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Organize to Generate Innovation: Tools to Measure Technical Change, Productivity and Change-Generating Efforts

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Organize to Generate Innovation: Tools to Measure Technical Change, Productivity and Change-Generating Efforts*

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Résumé / Abstract

Cet article propose des outils et des méthodes permettant de mesurer des capacités technologiques (capital humain et engagement organisationnel au changement), des processus de changements techniques, et la croissance de productivité. Il examine les relations entre ces diverses mesures. Cette étude est basée sur des données de première main collectées dans neuf usines de pâtes et papiers dans deux pays (Canada et Inde) sur un période de cinq à sept ans. Les évidences empiriques démontrent que la croissance de productivité réalisée grâce à l'engagement organisationnel à générer des changements techniques, n'est pas uniquement le résultat des ressources humaines ayant dans qualifications académiques (capital humain). Dans les usines les plus productives, les activités de changements, génératrices de productivité, ne sont pas exécutées que par des « spécialistes » mais par une plus large population d'employés.

Why is it that firms that compete within the same industrial sector have divergent productivity growth over time? Is this phenomenon related to specific characteristics of their organizations, their human capital, their capital investments or a mix of all of these parameters? This paper provides tools and methods to measure technological capability (human capital and change-generating efforts), technical changes processes and productivity growth. It examines the relationship between these various measures. The case material is based on first-hand empirical data gathered at mill level in two countries (India and Canada) over a period of five to seven years in the pulp and paper sector. The empirical evidence demonstrates that change-generating efforts leading to productivity growth are not only a result of formally qualified individuals (human capital). Change-generating activities were not performed only by "specialists" but by a larger population of workers in the most productive mills.

Mots Clés : mesures de performance, capacité technologique, capital humain, changement technique, engagement organisationnel

Keywords : performance measurement, technological capability, human capital, technical change, organizational commitment

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"If you can't measure it you can't change it" [1]

1. Introduction

The latest World Investment Report [2] stated that business globalization continues to boom and developing countries are gaining importance. Whereas markets within industrialized countries are saturated, those of industrializing nations are moving fast, with increasing growth rates which are, in general, by far superior. This trend is drastically changing the nature of competition and "places a premium not only on price/quality relationships but also on firm-level ability to innovate and to adapt to changing circumstances and demands" [3]. Firms in both industrialized and industrializing countries need to continuously increase their productivity. Investing in technical change-generating activities is believed to achieve this, but to what extent? Why is it that firms that compete within the same industrial sector have divergent productivity growth over time? Is it related to their capital investments? Is it linked to the quality of their investment types? Finally, is this phenomenon related to specific characteristics of their organizations, their human capital or a mix of all these parameters?

This paper provides tools and methods to measure technological capability (human capital and change-generating efforts), technical change processes and productivity growth. It re-examines data presented by Tremblay [4-6]. It deepens the analysis of performance indicators and focuses on the links between technical changes, change generating-efforts and human capital.

Special attention is given to development issues in this paper. It is believed that industrializing countries' contribution to the world economy will be increasingly significant in the years to come. However, to be sustainable, their development must pass through a process of technological capability building not only at a national level, but also at a firm-level. This, in turn, will lead to greater technical change generation, increased productivity growth and healthier economic conditions.

The case material is based on first-hand empirical data gathered at the firm-level (nine mills) in two countries (India and Canada) over a period of five to seven years in the pulp and paper manufacturing sector.

2. Background

This paper is part of a broader research program [4] which addresses 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 in their productivity performance, the nature of their "technological capabilities", and the relationship between the two?

In answering these questions, the research explores the link between technological capabilities (causal variables) and productivity growth (end-result variable) by examining how technological capabilities are actualized into the generation of technical changes (intermediate variables) leading to productivity growth. Technological capabilities is defined similarly to Bell and Pavitt's definition [7,8]. 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. (Other definitions are given in [9-12]).

This paper is based on research which is located at the interface between two different streams of micro-level research concerned with technical change and the economic performance of industrial firms.

One body of research has focused on industrial firms in industrializing countries, examining either their productivity growth paths or their development of technological capabilities - and occasionally both [13-20]. However, there are three limitations to these studies. First, according to Romijn [20], "there is still no suitable set of indicators by which capability at the firm level can be measured more or less objectively, and which could serve as a basis for a systematic assessment of alleged contribution of this variable to productivity increase and growth" [21]. Indeed, there are very few studies which have systematically analyzed the link between technological capability and productivity growth. This may be due to major difficulties encountered in securing the necessary data for productivity growth calculation and proper tools to assess technological capability. Second, most of the studies consist only of case studies of individual firms [22]. Comparative analysis is rare, if not almost totally absent. Third, most of the literature has focused on technological capabilities embodied in human resources or "latent" capabilities rather than on organizational systems within which individuals work. Beer [23] and Kurosawa [24] also make a distinction between "latency", productivity and performance in regards to "potentiality", "capability" and "actuality" [25]. Though their definitions differ from the ones in the present research, the underlying concepts are similar: they stress the importance between what can potentially be done, with what in fact is achieved, as the following formula shows:

$$\underset{\textit{(Productivity of Total Cost)}}{\frac{\text{Total Output}}{\text{Total Cost}}} = \underset{\textit{(Latent Productivity)}}{\frac{\text{Potential Output}}{\text{Total Cost}}} \times \underset{\textit{(Realization Ratio)}}{\frac{\text{Realized Output}}{\text{Potential Output}}} \quad (1)$$

> "The latent productivity is formed in technological, organizational and corporate cultural terms in the course of the corporation's history. The realization ratio expresses the degree to which this latent capability could be manifested, and is the aggregate result of all capabilities of the given corporation during the period under consideration" [24].

Though the left side of the equation can be measured, it is extremely difficult to approximate the items on the right side, especially the Potential Output. However, rather than estimating the "potential output", one may measure the "potential capabilities" and its implementation through technical change generation using the underlying framework of this equation. Therefore, on the left side there could be a total productivity growth index and on the right-hand side there can be indicators of the capabilities embodied in human resources and in organizational systems. The proximate measure of the realization ratio can be given by the technical change generation - the functional linkage between capability and productivity. Tremblay [4-6] demonstrated empirically that human resources capabilities measured as formal academic qualifications (a different measure of "potentiality") did not provide a suitable explanation for total productivity growth differentials [26]. However, he found a positive relationship between the generation of technical change (a more or less equivalent measure of Kurosawa's "realization") and total productivity growth. Finally, empirical measures of organizational commitment to change (employees' involvement in change-generating activities) showed a positive relationship with total productivity growth. These results clearly question the literature which focuses only on human resources competencies or human capital, rather than on organizational systems.

A second body of literature has focused on technical change at the firm level as being a source of improvement. Much of the literature on innovation and technical change has concentrated on two issues. On the one hand, it has centred on "radical" or "breakthrough" changes. What is more, it has been seen for a long time as a "specialist activity, concentrated in the hands of relatively few staff in R&D, engineering, and related functions" [27]. An example of such research is the study by Deolalikar and Roller [28] on patenting by manufacturing firms in India. They used productivity growth as an indicator of the economic effects of innovation reflected in past patenting. Patenting was used as an intermediate inventive output with R&D personnel and expenditures, among other things, as its inputs and productivity growth as the final output. This enabled the authors to study both the production of innovation as well as its impact on productivity growth. The underlying model of that study is similar to the one involved in this research, although the specific variables used are different. It is therefore interesting that the study finds significant positive relationships between (i) patenting (a proximate measure of "technical change"); (ii) R&D personnel and expenditures (aspects of the firms' underlying "technological capability"), and (iii) the growth of productivity. Measuring productivity and performance of R&D at the firm or corporate level involves major challenges. Stainer and Nixon [29] argue that total productivity is the most effective means of control of R&D. Moreover, they advocate that the strategic link between productivity and performance can be explained by measures of capability and latency.

R&D efforts and strategies in the pulp and paper industry are not focused on radical innovations. They are instead oriented towards "i) improving the quality and features of existing products and ii) improving manufacturing processes" [30]. Furthermore, the paper industry's R&D spending is very small (Canada: 0.4% sales, 1985 [30]). What is more, the input of R&D laboratories in the process of change in most case mills analyzed in this paper, can be qualified as little or insignificant [6]. Therefore, the present study concentrates on the other issue: smaller changes and/or incremental changes.

Since the classical studies of Enos [31] and Hollander [32], there has been a dearth of empirical evidence showing that the cumulative effect of small changes can often exceed that of occasional, radical changes. It is only recently that the importance of such changes has gained importance in the literature on total quality management [33] and continuous improvement

[27,34-36 and the recent IJTM Special Issue on Continuous Improvement 37]. Meanwhile, the body of literature on learning curves, production functions [38] and other passive types of learning such as "learning-by-doing" has obscured reality. Bell and Scott-Kemmis [39] show that progress does not occur automatically. Tremblay [5] demonstrated that change-generating efforts are required to generate productivity growth. Finally, Tremblay [6] has empirically demonstrated the importance of this pattern of incremental changes.

There are major difficulties in measuring such technical changes. How does one measure simply, and in a practical manner, this type of incremental change? The same literature also emphasizes employee participation for the generation of change, but very little is mentioned about measuring this. Again, how does one measure this simply, and in a practical manner? Finally, factual and quantitative measurement of performance and productivity growth is frequently problematic.

3. Methodologies

Three types of indicators were used and/or created for this research:

1. Performance indicators
2. Technical change generation pattern indicators [6]
3. Technological capability indicators
   a) Human resources competencies [5]
   b) Organizational commitment to change [5]

3.1 Performance indicators

There is a great deal of confusion in defining performance and productivity [40,41]. For example, in some research, productivity is mixed in with profitability (e.g., ROI measurements of productivity [42]) or with mixed elements like measures of business attractiveness and in-house competence (e.g., "constraint analysis" measurements of productivity [42]). What is more, there is a wide array of measures available [43].

One of the major strengths of this study is its comprehensive data base. For the purposes of this research, data was compiled over a period of five to seven years. It includes both financial, physical and engineering data obtained from mill documentary records and direct observation at the mill level (Table 1). Such a wide spectrum of data permitted the study to choose from various performance indicators.

Table 1: Data obtained form mill documentary records and direct observation

Production data:	• Products: Major grades produced and changes in products over time; • Gross and Net Production of each production unit; • Data on rejects and lost time - per production units; • Energy production: Sources and quantity • Energy consumption per units of production; • Raw material: Fibers processed at the mill per categories such as Bamboo, Bagasse, Reed, Agricultural residues, etc.; Fibers from other sources such as market pulp (National and International), waste paper, etc.; Chemicals; • Labor inputs.
Financial data	• Detailed Profit and Lost accounts; • Detailed Balance Sheets; • Detailed Financial reports to shareholders; • Detailed Capital plans and budgets • Any other internal financial reports available. • These financial documents were searched to find data on the following costs: Materials, Energy, Labor (including overhead), Maintenance, Capital (Financial cost), Capital investments, Depreciation, Sales revenues adjusted for inventory, etc.
Engineering data	• General technical audit: general description of processes and equipment and a list of all the capitalized technical and technological changes. • Detailed engineering records on specific projects

Direct Observation	The following members of the organization were interviewed at each of the mills visited:
	• General Manager (Managing Director)
	• Heads of following departments:
	  • Engineering
	  • Technical services
	  • Production (Pulp mill, Paper mill, other production departments)
	  • Maintenance
	  • R&D laboratory (when located at the mill)
	  • Marketing and Sales (when located at the mill)
	  • Financial and Costs accounting
	  • Purchasing
	  • Human Resources and Training

As for the research design, four elements must be acknowledged. First, the analysis focused on the technical change processes and its underlying set of intra-firm capabilities. Thus, the boundaries of the case studies are the mill itself, excluding sales and shipment of products. What is more, the capabilities of the human resources in choosing various inputs according to their changing price values have no direct impact on the mill’s technical change processes. Though these capabilities are useful to maintain a mill’s competitiveness, the study does not examine this latter issue. In consequence, measures that assess attributes of financial resource utilization (profitability/budgetability measures [43]) are rejected. Profitably indicators though available, did not indicate that differences exist between mills as per their technological capabilities. Some mills had been increasingly profitable, yet this gain in profit margin could partially be attributed to price factors of inputs and not to factors related to the firm's internal behavior. Second, the study is longitudinal - it analyzes performance trends. Therefore, any financial figures must be deflated to a base period. Third, the study is comparative in nature. Therefore, the performance trend indicators need to be capable of performing a firm-level comparative analysis. A homogenous set of data is required. Unfortunately, not all mills collect the same performance data. Finally, quality improvement could not be measured comparatively. Though all mills are producing paper, none of them manufacture exactly the same product mix and grades of paper over the same time periods.

Three types of indicators were used: physical performance indicators, partial and total productivity indicators.

3.1.1 Physical performance indicators

Various "physical" performance indicators were used to differentiate the case mills. Examples of such indicators are given in Table 2.

Table 2: Example of physical performance indicators.

- Paper machine production (MT/day or year)
- Paper machine production efficiency (% actual production/maximum achievable production, adjusted for a specific speed, trim, basis weight and operating time)
- Pulp mill yield (% Pulp produced/Fibers used)
- Power consumption (Giga Joules/MT of finished production)
- Steam consumption (Giga Joules/MT of finished production)
- Labor productivity (kg of finished production/man-hours)
- Lost time (% lost time/operating time)
- Broke (% MT Reject/MT gross production)

3.1.2 Water consumption (Meter^3/finished production)Partial Productivity Indicators

Following the practice of productivity textbooks [44,45], productivity indicators were examined/calculated. Partial productivity (PP) indices were assessed: Material, Energy, Labor and Capital. The indices were calculated as follows for each year (*i*):

$$PPx_i = \frac{\sum_i Ouput}{\sum_i Input_x} \quad (2)$$

x refers to each component: Material, Energy, Labor or Capital.

Each element is priced in "Real Terms" or in constant prices. For all of the various Outputs and Inputs, the base year for deflation is the latest completed fiscal year. As much as possible, Paasche indices were created from mill data for deflation purposes. Such an index requires physical quantity values in each current year and price values of the base period. For example, an Item x of quantity Q of cost C for a period *i* is deflated to the base period *b* as follow:

$$C_i x_{(b)} = Q_{x_i} * \frac{C_{x_b}}{Q_{x_b}} \quad (3)$$

In most modern economic analyses, the orthodox Paasche/Laspeyres indices for productivity change have been discarded in favor of indices which suffer less from the base-weight vs. current-weight problem. Given the data underlying the present analysis, it was possible to use other indices such as the more straightforward Fisher Ideal Index or the use of chain indices such as the Divisia index. However, since the time series are very short (five to seven years) it would not make much difference to the final results. In addition, the comprehension of mill managers of the productivity indices was necessary for constructive discussions. Hence, it was most significant for them to talk about the mills' technical history with financial figures of the latest period - they could compare their past results with their most recent ones. When indices could not be calculated with physical quantities, indices from official government sources were used [46].

Each year *i* was itself indexed to the last period which is the base year = 100. The partial productivity growth (PPG) was assessed by calculating the slope of a linear regression of the productivity index against time (years). Thus, a mill with a PPG equal to 0 is a mill that has shown no improvement in productivity over time. A negative figure represents a decreasing productivity over time, and a positive figure represents an increasing productivity growth. Finally, since the intercept of the productivity curve at year "0" is 100, the value of PPG (or slope of the linear regression) is a percentage of growth per year.

The Output, Material Inputs, Energy Inputs, Labor Inputs and Capital Inputs variables are calculated as indicated in Table 3. Since the Capital Input variable is frequently at the center of productivity debates, the assumptions used in this research are briefly detailed below.

Table 3: Output and Inputs variables calculation assumptions.

Variables	Assumptions and calculations
Output	Sales income adjusted for inventory changes at the immediate outlet of the mill - before shipping. Interest, dividend income and property income excluded from revenue.[47]
Material	Fiber costs in all its various forms; all chemical costs; all operation material costs such as felts and wire replacement, etc.
Energy	Values calculated on the assumption that mills consume energy already transformed into electricity and steam. Productivity gain or losses from energy transformation equipment is not taken in account.[48]
Labor	Blue and white-collar employees at mill level only.
Capital	Working Capital costs, costs of maintenance, real terms linear depreciation.

Capital was calculated in a very simple manner following a method similar to that of Kendrick and Creamer [49]. Yearly real terms Working Capital costs were added to the real terms depreciation as calculated (book value) by each mill's accountants. Stainer [50,51] advocates that replacement cost capital input is a better method than the historic cost adjusted for inflation. Unfortunately, given the wide scope of the comparative research, the complexity of capital equipment used by the pulp and paper manufacturing industry and finally, the age of some mills, it was virtually impossible to calculate such a replacement value. However, the real terms costs of maintenance were also added. The real fixed capital values have been adjusted for capacity utilization. Such adjustment assumes that fixed capital has a cost regardless of intensity of use. However, this measure is necessary to eliminate large fluctuations in capacity utilization, especially for the start-up of greenfield mills such as mill Q and S. In addition, this adjustment reduces the impact caused by the external environment. This is essential when comparing Indian cases constrained by harsh environments with Canadian cases. The utilization rate of Indian mills is very low compared to that of industrialized countries. As discussed by Hayes [52], "this 'depreciation-based' approach to measuring the amount of the capital equipment used in producing a certain product has unfortunate drawbacks. It is essentially just a means for spreading the machine's historical cost over a period of years, and does not reflect the actual current "value" of that equipment." Besides, such a surrogate is far better than excluding the capital costs from productivity calculations.

3.1.3 Total Productivity Indicators

The approach used in measuring total productivity in this research was to use an elementary, additive model. It followed the methods developed by the American Productivity Center [49,53] and also those described in various textbooks [44,45]. Total Productivity for each year (*i*) was calculated as:

$$TP_i = \frac{\sum_i Ouput}{\sum_i Material + \sum_i Energy + \sum_i Labour + \sum_i Capital} \quad (4)$$

In the same way as for the partial productivity indices, each element was priced in constant prices of the latest period. The TP index is a weighted average of the partial productivity indices - the weight being the cost contribution of each input component to the total cost. The total productivity growth (TPG) was assessed as for the PPG. A fifth cost component ("Other Costs" such as insurance, local taxes, etc.) is sometimes included in some textbooks' TP calculation, but not in this study. These elements seldom exceeded 2 percent of total costs and were typically less than 0.5 percent. "Others" were not regarded as elements differentiating the mills' technological capabilities.

3.2 Technical change generation pattern indicators

Tremblay [6] has analyzed technical change processes. The assessment is summarized below. The analysis distinguished between two general categories of technical changes: (a) technical changes recorded by the company as Fixed Capital Expenditure (RFCE); and (b) technical change unrecorded as Fixed Capital Expenditure (UFCE). These technical changes were accounted for in the bulk of operating and/or maintenance expenses.

The RFCEs were identified for each mill in the form of a ratio to the value of the Total Gross Fixed Assets taken at the end of the period covered by this study (GFAe) - using the same base year as for productivity growth indices. Furthermore, the analysis of all RFCE technical changes permitted the isolation of improvement-centred capital expenditure. Finally, the size distribution of RFCE technical changes was divided into four categories (minor 0.3%, small ≤1%, 1%> medium ≤10%, and large >10% of GFAe)

For the UFCE, it was difficult to obtain much quantitative information. However, it could be assessed semi-quantitatively by two measurements. First, using a Likert scale, mills were ordered comparatively by the intensity at which technical change UFCEs were introduced. This was possible since as complete a listing as possible was made of the individual changes (identifiable change projects) from mill level interviews and documentary records. Second, using again a Likert scale, mills were ordered comparatively by the availability of uncommitted resources to generate change activities.

3.3 Technological capability indicators

Tremblay [5] has analyzed two types of technological capability indicators: human capital and change-generating efforts. The assessment is summarized below.

The human resources competencies or human capital were assessed via formal qualifications, focusing on employees with operation, management and technical activities, and possessing at least an undergraduate degree. Two ratios were used: i) the number of degree holders / production capacity; and ii) the number of degree holders / total workforce.

Using a Likert scale, change-generating efforts (or the organizational commitment to change) were measured by four variables: scale, intensity, role and responsibility . The *scale* variable was assessed by the ratio of the number of individuals (regardless of qualifications) committed to change to the total number of employees in a mill. The *intensity* variable assessed the frequency at which change-generating activities were performed. The *role* variable was defined by the type of activities performed (none, trouble-shooting, execution, generation). The *responsibility* variable assessed the amount of responsibility felt by each member of the organization to commit themselves to change.

4 Empirical testing of performance measurements

Physical performance indicators could provide only a partial indication of production efficiency and could not be used except to ascertain the validity of the more aggregated measures of partial and total productivity growth. A solution to this problem would be to create a multi-factor physical performance indicator. However, this would also require basis weight for each partial element and could bias the analysis in addition to being as complicated and difficult as using a total productivity index.

Partial productivity growth indicators, as shown in Table 4, were not suitable for the present study. There were clear differences between the mills in long term trends in their overall production efficiency - as reflected in their productivity growth indices. Several more detailed aspects of this pattern can be noted. In some cases, as in the case of mill A, the rapid rate of falling efficiency was reflected by negative trends on all four of the partial productivity indices. However, for other mills that improved performance more steadily, the relative importance of the partial contributions to improvement differed. For example, mill C increased its total productivity mainly as a result of improved efficiency in material and labor. Mill D increased its productivity mainly as a result of material performance (especially after the start-up of a deinking plant). Mill E increased its productivity on all fronts (of course, except capital due to major investments in the pulp mill plant), and succeeded in increasing its performance regardless of disruptive changes in pulp furnish. Therefore, the surveyed mills had different orientations in improving performance.

Table 4: Total Productivity Growth (TPG) of case Mills (% growth/year)

Mill	**TPG**	Material	Energy	Labor	Capital
A	**-2.01**	-0.67	-2.48	-0.67	-1.41
B	**0.37**	0.64	0.27	2.84	-4.56
C	**0.51**	0.91	0.10	2.06	-3.92
D	**1.09**	4.74	-3.74	1.77	-7.32
E	**1.49**	3.14	0.58	2.07	-3.01
Q	**-2.46**	-4.32	-1.42	-1.62	-1.44
R	**-0.77**	-1.46	-4.83	7.07	-0.20
S	**0.14**	0.63	2.04	-5.51	-0.68
T	**0.92**	-3.19	2.83	5.21	2.40

The total productivity growth indicator proved to be successful. It also corroborated the findings of the other partial productivity indicators and physical performance indicators.

5. Results and discussion

The link between the total productivity growth and technological capability embodied in the human resources (human capital or "latent" capabilities) and also embodied in organizational systems (the change-generating efforts or organizational commitment to change) was examined by Tremblay [5]. A high correlation was demonstrated between organizational commitment to change and total productivity growth. However, productivity growth differentials could not be explained by the "latent" capabilities.

Furthermore, the link between the total productivity growth and technical change processes has also been examined by Tremblay [6]. The total investment, recorded as capital expenditure, did indeed correlate positively with total productivity, yet the relationship was weak. A larger correlation was found between improvement-centred investment, recorded as capital expenditure. Finally, the strongest correlation was found between the two measures of improvement-centred investments unrecorded as capital expenditure.

The present paper examines three new aspects of the measures considered above.

1. The link between the capabilities embodied in human resources (human capital or "latent" capabilities) and the technical change-generating efforts (technological capabilities embodied in organizational systems).
2. The link between the technological capabilities embodied in human resources (human capital or "latent" capability) and the technical change processes.
3. The link between the capabilities embodied in organizational systems (technical change-generating efforts or organizational commitment to change) and the technical change processes.

Table 5 shows the spearman correlations of the "latent" capabilities and technical change-generating efforts. One would have expected there to be a substantial relationship between the degree to which human resources have academic qualifications and their commitment to change. However, all correlations were insignificant, except for the relationship between Responsibility and degree holders /Production capacity. This one significant relationship may be explained mainly by the fact that although human resources in Indian mills are by far more academically qualified (both in absolute and ratios) than human resources in Canadian mills, Indian organizations are much more functionalized and the responsibility for change-generating efforts is given only to qualified human resources. However, in

Table 5: Spearman Correlations
Human Capital ("latent" capabilities) and technical change-generating efforts

Change-generating efforts →	**Scale**		**Intensity**		**Responsibility**		**Role**	
Human Capital↓	R_s	p	R_s	p	R_s	p	R_s	p
Degree holders / Total workforce	-0.1141	-	-0.5985	*	-0.5067	-	-0.5249	-
Degree holders / Production capacity	-0.3222	-	-0.5216	-	-0.6885	***	-0.3912	-
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								

Canadian mills, the responsibility for change is more decentralized and is not limited to formally qualified human resources. In other words, at the two extremes of the spectrum, there are mills (mainly those in India) with a large number of qualified individuals with limited and confused responsibility for change-generating activities and mills with a small number of formally qualified individuals within a large group of individuals committed change.

Even though the correlation between total productivity growth and human resources is not significant, it can be instructive to analyze the contribution of formally qualified human resources to productivity growth. Using a parallel approach to that of Beer [23] and Kurosawa [24], one may divide the total productivity growth by the "potentiality" variable expressed here as human capital or "latent" capability (Degree holders / Production capacity), to give an indication of a mill's ability to make use of its "specialists". This information is presented in Figure 1. Figure 1 clearly shows that some mills are very good at using their qualified manpower (e.g., mill E - also the best performing mill as per its TPG).

The international comparison reveals that Indian mills have been relatively weak in terms of using their qualified human resources. This finding is striking since these mills had by far more qualified human resources in terms of academic qualification than did Canadian mills.

Figure 1

Ratio of human capital on total productivity

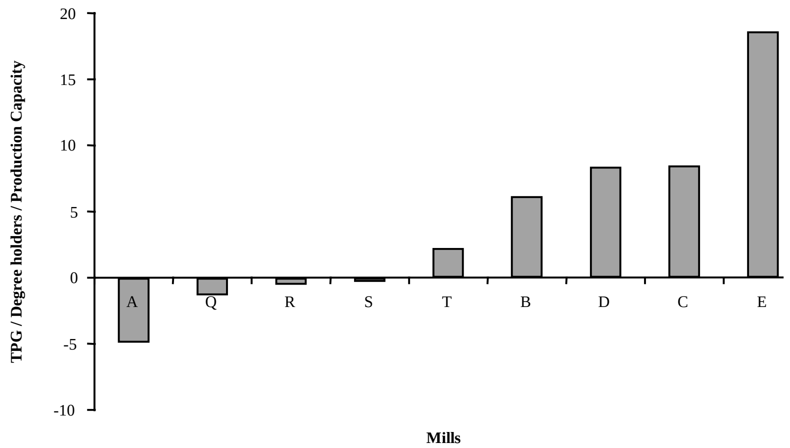

Table 6 demonstrates that contrary to what we might have expected, the correlations between human capital and the technical change processes were not significant except for the relationship between total recorded capital

Table 6: Spearman Correlations
Human Capital ("latent" capabilities) and technical change patterns

Human Capital ("latent" capabilities)→		**Degree holders / Total workforce**		**Degree holders / Production capacity**	
Capital expenditure ↓		R_s	α	R_s	α
Recorded	Total	-0.4333	-	-0.7563	***
	Improvements	-0.6000	*	-0.3291	-
Unrecorded		-0.2565	-	-0.6387	-
Uncommitted resources availability		-0.5874	*	-0.5537	-
R_s = Spearman coefficients; p=level of significance for the two-tailed test * p<0.1, ** p<.05;*** p<0.01, **** p<.001					

Table 7: Spearman Correlations
Technical change patterns and technical change-generating efforts

Change-generating efforts →		**Scale**		**Intensity**		**Responsibility**		**Role**	
Capital expenditure ↓		R_s	α	R_s	α	R_s	α	R_s	α
Recorded	Total	0.5934	*	0.6156	*	0.7214	**	0.3652	-
	Improvements	0.5934	*	0.8293	***	0.8072	***	0.6390	*
Unrecorded		0.7493	**	0.8904	***	0.8855	***	0.7376	**
Uncommitted resources availability		0.7460	**	0.9956	****	0.9036	****	0.7343	**
R_s = Spearman coefficients; p=level of significance for the two-tailed test * p<0.1, ** p<.05;*** p<0.01, **** p<.001									

expenditure and degree holders /production capacity - and it is negative. This correlation to some extent, compared to all of the other non-significant relationships, may look like an anomaly and common sense could argue that all of the other variables are mere aberrations. However, this significant relationship can be explained by the fact that most of the large and medium technical changes had been introduced by external sources (and technological capabilities) to the mills [6]. It did not appear important to mill management to have a large internal pool of academically qualified human resources to contribute to these later changes since it could rely on external expertise. Furthermore, the size distribution of technical changes also helps to explain why the correlation is higher between technical change-generating efforts and the unrecorded capital expenditure variable than with the recorded capital expenditure variable (Table 7). Improvement-centred changes recorded as capital expenditures included large and medium changes made possible by external technological capabilities (over 1% GFAe). Improvement-centred technical changes unrecorded as capital expenditure were all judged small by the mill's personnel (below 1% GFAe) and all generated in-house.

The strongest relationships were found between unrecorded capital expenditures and the intensity and responsibility of the change-generating efforts, as well as the availability of uncommitted resources and the intensity and responsibility of the change effort. These results suggest that in mills where a large number of human resources feel responsible for change-generating activities and the intensity of the change effort is high, a large amount of unrecorded capital expenditures have been made and uncommitted resources to support change actions exist.

6. Conclusion

As reviewed in the background section, most of the literature on technological capability has focused on human capital. Furthermore, the literature on innovation has concentrated its attention on the fact that technical change generation is due to "specialists" such as staff in R&D, engineering and related functions.

The empirical evidence presented in this paper demonstrates that change-generating efforts leading to productivity growth are not only a result of formally qualified individuals. In fact, organizational commitment to change (the "scale" variable), measured by the number of individuals participating in technical change-generating activities (regardless of academic qualifications) does not correlate with the extent to which individuals are academically qualified (Table 5). This was clearly observed through interviews and a review of mill documentary records. Change-generating activities were not performed only by "specialists" and in the case of the best performing mill (mill E, as per TPG), "specialists" comprised the minority of participants in change-generating efforts (less than 30%). The present empirical evidence corroborates Bessant's [27] arguments that continuous improvement is the responsibility of all stakeholders of a firm - not just the "specialists".

The empirical evidence also indicates the importance of changes that are unrecorded as capital expenditures. Managers should invest more time in recording these changes since they clearly contribute to productivity growth. As per the performance indicators, total productivity growth was the best measure of performance to analyze technological capability. Stainer [54] demonstrated that there is a definite move towards the utilization of a total productivity measure by organizations in the UK. This paper encourages managers to follow this trend even if the amount of data required is large and detailed calculation is difficult. Its overwhelming explanation power is worth the effort - the effort to generate changes and innovate.

Technological capability assessed by human resource formal qualifications is a very poor indicator of productivity growth. Based on the present empirical evidence, an analysis of "potential output" predicted by these capabilities would be misleading and precarious. However, using the ratio of total productivity growth / "latent" capabilities is a good indicator of the real contribution of formally qualified individuals. It was observed during interviews and mill visits that some organizations with a large population of qualified individuals used these individuals only for routine operations. This was particularly striking in Indian mills. In other words, the empirical evidence demonstrated that athough an organization may have a potentially good pool of academically qualified individuals, this by no means guarantees a higher level of technical change generation. If these knowledgeable human resources are not responsibilized to perform change-generating activities, how can one expect a growing productivity trend? Therefore, future research would be more profitable if researchers concentrate on experience gained in change generating efforts as opposed to experience accumulated in routine operations (learning-by-doing). Such research could guide policy makers and managers towards a greater appreciation of in-house capability development and a greater utilization of its "latent" capability for change generation. Comparative analyses including firms in developing countries would be most profitable.

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