of skills and experience. These resources are located within organizational systems which may have a considerable influence on the effectiveness of individuals in contributing to technical change and performance improvement. Therefore, it is argued that these organizational systems should be viewed as an integral component of the technological capabilities of a firm. The present research addressed this issue in two ways. First, organizational dimensions that are 'directly' concerned with managing human resources in the pursuit of technological change (the "organizational

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[6] This research focuses on technical change rather than solely on innovation. Concentrating on classical measures of innovation such as R&D expenditure would have been inconclusive. In this research, it was extremely surprising to discover that the input of R&D labs in the change process is, in most case mills, small or insignificant. Much more important were the innovative changes not resulting from formal R&D.

commitment to change") were assessed. This element is addressed in (Tremblay, 1997, 1998a). A summary of the findings is provided in Table A.2 of the Appendix. Second, wider organizational dimensions of firms that may influence change-generating activities were examined. The nature of technological capabilities embodied in wider aspects of organization and management is examined by exploring the relationship between performance and a set of organizational variables (Table 1). Drawing from the academic and management literature (Table 2; see Tremblay, 1994 for a review of the literature), ten variables concerned with wider organizational dimensions were chosen. The choice of these variables was based on suggestions made by previous authors that they are the key elements to improving productivity growth. The ten variables are presented in Table 1. For each variable, two columns are included which illustrate two extreme forms they may take within a spectrum of organization and management practices. The left-hand column describes the forms of organizational practices that are considered to contribute to 'poor' performance. The right-hand column describes the forms of organizational practices that are said to contribute to 'high' performance.

For the present comparative and longitudinal research, the author chose a method and research instrument that have already been shown to be successful in generating empirical evidence linking various aspects of organization and management with performance. The Institute for Social Research, through its *Intercompany Longitudinal Study,* has developed such tools. This research used a slightly modified version[7] of Likert's questionnaire (Likert and Gibson-Likert, 1976, pp.331-345). However, the questionnaire allows only the first seven organizational variables presented in Table 1 to be measured. The following three important organizational characteristics were not explored with the above tool: Type of Hierarchy, Organizational Slack and Management Attitude to Human Resources Development. These three characteristics were assessed on the basis of an extended section of the Likert questionnaire.

- "Type of Hierarchy". This is concerned with the extent to which an organization is structured as a flat, flexible, unit built of cross-functional groups and networks. This is reflected by (a) the degree of departmentalization (or functionalization) and ordering of groups within the organization and (b) the scalar chain and span of control.

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[7] Refer to Tremblay, (1994) for details of the modifications.

Table 1: **Wider Organizational Dimensions Variables**

Variables	**Forms of organizational practices contributing to:** ****’Poor’ Performance****	****’High’ Performance**.**
Supportive Relationships	Trust in subordinates: low; Their ideas are seldom used.	Trust in subordinates: complete; Their ideas are always used.
Motivation and Commitment	Motives tapped: security, status; Level of satisfaction: low; Commitment: extremely low.	Motives tapped: self-realization; Level of satisfaction: high; Commitment: high.
Decision-making	"Management knows best"; Locus: top; Subordinates not at all involved.	Participatory decision making; Locus: all levels; Subordinates fully involved.
Control	Vertical control; Locus: top.	Horizontal self control; Locus: all levels, self assessing.
Channels of Communication	Highly structured, Directives: top-down.	Open, shared; Multiple flow: horizontal, vertical, lateral.
Information flow	Restricted information flow. Closed, proprietary; Often inaccurate	Open/free flow of information throughout the organization. Generally accurate
Interaction-Influence	No cooperative teamwork; Very little influence and interaction between members/departments within the organization.	Substantial cooperative teamwork; A great deal of influence and interactions between members/departments.
Type of Hierarchy	Pyramidal and stable; Long scalar chain/narrow span; Cascades of supervisory levels; Separate specialized functional departments.	Flat, lean and flexible; Short scalar chain/wide span; Self-assessing and -improving units; Cross-functional units and networks.
Organizational Slack	Uncommitted resources unavailable.	Uncommitted resources available in order to generate changes.
Management Attitude to Human Resources Development	No conscious efforts to upgrade human resources competencies.	Conscious efforts to use and nurture all possible means of learning increasing the capability of human resources.

- "Organizational Slack". This is concerned with the extent to which uncommitted resources are available to the organization to support change activities.
- "Management Attitude regarding Human Resource Development". This is concerned with the extent to which efforts are deployed to develop human resources capacities.

Table 2: **Organizational Variables / Selected authors**

	Organizational Commitment		Wider Organizational dimensions									
	Commitment	**Organization of Work**	**Supportive Relationships**	**Motivational Forces**	**Decision-Making**	**Control**	**Communication**	**Information**	**Interaction-influence**	**Organizational Slack**	**Hierarchy**	**Management Attitude**
Covin & Slevin (1988, 1990)		X	X		X	X	X	X	X			
Likert (1961, 1967, 1976)		X	X	X	X	X	X	X	X			
Denison (1990)	X	X	X	X	X	X	X	X	X			
Perez (1991)		X			X	X	X	X	X	X	X	X
Imai (1986)	X	X	X	X		X	X	X				
Peters (1990, 1991)	X	X	X		X		X	X		X		X
Beer et al (1990a,b)	X	X	X	X	X		X	X			X	X
Sirkin & Stalk (1990)	X	X	X		X		X	X				
Zuboff (1991)	X				X							X
Starr (1990)		X		X		X					X	
Chew et al (1991)												X
Kozlowski & Hults (1987)			X									X

Responses to each question are scored on an eight-point Likert scale. The calculation of scores for each mill involves two steps. First, a score for each variable is calculated as an average of responses to each question. Second, an overall score for the organization as a whole is calculated as a simple average of the variable scores. Thus, each variable has the same weight in the overall assessment regardless of the number of questions.

3.4 The Comparative Framework: Countries and Sample Mills

As already indicated, a central research issue involves the comparison of industrialized and industrializing countries. In the present research, mills from two countries were compared -- Canada and India. Given that it is generally difficult to secure the data necessary for this type of study, the author concentrated on areas of the industry known to him. His familiarity (having worked in the industry for a few years) with the Canadian pulp and paper industry played a major role in choosing Canada. The choice of an industrializing country was based on three comparative elements. First, the country should have a relatively well-established pulp and paper industry. Second, it should have products and process technologies similar to those found in Canada and finally, it should have a comparative pattern of production. Based on these elements, India was decided to be the best choice[8].

The Canadian and Indian samples are composed of five and four mills, respectively. For confidentiality purposes, the Canadian mills have been labeled Mills A to E while the Indian mills have been labeled Mills Q to T. The two sets of mills are sorted in increasing order by the value of their total productivity growth index. In each country, two newsprint mills with similar paper machinery and two mills producing paper and paperboard other than newsprint were chosen. All mills are composed of a pulp mill (or deinking plant in one case). For obvious reasons, it was impossible to find newsprint mills with comparable production capacity across the two countries. Customarily, Canadian newsprint mills are comprised of more than one paper machine coupled with large multiple pulp mills. In contrast, such large installations are physically unsound in India due to inadequate local fiber supply. Consequently, the mills in India usually have only one newsprint paper machine. Nevertheless, the paper machines are of similar design, age and production capacity across the two countries.

4. The Results - Wider Organizational Dimensions

This section examines the data for the Canadian (A-E) and Indian (Q-T) mills and explores the relationship between productivity growth and wider organizational dimensions. As shown in Table 3, clear relationships exist between TPG and the scores on all the organizational variables assessed.

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[8] When analyzing the possible sample to compare with Canada, firms in India seemed to be a better choice than Latin American or African countries such as Brazil or Morocco. First, Latin American and African countries' production was not as diversified as production in India and Canada. Secondly, India had a far longer history of paper making. Finally, Canada and India have had a similar pattern of production for a relatively long period. On the one hand, the commodity grade newsprint sector in both countries has been pushed for a long time by "production-minded" executives. As such, there were market pressures on Canadian newsprint manufacturers to fulfill a large demand and in India, there was strong internal pressure for import-substitution of Newsprint paper. On the other hand, other market sectors of the paper industry in both countries were governed by stiff trade barriers, especially in India.

Table 3: **Spearman Correlations:**
Wider organizational dimensions and total productivity growth

Variables	R_s	p
Supportive Relationships	0.83333	***
Motivation and Commitment	0.86667	***
Decision-making	0.84520	***
Control	0.81667	***
Channel of Communication	0.83333	***
Information flow	0.85000	***
Interaction-Influence	0.86667	***
Type of Hierarchy	0.87398	***
Organizational Slack	0.96192	****
Management Attitude to Human Resources Development	0.96192	****
Average of all Variables	0.98333	****

R_s = Spearman coefficients; p=level of significance for the two-tailed test
* p<0.10, ** p<0.05;*** p<0.01, **** p<0.001

When all ten variables are averaged, an approximately linear relationship is obtained between the overall organizational score and the rate of productivity growth (Figure 1). This strong level of correlation does not appear to be coincidental given the multiple approaches used to assess the organizational characteristics, the usual consistency among them, and the persistence of the relationship at the level of the disaggregate data.

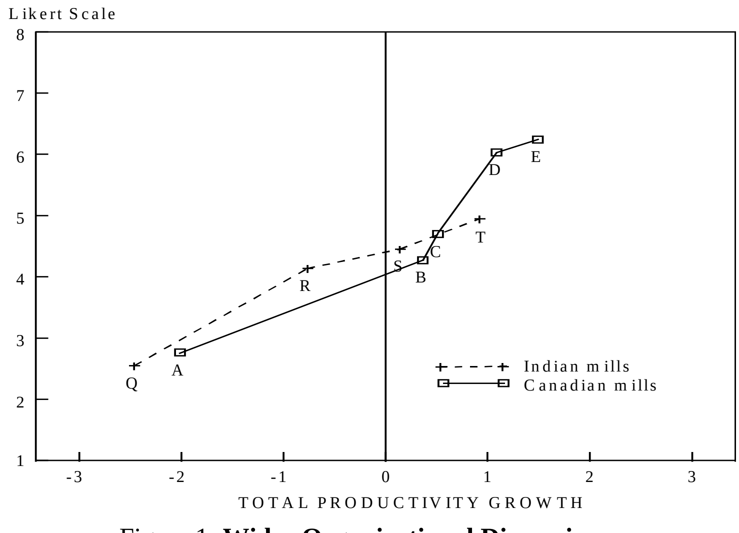

Figure 1: **Wider Organizational Dimensions**
Average of all variables

Pooling the data from Tremblay (1994, 1997, 1998a, b) provides a greater understanding of the above results and underscore the importance of the organizational dimensions of technological capability. In the following, the wider organizational dimensions variables are coupled with organizational commitment to change variables, technical change generation pattern indicators and productivity growth. Overall, the sample mills can be divided into three groups:

1. The best performing mills: D and E. (TPG over 1%)

   These two leading mills introduced a substantial amount of improvement changes throughout the period surveyed (Table A.1, 6-10% GFAe). They also demonstrated the highest degree of organizational commitment to change (Table A.2). Furthermore, the values of the indicators of wider organizational dimensions are distinctly larger than the other mills.

2. The middle groups: B, C, R, S and T (TPG between 1% and -1%; mills maintaining their performance or slightly improving or declining)

   Mill T, an above average performance mill, introduced a moderate amount of improvement changes (3.6% GFAe). This leading Indian mill also demonstrated the highest degree of organizational commitment to change within the Indian sample. Furthermore, it showed the highest scores on all the wider organizational dimensions variables. Given its TPG score of 0.92%, mill T might have been placed in the best performing mills group. However, the wider organizational dimensions variables show that mill E and D have a clearly different approach to management.

   Mills B and C introduced a moderate amount of improvement changes (Table A.1, 3-7% GFAe). Their commitment to change was also moderate (Table A.2). Finally, the scores of the indicators of wider organizational dimensions are situated in the upper middle range of the spectrum (i.e., B=4.27 and C=4.70).

   Mill S maintained its productivity level and introduced a small number of improvement changes. Its commitment to change was moderate. Finally, scores of the wider organizational dimensions variables are situated in the middle range of the spectrum (4.45).

   Mill R maintained its productivity level somewhat and introduced a moderate amount of improvement changes. However, investments were focused mainly on overcoming external constraints (4% GFAe). Furthermore, its commitment to change was small. Finally, the indicators of wider organizational dimensions have lower scores than mill S, that is, they are situated in the lower middle range of the spectrum (4.14).

3. The "Laissez-faire" performance mills: A and Q (TPG below 1%)

   Mill A introduced few improvement changes. In addition, its commitment to change was weak. The evidence from the wider organizational dimensions indicators show distinctly smaller values that of the other mills.

   Mill Q showed a rapid decline in productivity and introduced very few improvement changes. Similarly, its commitment to change was very weak. Finally, the indicators of wider organizational dimensions have distinctly smaller values than all the other mills.

The empirical evidence presented here is clearly consistent with the trends discussed in the literature review (Tables 1, 2; Tremblay, 1994). The best performing mills, as measured by the TPG score, have the highest scores (on the Likert scale) for the wider organizational dimensions variables. That is, they clearly use the organizational practices presented in the right-hand side of Table 1.

This causal relationship is supported by an analysis of the intermediate variable (summarized in Table A.1 of the Appendix; Tremblay, 1994 1998b). That is, the correlations between various types of technical change processes and the average of the wider organizational dimensions variables is positive (Table 4). It is worth mentioning that the total investment recorded as capital expenditure is not statistically significant. In contrast, it is positively significant when the analysis focuses on "Improvement-type" changes recorded as capital expenditure, and even more significant when concentrating on improvement-type changes unrecorded as capital expenditure. The latter group is composed almost exclusively of small incremental changes which are usually accounted for in operating costs and not in official capital expenditure.

Table 4: **Spearman Correlations Wider Organizational Dimensions and Technical change generation patterns**

Variables (Investments in technical changes)	R_s	p
Recorded as capital expenditure - All expenditure	0.56667	-
Recorded as capital expenditure - Improvement-type	0.73333	**
Unrecorded as capital expenditure - Improvement-type	0.88918	***

R_s = Spearman coefficients; p=level of significance for the two-tailed test
* p<0.10, ** p<0.05;*** p<0.01, **** p<0.001

5. Conclusion

5.1 Technological capability and productivity growth of firms

The review of the literature in the background section of this paper emphasized three points. First, although several studies have examined the development of technological capabilities in firms in industrializing countries, only a few have systematically analyzed the link between technological capability and indicators of economic or business performance such as productivity growth. Second, despite a general concern about 'catching up', very few studies have carried out inter-country comparative analyses, especially between industrializing and industrialized countries. Third, most studies have focused on human resources as the core (or only) component of technological capabilities. Although a few studies have highlighted the importance of organizational dimensions of technological capabilities in developing countries, they have done so only in general terms or by focusing on organizational "techniques". Moreover, the literature on technological capability has usually omitted the significance of the organizational dimension. Hence, the link between productivity growth and the dimensions of technological capability that are embodied in organizational systems remains almost unexplored.

The goal of the overall research program presented in this paper and elsewhere (Tremblay, 1994, 1997, 1998a, b) was to empirically explore the link between (i) technological capability (the causal variable) (ii) the generation of technical changes (intermediate variable) and (iii) productivity growth (the end-result variable). The role of three kinds of 'resources' in contributing to technical change and productivity growth was examined:

a) technologically qualified human resources - more specifically, technical and managerial staff with degree qualifications;
b) aspects of organization and management concerned directly with actualizing the latent change-generating capability of human resources;
c) wider aspects of the organization and management of firms that may influence their change-generating activities.

As mentioned earlier (Tremblay, 1997), the case mills did not show any correlation between productivity growth and technological capability embodied in human resources when narrowly defined, i.e., treating human resources as assets and focusing primarily on the stock of individuals within the firm rather than on the structure of groups and of the overall organization within which individuals work. In contrast, the case mills did show an explicit relationship between firms' technological capability embodied in organizational systems and productivity growth.

Key features concerned with 'resources' (b) and (c) can be exemplified from the findings regarding the two best performing mills D and E. These two mills had the highest total productivity growth scores. They were the only mills that demonstrated a high degree of organizational commitment to change where responsibility for change was diffused to a large part of the workforce. Furthermore, these mills had the largest number of individuals who were committed (highest intensity) to change-generating activities. Moreover, these mills had both the greatest intensity technical change investments unrecorded as capital expenditure and the highest value of minor improvement changes. The latter two elements were of crucial importance for Mill E and gave the mill an undeniable productivity advantage over all other mills at low capital costs (Tremblay, 1998b).

Common elements embodied in organizational systems are found in the best performing mills. These elements, categorized into the various wider organizational dimensions variables, form a set of capabilities necessary to generate a continuous stream of improvement-changes. In particular, it seems clear that in order to motivate employees to commit themselves to change activities, a set of key characteristics is required. Groups of individuals committed to change need a substantial amount of support from top management. Implicitly, a fair level of trust in subordinates by top management is required. This was clearly illustrated by the *Supportive Relationships* variable (score > 6). Other variables also support this argument: A large part of the workforce was involved in the *decision-making* process (score >5.5) at much lower levels (in the hierarchy) than in any of the other mills. Moreover, management made efforts to nurture various learning processes to increase the capability of human resources (score > 6). The formal training given was consciously expanded by other learning mechanisms such as learning via the involvement of employees in change-generating activities. Finally, top management gave its support to employees by providing them with uncommitted resources for change-generating activities (*Organizational Slack*, score > 6)

5.2 The comparative analysis

The comparative analysis of the rates of productivity growth does not indicate large productivity differentials between Indian and Canadian mills. However, the productivity growth mean of the Indian sample is lower than that of the Canadian sample (Table A.1, in the Appendix, Tremblay, 1998a).

The comparative analysis of patterns of technical changes (Table A.1, in the Appendix, Tremblay, 1998b) indicates that total investments are generally larger in Canadian mills. However, such differences are much less apparent when improvement-type technical changes are compared.

The review of the "latent" capabilities (Tremblay, 1997) indicated that Indian mills have a greater number of qualified individuals both in absolute terms and as a ratio to the total workforce or yearly production capacity.

The inter-country analysis did not show significant differences across countries in terms of organizational commitment to change (Tremblay, 1997, 1998a, b) with the exception of the *scale* variable (Indian cases have far larger workforces than their Canadian counterpart) and the *responsibility* variable (Indian mills are more centralized and functionalized and therefore their change-generating activities are confined to specific groups and not generalized across the organization).

The analysis of wider organizational dimensions did not provide a clear dichotomy between the Indian and Canadian mills - the overall patterns of data were very similar apart from the position of the Canadian mills D and E. The latter mills were 'exceptions' among the Canadian sample and not just in comparison with the Indian cases. The overall picture therefore suggests that there was no significant 'country effect' in the data apart from the fact that none of the Indian mills had yet adopted the management structure and behavior that characterized these two Canadian mills.

In conclusion, the inter-country analysis did not indicate that a clear dichotomy exists between industrialized (Canada) and industrializing (India) countries with regard to productivity growth. Similarly, there was no dichotomy in terms of technological capability embodied in organizational systems. Inter-mill differences in productivity growth did not seem to be as strongly influenced by the 'country' context as by the efforts made by individual organizations to generate change. Furthermore, these changes could be explained by technological capabilities embodied in organizational systems. Consequently, the debate regarding the developed/developing countries dichotomy would probably be more fruitful if efforts were devoted to analyzing the resources required to manage and actualize the generation of technical changes.

5.3 Policy Implications

Contrary to most of the literature on technological capability which has adopted a rather narrow perspective regarding the composition of technological capabilities, the present empirical research implies that policy, management and research should focus not only on issues concerned with human capital creation but on organizational issues as well.

This research was not specifically designed to address issues concerned with government policy. Nevertheless the findings do shed some light on some aspects of current policy debate. A recent World Bank (1993, pp.84-85) report, for instance, has emphasized that: "...sustained growth results from the positive interaction of four critical aspects of economic policy; macroeconomic stability, human capital formation, openness to international trade, and an environment that encourages private investment and competition". In the following section two issues will be briefly discussed: (i) human capital creation, and (ii) the combined effects of trade policy and other aspects of a competitive environment.

5.3.1 Human Capital Creation

Recent studies on the role of policy for human capital formation and economic performance have emphasized the central importance of primary and secondary education, implying that developing countries may have overinvested in public systems for tertiary (university) education (for example, see World Bank 1993). One of the findings of the present research appears to be consistent with this view: the apparent absence of a correlation between TPG in the mills and the extent of formal university education of mill staff. However, it is important to bear in mind that the relatively high rates of performance improvement in some of the mills stemmed directly from the implementation of <u>technical</u> changes that were developed and introduced mainly by personnel with significant <u>technical</u> competencies that are usually associated with core groups of people who have higher level university-type education. The key implications for policy therefore are not that university-derived competencies have little importance, but that they should be complemented by further intensive efforts to create human capital <u>within</u> firms.

It is striking to note that it is once again within mills D and E that the intensity of training was the greatest. Moreover, these training efforts were not limited to training for routine operation. They also targeted other technical competencies such as general process understanding, specialized technical skills, statistical methods, and so forth. Mill E, in particular, had the most intensive training program of all mills - with an average investment of 74 000 human-hours per year (nearly 60 hours/human per year) of which 15%, 17% and five percent were concerned with routine operation, general process understanding, and management, respectively. More than 60% of training was concerned with developing specific technical abilities. Moreover, as much as 20% of the work force within mill E was typically involved in change-generating activities, had received training on general pulp and papermaking processes, and were required to master basic statistical methods as a prerequisite for membership in the Ad Hoc groups. Hence, building firm specific skills in the case of mill E was most valuable for change generation. Policies aiming at human capital creation might therefore focus on the development of firm-specific skills such as change-generating capabilities.

5.3.2 Competition and trade policy

The comparative case studies in this research suggest that competition is indeed an element contributing to more intensive technical change and higher productivity growth. Mills D and E were exceptions to the general pattern in two ways: they demonstrated the highest rates of change and performance improvement, and they (or at least their parent companies) operated in market environments that were different from those of the other mills.

In both Canada and India the paper industry was protected from competition from imports, except for the newsprint industry in Canada. Canadian mill E (a newsprint mill and exporter) was therefore confronted by competitors in the international market. Mill D, however, operated in a protected domestic paperboard market. Nevertheless, several of its subsidiary companies had been exposed to intense competition in European paperboard markets and had built up first-hand experience in those markets with the types of technical change that contributed to its high rate of performance improvement in Canada.

In contrast, all the other mills except one operated within a protected market and had lower productivity performance, lower intensities of technical change, and lower degrees of organizational commitment to change. The exception, mill B, produced newsprint within a competitive market, but did not have a pattern of change and performance improvement similar to mill E, - the other Canadian newsprint mill. This suggests that exposure to a competitive environment may not on its own be sufficient to stimulate effective change-generating behavior by firms. What may also be required is that firms have the capabilities, both technological and organizational, to respond to a competitive environment.

5.4 Research Implications

The research has shown that most of the literature on technological capability and learning in developing countries has adopted a rather narrow perspective. In particular, this paper has emphasized the importance of organizational dimensions of technological capability, especially generative capabilities. Moreover, it has supported each of its arguments with hard data on economic performance and technical change generation.

Unfortunately, performing such a study requires a massive amount of data (financial, technical[9] and organizational) and sufficient resources to overcome the costly and arduous task of gathering and processing these hard data. These are perhaps some of the reasons why there is a very limited number of similar studies. However, more studies are needed to further our understanding of the determinant of technological capability in order to generate change beneficial to the population of industrializing countries.

[9] Not only access to detailed financial information (quantity and price) is required for the TP calculation but production data is also necessary to validate the TP indices with other performance indicators specific to the industry. In all the mills surveyed, access to financial data, production data and engineering records was granted without restriction. The accessibility to such wide-scale data made this research most valuable.

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6. Appendix

6.1 Technical change processes (Tremblay, 1998b)

Table A-1 presents the data for the Canadian (A-E) and Indian (Q-T) mills according to their technical change recorded and unrecorded as capital expenditure. Column one presents the mill's TPG ordered by their increasing performance. Column two gives the total technical change recorded as annual capital expenditure - expressed as a ratio of gross fixed assets taken at the last period (end) surveyed (GFA_e). Column three presents the total expenditure committed to improvement-type of changes. Column four presents the minor expenditure (below 0.3% of GFAe) committed to improvement-type of changes only and finally, column five presents technical changes unrecorded as capital expenditure.

6.2 Organizational commitment to change (Tremblay, 1997)

Tremblay (1997), has demonstrated that organizational commitment to change (OCTC) can significantly explain inter-firm differences. The OCTC was assessed by four variables: scale, intensity, role and responsibility (Table A.2). The analysis provided significant elements: First, the responsibility and intensity variables, when examined semi-quantitatively, showed a near linear relationship with TPG. Second, the two lowest performing mills, in terms of TPG (Q and A), only performed troubleshooting tasks and executed changes without generation of new changes. Third, the two highest mills in terms of TPG (D and E) are clearly outstanding with regard to the main group by their OCTC scale. There was a substantial number of individuals continuously or semi-continuously engaged in generating technical changes. Finally, in these two mills, responsibility for change-generating activities was not confined to specific departments but was diffused throughout the organization.

Table A.1: **Underlying patterns of technical changes** (Tremblay 1994, 1998a, b)

MILLS	TPG	Capital Expenditure			
		Recorded			Unrecorded
		Total Investments %GFAe	All Improvements %GFAe	Minor Improvements %GFAe	6 points Likert Scale
	1	2	3	4	5
Q	-2.46	0.5	0.13[a]	0.13	Negligible
A	-2.01	6.7	1.26	0.20	Negligible
R	-0.77	4.9	4.42[b]	0.16	Meager
S	0.14	0.6	0.22[a]	0.22	Moderate
B	0.37	5.3	3.23	0.20	Meager
C	0.51	11.2	6.70	0.28	Moderate
T	0.92	3.9	3.60	0.15	Meager
D	1.09	11.6	10.23	0.32	Significant
E	1.49	7.8	6.57	0.30	Very substantial

GFAe: Gross Fixed Assets at the end of the period surveyed.; [a].Maximum possible value - average value spent on plant machinery; [b].Approximate value from book value of projects versus all expenses.

Spearman Correlations					
Rs	TPG	0.6167	0.7667	0.6360	0.8464
p		*	**	*	***

Rs = Spearman coefficients; p=level of significance for the two-tailed test (* $p<0.10$, ** $p<0.05$;*** $p<0.01$)

Table A.2: **Organizational Commitment to Change Variables and TPG**
(Tremblay 1994, 1997)

Mill	TPG	Scale	Intensity	Responsibility	Role	
Q	-2.46	2	2	2	troubleshooting	(2)
A	-2.01	2	2	2	execution	(3)
R	-0.77	2	3	3	generation	(4)
S	0.14	2	3	3	generation	(4)
B	0.37	2	3	4	generation	(4)
C	0.51	2	4	4	generation	(4)
T	0.92	2	4	3	generation	(4)
D	1.09	4	5	5	generation	(4)
E	1.49	5	6	5	generation	(4)
Spearman Correlations						
Rs	TPG	0.7303	0.9747	0.7303	0.8845	
p		**	****	**	***	

R_s = Spearman coefficients; p=level of significance for the two-tailed test
(* p<0.10, ** p<0.05;*** p<0.01, **** p<0.001)

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