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Beyond the 'Creative' Side of Innovation: Exploring Outcomes of Firm-level Innovation Capability Building

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Abstract
This paper examines outcomes of firms’ innovation capabilities in natural resource-processing industries in an emerging economy. Based on fieldwork evidence of six large forestry and pulp and paper firms in Brazil (1950-2010), this study finds that: (i) in terms of innovation capability-building, the firms took a *different direction* in terms of technological development than global leaders and introduced a qualitatively different segment at the international technological frontier; (ii) as these firms reached world-leading capability levels, different outcomes could be identified: implemented innovations, improved operational and environmental performance, the diversification of output and spill-overs, and welfare outcomes. Therefore, firms’ capability-building efforts to create new technological trajectories do pay off in terms of generating benefits for not only the innovative firms themselves but also to the industry and, consequently, the economy. These efforts should receive specific policy attention and support.

Keywords: innovation capability building; latecomer firms; natural resources; competitive performance; Brazil.

JEL: M1, O3, Q

1. Introduction

In this paper we are concerned with some of the consequences of the attainment of world-leading levels of innovation capabilities by firms in developing and emerging economies, known as latecomers. Despite the relevance of understanding the outcomes of firm-level innovation capability building to researchers, corporate actions and policy making, there has been a surprising scarcity of systematic investigation of this issue in the related literature.

Over the past few decades, significant attention has been devoted to the importance of innovation capabilities and the underlying learning processes or knowledge-building activities that function as sources of firms' competitive performance in both advanced and developing/emerging economies. Specifically, great emphasis has been placed on the 'creative side' of innovation activities, in terms of investigating the nature of firms' innovative capabilities, either within and outside firms, and the various sources of knowledge with regard to developing, sustaining and nurturing the firms' innovation capabilities and related organisations. However, less attention has been devoted to the 'outcomes' of the accumulation of these capabilities at the firm level.

Such neglect in the investigation of outcomes of innovation capability building is particularly notorious in the context of latecomer firms. Most researchers have been concerned with the paths and sequences by which firms move from production to successive levels of innovation capabilities in association with the nature of sources of innovation capability building or learning processes. However, the consequences of such creative efforts have been under-researched. Additionally, research on innovation capability-building paths and its consequences is particularly scarce with regard to latecomer natural resource-processing industries. Consequently, these industries, which are highly relevant to the economies of several developing and emerging market countries, have been subjected to common and negative generalisations in terms of technological development and related outcomes, which may generate inputs that are misleading for policy makers and corporate managers.

By drawing on first-hand and long-term firm- and industry-level evidence, this paper examines the issue of latecomer innovation capability-building paths and explores outcomes that may be directly or indirectly associated with firms' technological capability-building processes. These issues are examined in the context of six large firms in forestry, pulp and paper industry in Brazil during the period of 1950-2010.

This paper contributes to the research field and policy debate on technological development in developing/emerging economies by (i) clarifying the consequences of innovation capability building paths for latecomer firms; (ii) shedding new light on the academic and policy debate on the role of natural resource-processing industries in industrial innovation and growth in developing and emerging economies; (iii) generating insights for corporate strategy as well as for government policy geared towards technological capability building and industrial innovation; and (iv) suggesting conceptual, methodological and empirical frameworks and providing new insights for further research.

The remainder of the paper is structured as follows. Section 2 contains the study background leading to the research questions around which this paper is organised. Section 3 presents the conceptual framework for addressing the research questions, and Section 4 contains the methodological approach to answering the research questions and the study's empirical context. Section 5 presents the findings and is followed by discussions in Section 6. Finally, Section 7 outlines the paper's conclusions and implications.

2. Study Background and Research Questions

Systematic research interest in the consequences of innovation began with J. Schumpeter (Schumpeter, 1928). Based on a macro-level perspective, his works were concerned with the consequences of radical innovations for economic development. From an industry-level perspective, Enos (1962) focused on small-scale and continuous innovations. By drawing on evidence from the petroleum refining industry, he found that the cost reductions achieved through continuous improvements in the four major process technologies were greater than the cost reductions achieved when these technologies were introduced. In a similar vein but based on a micro-level perspective, Hollander (1965) systematically examined DuPont's plants in the US and found that cumulative minor technical changes, most of them supported by changes to the firm's industrial organisation, were responsible for more than 70% of the total cost reduction achieved within the firm and were greater than the impacts of major technical changes.

Edith Penrose's (Penrose, 1959) and Alfred Chandler's (Chandler, 1962) classical case studies made subsequent important contributions to our understanding of the consequences of innovation. Their studies demonstrated that by innovating their resource base through product and geographical diversification, firms could achieve growth, in the sense of transformation, and competitive performance. Chandler's case studies (Chandler, 1962) also created a basis for our understanding of the remarkable business performance outcomes that can be achieved with organizational and managerial innovations. However, over the following years, such carefully crafted and detailed case studies became scarcer.

Other types of studies appeared to examine some of the impacts of research and development (R&D) activity and expenditures and patenting efforts on firms' performance (e.g., Mansfield, 1968; Comanor and Sherer, 1969; Griliches et al., 1991). Especially since the mid-1990s, such studies have influenced the emergence of further investigations into the consequences of innovation, proxied as R&D expenditures and patenting statistics on firm performance in terms of size, growth rate, productivity, productivity growth rates, and profitability in firms and industries in Europe and North America (e.g., Audretsch, 1995; Gerosky et al., 1997; Del Monti and Papagni, 2003).

Although the abovementioned studies have yielded explanations of the effect of innovation on firm performance, they focus on leading and highly innovative firms and industries that are located in advanced economies. In the context of these firms, innovation capabilities generally *already exist* because the firms normally operate at or near the international frontier of innovation. Therefore, researchers tend to focus on how these firms *exploit* and *augment* such innovation-related resources to push the international technological frontier forwards. Consequently, it is understandable that related studies track innovation performance on the basis of patent citations and/or R&D expenditure.

However, in contrast to the situation in advanced economies, those firms that operate in developing or emerging economies may be characterised as 'initially imitative', regardless of how dislocated they are from markets and technology sources (Bell and Figueiredo, 2012). These firms must first familiarise themselves with various ways of acquiring knowledge to *learn* how to undertake production and to engage in innovation activities at a basic level (Bell and Pavitt, 1993; Kim, 1997).

There is indeed a relatively well-consolidated research tradition devoted to the investigation of processes of innovation capability building in latecomer firms. This tradition began during the mid-1970s with a programme of studies led by Jorge Katz in Latin America, which gave rise to the research field focussing on innovation capability building in latecomer firms, as the studies performed the following (Bell, 2006): (i) emphasised the *dynamics* of micro-level paths of capability accumulation; (ii) explored the role of the learning mechanisms underlying those paths and, particularly, explored some of the implications of different patterns of capability building for the improvement of firms' performance, including growth in productivity and operational improvements, as noted by Bell (2006). For instance, Dahlman and Fonseca (1978) found that rapid rates of operational improvement at a steelmaker in Brazil (Usiminas) were associated with continuous and competent in-house capability building efforts, from production-based to intermediate innovation activities. Dissimilarly, Katz (1987) found that moderate labour productivity growth at a DuPont rayon plant in Argentina was associated with intermittent efforts to improve the plant's operating standards processes and products. However, Bell et al. (1982), who focussed on an unsuccessful case, found that the poor performance improvement of a steel galvanising plant in Thailand derived from the absence of firm efforts to achieve innovation capability building.

Since these classical studies, there have been only few studies on the implications of capability building for the improvement of firms' performance. For instance, Mlawa (1983) found slow and negative rates of productivity changes to be associated with absent innovation capability building efforts in five Tanzanian textiles mills. By drawing on a comparison between two steelmakers in Brazil, Piccinini (1993) demonstrated that the company that developed technological capability by utilising interactive knowledge flows achieved better energy performance than the company that did not.

Building on these studies, Figueiredo (2002) examined the differences between two large steelmakers in Brazil (Usiminas and CSN) in terms of the manner and speed of their capability accumulation paths and implications for their improvement in operational performance over their lifetimes of 35 and 50 years, respectively. Furthermore, he examined implications of capability building with regard to economic performance differences between these two firms. The study demonstrated that Usiminas outperformed CSN in terms of all 14 indicators, especially during the period of 1963-89. Consequently, Usiminas was able to catch up with international competitive levels of operational performance more rapidly than CSN.

Also examining these issues in natural resource-processing industries, Dijk and Bell (2007) found that, in the pulp and paper industries in Indonesia, some firms were able to quite rapidly narrow the gap between their *production* capabilities and those of other firms at the international production frontier, thus attaining an impressive level of competitive performance. However, most of these firms did not move towards significant levels of *innovation* capabilities, thus remaining far behind the international innovation frontier. Also examining the paper industry in West Java, Indonesia, although from a narrower unit of analysis based on 29 paper machines at six firms, Jonker et al. (2006) found a significant association between yield, their primary indicator of capabilities, and value added. Their findings suggested that improvements in technological capabilities at the machine level contributed to the economic performance of these paper machines. In line with Dijk and Bell (2007), the authors also found that the Indonesian paper industry has grown through investments in embodied technologies rather than indigenous capability building.

However, in recent years, studies exploring the different types of outcomes of technological capability accumulation in latecomer firms, especially in the context of natural resource-related industries, have been rare. Such a scarcity of studies contributes to the emergence of common views and evidence-free (and negative) generalisations regarding technological innovation capability-building processes and their outcomes for latecomer firms and industries. Such views lead to the emergence of a misleading notion of the industrial reality, which potentially generates confusing inputs for policy making and corporate actions.

Such generalisations appear to proliferate with regard to natural resource-related industries in developing and emerging economies, especially Latin America, a natural resource-rich context. For instance, as argued in Cimoli and Correa (2005), natural resource-related industries tend to be deemed merely ‘mature sectors’, producers of ‘commodities’ with very little (if any) involvement in innovative technological activity. Castaldi et al. (2009) claim that that natural resources and natural resource processing industries (such as the pulp and paper, iron and steel, and vegetable oil industries) are “characterised by a low knowledge content and low opportunities for technological and organisational learning.” (pp. 64-5). However, such statements are not properly substantiated by empirical evidence on innovation capability building in natural resources industry firms. There is a corresponding scarcity of evidence of the consequences of the technological activities undertaken within natural resource-related firms.

Nevertheless, previous research has indicated that Brazil’s forestry, pulp and paper industries offer a rich empirical setting for the examination of this type of innovation capability-building path. For instance, Scott-Kemmis’s (1988) pioneer study examined firm-level capability development in these industries in Brazil (1940-1970) and captured embryonic research and development (R&D) activities with the aim of developing new varieties of eucalyptus for pulp making. Later, Dalcomuni (1997) found that five large Brazilian pulp exporters achieved internationally recognised environmental performance involving research into bleaching technologies for pulp production processes and research linked to upstream forestry activities. However, studies on the real nature of the technological capability adopted from the primary firms in the forestry, pulp and paper industries in Brazil from the 1950s and particularly from the 1970s to 2010, and the primary outcomes of such paths are scarce.

Therefore, this paper explores outcomes of firm-level innovation capability accumulation efforts in a set of firms in natural resources industries in an emerging economy, specifically, the forestry and pulp and paper industries in Brazil, by asking the following questions: (1) To what extent have these firms developed innovation capability over time? (2) If they have developed innovation capability, what types of outcomes have they generated over time? The conceptual framework for addressing these questions is presented the next section.

3. Conceptual Framework

This section provides the conceptual foundation for the examination of the research questions underlying this paper. We begin with a conceptual approach to latecomer firms' innovation capability building and potential related outcomes. Then, we demonstrate how these concepts are operationalised to achieve solid construct validity.

3.1 Pathways pursued by latecomer firms in the accumulation of innovation capabilities

Firms' capabilities include a stock of resources that permit them to undertake *production* and *differing degrees* of innovation activity. Such capabilities both involve the nature of 'human capital' (i.e., specialist professionals, knowledge bases and skills/talents that are formally and informally allocated within specific organisational units, projects and teams) and 'organizational' aspects (the firm's internal and external organizational arrangements such as their routines and procedures, linkages, and managerial systems (Bell and Pavitt, 1993; Leonard-Barton, 1995; Kim, 1997; Dutrénit, 2000; Teece, 2007). In line with previous relevant studies (Bell and Pavitt, 1993, 1995; Choung et al., 2006), this paper distinguishes between *production-based* and *innovation* capabilities and focuses on the development of the latter capability.

In this paper, the notion of innovation capability development (technological catch-up) reflects a narrowing of the gap between firms in terms of their capability to undertake *innovative* activities, or, in other words, closing the gap between a firm and the innovation 'frontier'. However, in the 'catch-up parlance', the term 'catch-up' suggests a single pathway, along which firms distributed are distributed seeking to reach a technological frontier, which is defined as an end-point or even a moving target previously defined by global incumbents.[1] Instead, this paper considers a technological frontier to be a fluid area or horizon to be explored and the notion of catch-up herein also encompasses so-called 'overtaking'.

Therefore, as the fluidity of the technological frontier may be explored by new entrants, which may engage in disruptive innovations and challenge incumbents firms (Christensen, 1997; Christensen and Raynor, 2003), latecomer firms may accumulate capabilities and create new technological segments in the technological frontier, with which they may pursue significantly new innovation *directions* that depart from the trajectories previously mapped out by earlier innovators, thus introducing *qualitatively different segments* of the international innovation frontier (Bell and Figueiredo, 2012).

3.2 Outcomes of firms' innovation capability-building for competitive performance

As argued in Dosi (1985, 1988), asymmetries between firms in terms of their operational performance are permanent. Firms can be generally ranked as 'better' or 'worse' according to their distance from the technological frontier. The achievement of distinctive performance is associated with levels of innovation capability that firms attain, which allow them to undertake innovative activities (Dosi, 1985; Pavitt, 1991; Lall, 1992; Bell and Pavitt, 1993). Innovative activities that firms undertake may vary in terms of an innovation degree of technological/market 'novelty'– the extent to which it differs from existing technologies, which allows innovations to range from innovations that are close to being pure imitations to those that are fundamentally different from anything currently existing (OECD, 1995). This type of differentiation has been widely used, especially in analyses of innovation in latecomer firms. Some of the important methods of identifying degrees of novelty were made in the 1960s and remain particularly useful today.

For example, with reference to the history of process innovation in petroleum refining, Enos (1962) distinguished between what he called the Alpha phase of innovation (the initial invention and commercial innovation of technologically novel processes based on new technological principles) and the Beta phase (successive improvements to novel processes that were created during a preceding Alpha phase). Hollander (1965) examined aspects of Enos's Beta phase innovation, using the example of the technical changes in rayon production that DuPont implemented a period of approximately 30 years, during which the company built a succession of new plants.[2] He demonstrated that process innovation did not necessarily depend on substantial investment in a new plant that embodied technological advances. Instead, a succession of small improvements could also be 'engineered into' existing plants during their lifetimes. He also demonstrated that a considerable proportion of such innovation could be based on the firm's existing stock of knowledge, in terms of that held by engineering departments and technical groups closely associated with production, rather on the development of new knowledge via formally organised R&D.

A major contribution of these two studies was their estimates of the relative economic importance of the various types of change – a valuable aspect of analysis that, surprisingly, has rarely been undertaken in recent years. Both cases demonstrated the considerable economic significance of minor/incremental forms of innovation. Enos demonstrated that the cumulated economic gains resulting from successive improvements to existing processes (the beta-phase of technological progress) were as significant in terms of their economic effects as the step-jump gains following the initial commercial innovation of novel processes (the alpha-phase). Hollander demonstrated similar patterns in the case of DuPont's 'minor' technical changes in rayon production. However, despite the economic benefits of these types of innovation, they may be considered sustaining innovations (Christensen and Raynor, 2003) and, compared with radical or disruptive innovations, they are less likely to guarantee long-term growth and technological leadership for companies (Pavitt, 1991, 2005; Tidd et al., 2005).

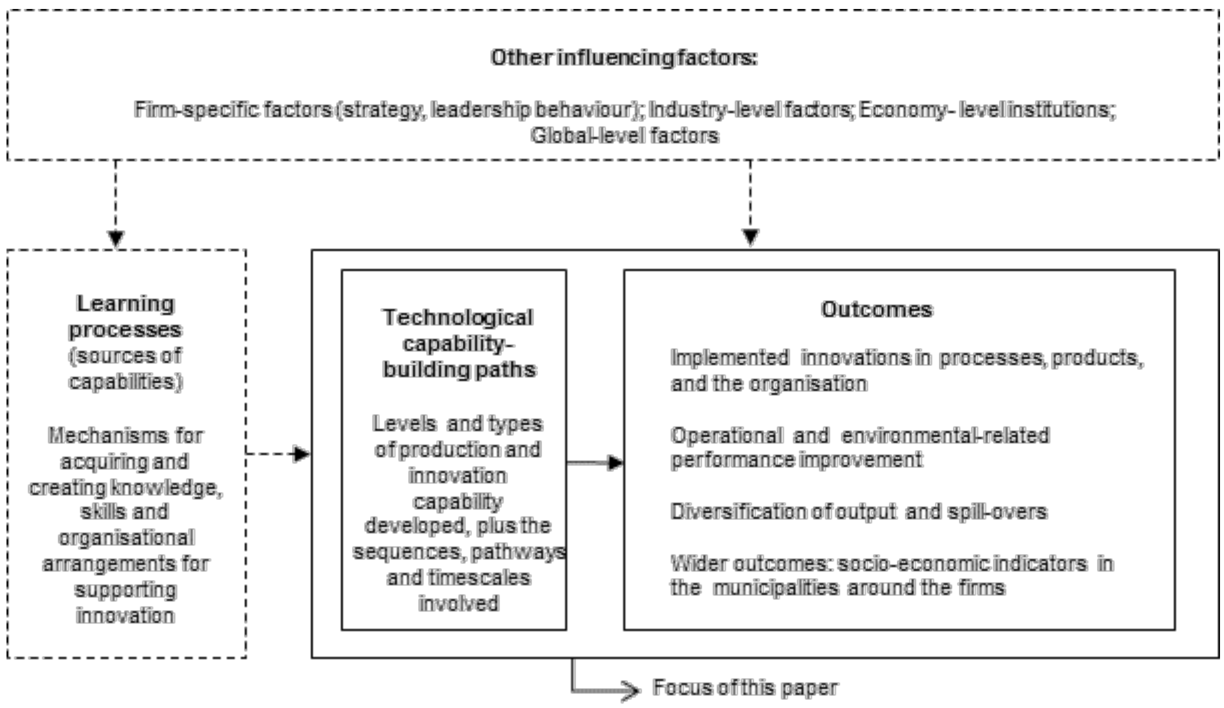
Additionally, the accumulation of innovation capabilities may contribute to the diversification o output either within the firm or externally via spill-overs. In contrast to the preoccupation with 'science parks' and similar initiatives as vehicles for the fostering of new enterprise creation through spillovers from R&D in research institutes and universities, less attention has been devoted to the generation of spillovers from innovation capability that has been developed in firms. Such spillovers may take the form of new enterprise creation through the use of more or less formally organised spin-off mechanisms. These mechanisms might involve a sequence such as the creation of internal 'units' of new activity, which are transformed into subsidiaries and then spun off as independent firms (Bell and Figueiredo, 2012), which may take the form of new enterprise creation through the use of more or less formally organised spin-off mechanisms such as the following: (i) the creation of new types of economic activity; and (ii) involuntary spillovers, as in the case of individuals or small teams who have constructed a base of technological and/or market competence and leave a firm to begin a business based on new-to-the-economy innovations. These teams often appear to have been concerned with supplying inputs to the firms that were initially responsible for creating and accumulating the capabilities that spilled over. This second type of spill-over is briefly explored in this paper.

However, there is interest in broader types of outcomes in the technological development literature and the business literature. Initially, there was concern regarding the impact of technological development on the distribution of income and employment (Stewart, 1978; Kaplinsky, 1990). Since the early 2000s, there has been renewed interest in the impacts of firms' activities, particularly their technological related activities, which extends beyond issues such as capital and labour to focus on energy, materials and natural resources. This interest has been based on a type of win-win technology that reduces both costs and environmental damages. A large portion of the studies addressing these issues have emphasised the role of incremental innovation efforts in achieving these goals. For instance, by drawing on evidence of energy-saving achievements in a cement plant in Thailand and waste-reducing measures in an electronics cluster in Malaysia, Rock and Angel (2005) and Rock et al. (2009) have stressed the importance of engineering-based and incremental innovation in contributing to sustainable impacts of technical change. In other words, it has been argued that latecomer firms' progressive accumulation of innovation capabilities firms may contribute to greener industrial development (Bell and Figueiredo, 2012).

Another type of approach is similar but involves a broader business perspective, which, to an extent, involves technology and innovation aspects in terms of not only with solely product innovation aimed at the bottom of the pyramid – BoP (Prahalad, 2006) or corporate 'social responsibility', but also wider welfare impacts. For instance, through his 'blended value' approach (Emerson and Twersky, 1996) argues that corporations can increase shareholder value by increasing the positive social and environmental impacts of their work while simultaneously addressing the concerns of wider stakeholder groups. Such an approach is consistent with the 'sustainable value portfolio' perspective (Hart and Milstein, 2003), in which environmental sustainability and profits are viewed not as trade-offs, but rather as sustainability generating profit. In a similar vein, Porter and Kramer (2011)'s the 'shared value' approach argues that firms' achievement of competitive performance involves the creation of economic value in a manner that also creates value for society by addressing its social progress needs. Indeed, as argued in Porter and Kramer (2011), the notion that the purpose of the centring of a corporation on the creation of shared value and not profit *per se*, will drive the next wave of innovation and productivity growth in the global economy. However, there is a lack of empirical evidence in support of such perspectives.

By drawing on the above studies and in relation to the research questions previously outlined, we argue that latecomer as latecomer firms engage in the development of world-leading innovation capability, they are likely to generate different types of outcomes that may benefit not only the innovative firms themselves but also the industry and their economies. These issues constitute the components of the conceptual framework that underpins this paper (Figure 1).

Figure 1. The paper's conceptual framework



The remainder of this section outlines how the constructs underpinning the analytical framework and questions are operationalized herein.

3.3 Operationalising the constructs

3.3.1 Innovation capability building in latecomer firms

With regard to the operationalisation of the capability building construct, over the past two decades, in the context of advanced economies the assessment of innovation capabilities has been heavily based on quantitative measures such as R&D intensity and expenditures and patent counts/citations (Hagedoorn and Cloodt, 2003). Although it has been recognised that such measures have limitations as proxy indicators of innovative activity (Teece, 2007), they have been widely used in the innovation literature. However, such indicators reflect situations in which significantly deep levels of innovative capability already exist. Such measures thus reveal little about the prior process of developing and accumulating capabilities up to the point at which they begin to generate measurable R&D activities or officially recorded patenting. Therefore, these measures are not well suited to capturing data on latecomer firms on pathways of innovative capability building (see Bell, 2006; Bell and Pavitt, 1993; Lall, 1992). Tackling such a process is crucial for the study of innovation capability within latecomer firms.

Consequently, in this paper, we adopt an approach that has been the primary basis of research in this area since the earliest studies of the innovation capabilities of latecomer firms (Katz, 1987; Lall, 1987; Lall, 1992). This approach involves the direct acquisition of descriptive information on firms' technological *activities*. Differences in the qualitative characteristics of these activities have been deemed to reflect differing categories of underlying technological capabilities. The focus on *activity* reflects a concern with process and dynamics.

Specifically, this paper draws on a modified version of the typology developed in Lall (1992) and further refined in Bell and Pavitt (1995). The modified version of this typology identifies 'levels' of innovative capability that range from 'basic' to 'world leading' and are consistent with the characterisation of innovation as *degrees of novelty* (new to the firm, new to the economy and new to the world) and complexity in terms of the processes, products and organisation and is thus in line with the Oslo Manual (see OECD, 2005). Such a typology has been used intensively and successfully in studies, with different degrees of capability level disaggregation, which have reconstructed historical paths of capability accumulation over considerable time periods (e.g., Dutrénit, 2000; Figueiredo, 2002, 2010; Dantas and Bell, 2009) and studies have covered histories of capability accumulation in a much larger number of firms, although usually over shorter periods (e.g., Hobday et al., 2004; Tsekouras, 2006; Iammarino et al., 2008; Ariffin and Figueiredo, 2004; Ariffin, 2010). Rather than identifying capabilities in terms of the specific resources entailed therein, these works have identified levels of innovative *activity* and then inferred the various levels of capability that underlie patterns of *innovative performance*. A summary of the typology tailored for use in this paper is provided in Table 1. The first column shows four levels of innovative performance that extend from 'basic' to 'world leading'; the second column provides illustrative examples of these levels of capability.

Table 1. Typology to assess firms' innovation capabilities (condensed version)

Levels of capabilities		*Illustrative examples of these levels of capabilities*
Innovation capabilities	World leading [6]	Able to undertake cutting-edge innovation that provides the firm with a world-leading technological and market position in forestry, pulp or paper .
	Advanced [5]	Able to close in on global leaders in terms of introducing innovations based on fast-follower kind of strategy thus achieving a competitive position in local and export markets, but not as leader.
	Intermediate [4]	Able to implement relatively complex modifications to forestry techniques and to pulp and paper making processes and products. These permit the firm to achieve and sustain a competitive performance within the local national or niche markets.
	Basic [3]	Able to implement of basic levels of innovations which are novel to the firm and allow the firm to sustain a competitive performance in a regional market.
Production capabilities	Advanced [2]	Able to undertake production/manufacturing activities based on world-class production and management techniques so that firm closes in with the international production frontier. The supplies highly strict export markets based on highly respected international certifications.
	Basic [1]	Able to undertake manufacturing activities based on local and regional standards to meet local/regional markets.

Although the above framework emphasises those capabilities that are internal to the firm, it also recognises that a substantial part of a firm's capability to innovate is grounded in the activities of other organisations (e.g., consulting firms, research institutes, and universities). Consequently, the development of innovation capability is not necessarily confined within the boundaries of a firm but may instead involve several interdependent actors. However, for the firm to gain access to such a breadth of knowledge, it must develop a substantial level of in-house expertise (Mowery, 1983) or absorptive capacity (Cohen and Levinthal, 1990), as well as a demand for local R&D outputs (Bell, 1993). Such an approach is particularly appropriate when latecomer firms engage in the development of path-creating innovation capability at an *early* stage in their development, as examined herein.

3.3.2 Outcomes of innovation capability building

'Outcomes' will be examined as the 'impact' of technological capability building-paths on different indicators of performance, which are organized as follows: (i) *implemented innovations* of processes, products and the organisation; (ii) *operational and environmental performance* (e.g., process quality, productivity, costs, energy consumption, water consumption, product quality, air, and solid and liquid effluent emissions); (iii) the *diversification of output* into new types of business lines and industries and the generation of *spin-over*, especially in terms of small and medium enterprises (SMEs) suppliers of goods and specialised services, which originate within large firms and/or are stimulated by them; and (iv) *wider or 'welfare' outcomes* in the form of the evolution of socio-economic indicators in the municipalities in which the case firms are located (e.g., income per capita, illiteracy rates, and the proportion of households with adequate sanitation; and the municipality development index).

4. Methodology and Empirical Context

To answer the abovementioned research questions, the design of this study is based on a process approach, longitudinal evidence covering decades, and on an in-depth case study involving firms of a similar industrial sector and is thus in line with Pettigrew (1990) and van de Ven and Poole (2005). Such a research strategy proved appropriate for the tackling of issues entailed by the research questions because it facilitates understanding of what lies behind a subtle and under-researched phenomenon whose details and nuances would not be captured by other methods, especially aggregated analysis derived from purely quantitative methods (Eisenhardt, 1989; Strauss and Corbin, 1998; Yin, 2003). The original study underpinning this paper sought to examine the process of innovation capability building and the underlying learning strategies present in latecomer natural resource-based industries, focusing on the pulp and paper industry in Brazil. This empirical study involved a four-year fieldwork campaign (2006-2009, with a follow-up in 2010) and the intense triangulation of data-gathering techniques involving exploratory, pilot, and main fieldwork phases. Below we outline additional aspects of the research design and methods such as empirical setting, sampling, evidence-gathering strategies and analysis.

4.1 Empirical context

The study reported here is based on natural resource-based industries located in an emerging economy, namely the pulp and paper industries based on eucalyptus forestry. The pulp and paper industries are highly intensive in capital, processes and scale (Pavitt, 1984), while forestry itself is also increasingly knowledge science-based. The paper-making process involves the conversion of wood chips into pulp, which is processed to create paper. Pulp, the primary raw material used in papermaking, is obtained from trees such as pine (long-fibre or softwood) or eucalyptus trees (short-fibre or hardwood). Planted forests are renewable resources for diverse industries based on raw materials from fibres and lignocelluloses, particularly the pulp and paper industries. Trees that yield more cellulose generate gains across the entire production chain in the form of savings resulting from tree harvesting and transportation, which minimises the expansion of forests and reduces effluent waste. To achieve and sustain a global competitive position in this industry, firms must master innovation capabilities *near* or *at* a world-leading level, especially in forestry research in terms of the development of new genetic material.

In 2009, Brazil ranked as the world's fourth-largest pulp producer (all types), the largest producer of hardwood pulp ('eucapulp'), and the ninth-largest paper producer. All pulp and paper produced in Brazil is derived from planted forests. Although the pulp and paper industries in Brazil consist of more than 200 firms, approximately 85% of the total output derives from approximately 10 large firms. Brazil holds a leading market position in these industries, largely because of the innovation performance achieved by leading firms. Thus, in recent decades, Brazil has held a stronger leading market position in these industries, largely because of the innovation performance achieved by leading firms. From 1970 to 2009, Brazil's exports of pulp and paper increased, respectively, by 14.2% and 22.3% annually on average, while the average growth rates of Norscan countries were 0.18% (pulp) and 2.1% (paper) during that period. Brazil also achieved a superior export growth rate of pulp and paper exports in relation to other developing economies.[3]

4.2 Cases selection

Considering that our research interest in examining the implications of the learning strategies for variability across firms in similar industrial sectors, we opted for a theoretical sampling approach (Miles and Huberman, 1994; Strauss and Corbin, 1998). Therefore, we selected information-rich cases from which we can learn a great deal about issues of central importance to the purpose of the research (Patton, 1990) and that provide powerful examples of the phenomenon under study

(Siggelkow, 2007), including exemplary cases (Eisenhardt, 1989). The longitudinal design, in combination with a theoretical sampling approach permitted us to gather evidence of the accumulation of innovative technological capabilities and different types of outcomes.

In addition, the case selection process required the firms to satisfy the following criteria: (i) accounted for nearly 85% of the pulp and paper output in Brazil; (ii) were large exporters and/or domestic market suppliers; (iii) occupied relevant market positions in the world market. This process led to the selection of six firms and their particular business lines in the forestry, pulp, and paper industries (see Table 2). These firms are located in four states in Brazil. This number permitted the research implementation without amassing an unmanageable volume of information (Eisenhardt, 1989).

Table 2. The selected cases

Selected firms	Start-up year	Ownership	Business lines		
			Forestry [7]	Pulp [9]	Paper [11]
Alpha	1978	Brazilian	✓	✓	None
Delta	1945	Brazilian	✓	✓	✓
Theta	1974	Foreigner	✓	✓	✓
Kappa	1941	Brazilian	✓	✓	✓
Sigma-A	1988	Brazilian	✓	✓	✓
Sigma-B (d)	1988	Brazilian	None	✓	✓

Notes: (a)-(c): Their coverage in this study is from 1990; (d) Sigma-B does have forestry operations, but this business line is not covered in this study.

4.3 Evidence gathering process

We drew on the triangulation approach to evidence gathering to achieve robust internal validity and reliability (Jick, 1979; Eisenhardt, 1989; Yin, 2003). Specifically, we used open-ended interview designs, along with other evidence collection techniques, to reduce recall error and to reconstruct historical paths of capability accumulation and underlying learning mechanisms over considerable time periods. Therefore, during the pilot and main fieldwork, our data collection involved 155 formal 44 informal interviews (from one to three hours in length), 19 direct observations, and several consultations of archival records. Eleven formal interviews and 15 archival consultations were conducted at industry-related organisations (e.g. industry associations, consulting firms, suppliers, universities and research institutes).

We began by contacting the top-rank director of each firm to clarify the purpose of our research and to establish its legitimacy and relevance. Their approval allowed us to tap into various sources of information (e.g., industrial directors, managers, engineers, researchers, technicians, consultants, human resources and engineering departments, R&D units, labs, shop-floor, retired staff and archival records). Open-ended interviews were conducted using an interview guide that was constructed in the light of our analytical framework, constructs and typologies. Double and triple-checks of specific events were performed via e-mail and/or phone calls. After the completion of the main fieldwork, 259 follow-up questionnaires were sent to target informants. Because most of the informants had previously met the researchers during the fieldwork, a 95% response rate was achieved. The application of the questionnaire sought to expand the findings and, especially, to systematise evidence of the firms' innovative activities and various outcomes.

4.4 Analysis process

The analysis process began during the fieldwork phase. As we conducted the field interviews, we constructed associations between the manner in which each firm used its learning mechanisms and accumulated innovation capabilities over time. Such insights along with the interview transcripts, were de-briefed among the researchers as an initial first step in the analysis process. Formal analyses involved the following techniques: (i) harmonisation and combination of the evidence acquired from the interviews and observations with evidence obtained from the follow-up questionnaires; (ii) tabulation of the frequency and types of observations *over time* and the creation of systematic and successive 'cross-company display tables' based on a 'data reduction' procedure (Miles and Huberman, 1994). This process was essential to the reduction of the sheer volume of information to a manageable amount of information and to track the evolution of the

study's constructs in a coherent manner; and (iii) systematic matching of pieces of evidence from the cases with the components of the study's analytical frameworks to achieve solid construct validity (Campbell, 1975). Additionally, rather than reducing all qualitative data to quantitative observations, both types of evidence were used to form the study's dataset, to run statistical tests and to enrich the empirical analysis. The capability levels accumulated for these activities by firm were then aggregated into a single index – the innovation capability index – to represent the overall capability level of firms in forestry, pulp, and paper.

5. Empirical Findings

In light of the framework in Section 2, this section presents the main empirical findings and discussions. Section 4.1 describes the paths of innovation capability accumulation pursued by the case study during the 1950-2010 period. Section 4.2 explores some of the outcomes that were generated as these firms accumulated innovation capabilities.

5.1 Paths of innovation capability building taken by the researched firms

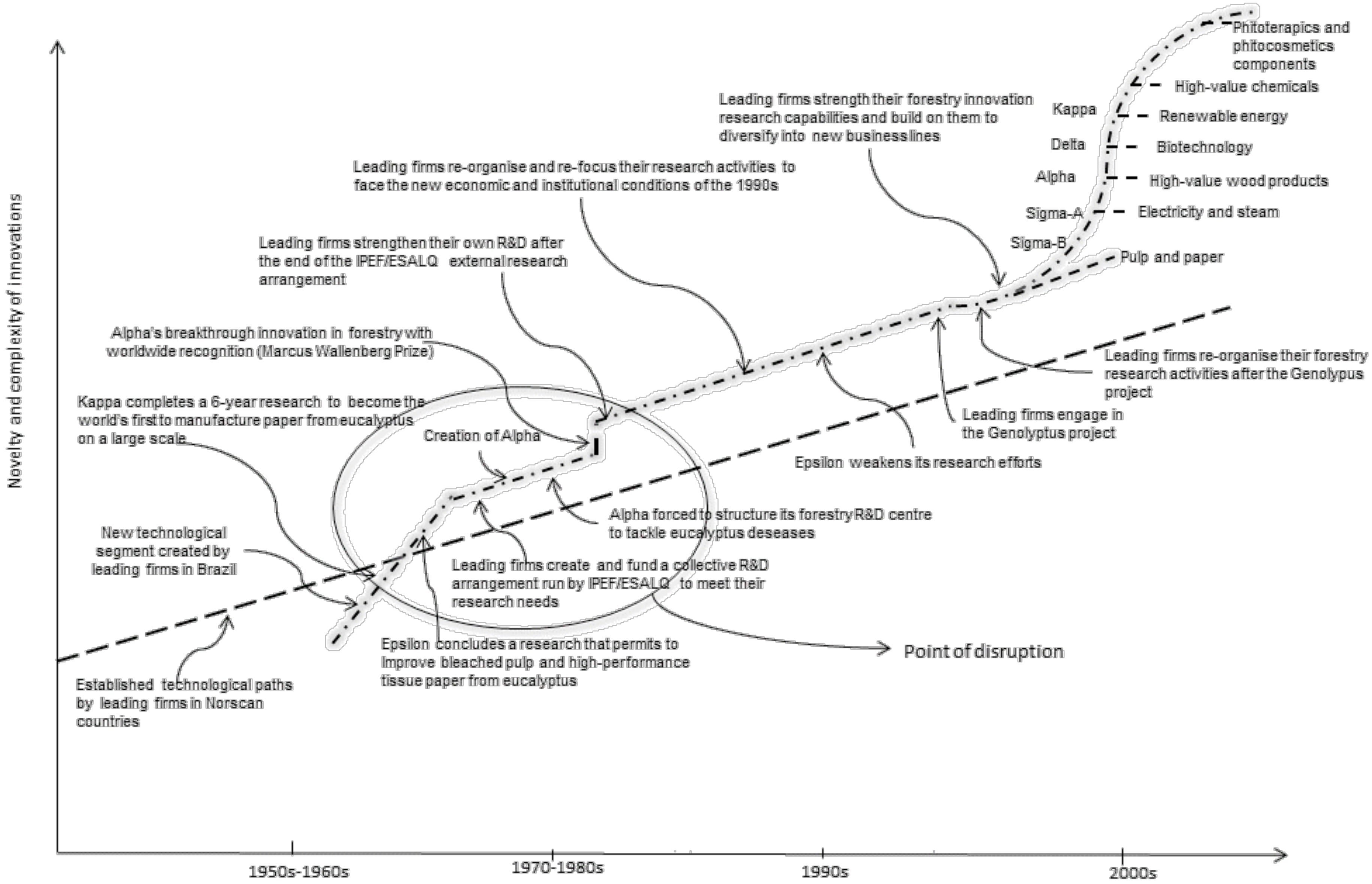
Historically, the world's main producers and innovators in the forestry, pulp and paper industries were the Norscan countries (Canada, the US and Nordic countries Sweden, Finland and Norway). However, the findings indicate that between the 1960s and 1970s, a major breakthrough in eucalyptus-based forestry technology was achieved, particularly in Brazil.[4] Indeed, leading firms such as Kappa, began to diverge from the existing technological trajectory at an *early stage* of the development of their innovation capabilities. Just after World War II, these firms began to produce pulp and paper from eucalyptus trees and to engage in activities in which firms in the Norscan countries were not engaged.

This development indicated that at a relatively early point, these firms could not simply copy the recognised global leaders but were instead forced to develop technologies more suited to their own somewhat dissimilar operations. These firms could not simply *imitate* because they were developing along a different trajectory. This trajectory involved the use of different raw materials (eucapulp), and to develop an effective means of using this material, these firms had to innovate their downstream pulp and papermaking processes because of the innovations that emerged in upstream forestry.

The experience of leading firms in Brazil's pulp and paper industry provides an example of seizing an opportunity to undertake world-leading innovation and achieving international leadership. Until the mid-1960s, paper produced by the world's leading firms in the US, Canada and Scandinavia (the Norscan countries) was produced from long-fibre pulp derived from conifers. These leading incumbents continued to develop along this technological trajectory but, as early as the 1960s, several paper producers in Brazil shifted to production based on short-fibre pulp derived from eucalyptus, a source of pulp with great potential in Brazil and compatible with Brazil's environmental conditions. This innovation involved the original development of new eucalyptus varieties, which were more productive and more resistant to disease. In parallel, the innovation involved the development of modified process technology that was installed in a succession of new plants over three decades. Specifically, the firms embraced a *different direction* of technological development from that of the global industry leaders. By doing so, these firms introduced a qualitatively different segment at the international technological frontier. By engaging in original R&D based on advanced biotechnology methods and, more recently, nanotechnology, since the 1990s, leading firms established worldwide leadership in what has become a new, technologically differentiated segment of the global paper industry.

This pathway contrasts with the majority of case studies reported in the literature: it involved a *qualitative discontinuity* from the established technological trajectory at an *early stage* in the development of their capabilities (see Figure 2). As illustrated in Figure 2, beginning in the mid-2000s, those firms that had achieved world-leading innovation performance, especially in the forestry industry, began to draw on their accumulated capabilities to diversify into different business lines.

Figure 2. Evolution of the eucalyptus-based technological path taken by Brazil's leading firms and some main related events



As shown in Table 3, most of the case firms have developed world-leading innovation capabilities. At this technological position, these firms are able to push the international innovation frontier forward. Consequently, these firms have accumulated innovation capabilities at world-leading levels and thus have been able to push the innovation frontier forward. This progress is also reflected in the number of patents acquired by some of these firms, although this number is still modest (Table 4).

Table 3. Innovation performance of the case firms

Levels of technological capability	Firms, business lines and the number of years taken to attain each innovative performance level		
	Forestry	Pulp	Paper
World leading	Sigma-A	Sigma-B	Sigma-B
	Alpha	Sigma-A	Sigma-A
	Delta	Alpha	Delta
	Theta	Delta	Kappa
	Kappa	Kappa	
Advanced	Attained by all firms	Attained by all firms, except Theta	Theta
Intermediate	Attained by all firms	Theta	Attained by firms
Basic	Attained by all firms	Attained by all firms	Attained by all firms
Production	Attained by all firms	Attained by firms	Attained by firms

Source: Derived from the empirical study.

Table 4. Evolution of number of patents in forestry activities in the case firms

Firms	1990s		2000s	
	Brazil	USPTO	Brazil	USPTO
Alpha	15	1	4	0
Delta	13	0	21	2
SigmaA/B	0	0	2	0
Kappa	10	1	10	2
Theta	5	0	23	1

Patents registered by Fibria are also included, since the merge between VCP and Aracruz.
* The patent is in application process stage.
** Three of them are being claimed by the referred firm.
Source: INPI (2011) and USPTO (2011)

5.2 Exploring outcomes of the case firms' innovation capability-building paths

In this section, we explore outcomes of innovation capabilities accumulated at the level of the case firms. We begin by presenting evidence of outcomes in the form of implemented innovations and operational performance improvement. We then explore outcomes in terms of the diversification of output and spill-overs and, finally, we address the evolution of socio-economic indicators for areas surrounding the researched mills as wider types of outcomes.

5.2.1 Implemented innovations and operational performance improvement in forestry cases

During the 1960s and 1970s, the firm Alpha took the lead in undertaking massive investments in forestry research. As early as the 1960s, Alpha's top management took the initiative of creating a dedicated R&D centre for forestry research. By the early 1980s, Alpha had introduced a breakthrough innovation based on the mass production of clonally propagated planting stock. In 1984, nearly 17 years after initiating its research activities, Alpha achieved worldwide recognition by being awarded Sweden's Marcus Wallenberg Prize.[5] Alpha's achievement of such world-leading innovation consolidated the new technological segment initiated by Brazil's pulp and paper firm forestry research at the international technological frontier. This innovation allowed higher biomass production per unit of planted area and significant improvements in wood quality as industrial raw material and energy input.

In terms of research activities, some firms sought to re-organise their research centres on the basis of more specialised and commercially oriented activities to sustain their innovation performance. These firms also realised the importance of partnerships to achieve this goal. For example, in 2002, Sigma-A and Sigma-B merged their R&D units into the Centre for Pulp Technological Development to accelerate the achievement of research outcomes. In 2005, this unit designed software based on a complex set of equations, to calculate the economic value of a clone, allowing the firm to choose the best clone for specific sites. In 2002, paper maker Delta reviewed and re-organised its research centre to not only deepen its research on new genetic material but also improve product and process development activities. Conversely, Kappa regained its innovative drive in 2006 after a period of unfocused strategy during the 1990s resulting from internal management problems. Kappa's new top management emphasised research-based innovation, especially in forestry, as a key driver of Kappa's international leadership.

One of the remarkable public-private research initiatives of that period was the emergence of the Genolyptus Project – Brazilian Network of Eucalyptus Genomics Research (2002-2008). Sponsored by one of the innovation funds of the Ministry of Science and Technology, this extensive research project involved 13 firms (among them Alpha, Beta, Gamma, Delta, Theta, Kappa, Sigma-A and Sigma-B) and seven universities, which were coordinated by the Brazilian Agricultural Research Corporation (EMBRAPA). Genolyptus gathered a large amount of genomic information to further the understanding of the underlying variation of genes. One of its novelties was a focus on wood and disease resistance and its implications for innovation and productivity increases and the international competitiveness of Brazil's pulp and paper industries (Grattapaglia, 2004; Grattapaglia and Kirst, 2008). With this successful project, Brazil became one of the few countries to undertake cutting-edge eucalyptus genomic research based on a nation-wide biotechnology network.

The end of Genolyptus in 2008 somehow forced the participating firms to make strategic choices regarding further forestry activities. For example, Alpha, Kappa, Delta, Sigma-A and Sigma-B built on the advances obtained from their participation in Genolyptus to intensify their interactions with world-leading research networks in Australia, Canada, Sweden, Germany, and US. In 2009, Kappa supplied a eucalyptus genome for use in a world-leading genomic research project led by a pool of leading research institutes. Alpha also implemented an intellectual property policy to intensify patenting. However, firms such as Beta and Theta pursued less ambitious avenues after Genolyptus. In summary, over the past 40 years, leading forestry firms in Brazil have drawn on their technological capabilities to implement different types of innovations in forestry (see examples of these innovations in Table 5).

The implementation of these innovations has contributed to the achievement of relevant competitive performance. Indeed, the attainment of progressively higher levels of innovation capability have permitted leading firms in Brazil to improve consistently in terms of relevant performance indicators in forestry during the period of 1970-2009 (Table 6).

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The implementation of these innovations has contributed to the achievement of relevant competitive performance. Indeed, the attainment of progressively higher levels of innovation capability have permitted leading firms in Brazil to improve consistently in terms of relevant performance indicators in forestry during the period of 1970-2009 (Table 6).

Table 5. Examples of implemented innovations in forestry

Firms	1970s-1980s	1990s	2000s
Alpha	New process of eucalyptus production by vegetative propagation leading to world's first large-scale eucalyptus clonal forest for pulp and paper.	Genetic improvement of eucalyptus leading to productivity growth from 6.4 tons of pulp/ha/year to 11.8 tons of pulp/ha/year, the world's highest productivity growth in this decade. It also involved wood quality improvement and reduction of environmental impacts of the planting process.	New eucalyptus varieties resistant to abiotic stress (drought and cold), which allows the planting of eucalyptus in regions of low temperature and subject to frost.
			Soil conditioner produced from organic wastes and dregs. This soil conditioner is already being applied on an operational scale, replacing lime and fertilizer.
Delta	New genetic materials in pine, with higher productivity features, most appropriate for the production of paper and greater disease resistance (in collaboration with Camcore (US)).	Somatic embryogenesis process to perform cloning in pine. The pine cloning is an advanced technique, and is a new process in Brazil and has been applied in countries such as Chile. The somatic embryogenesis permits uniform plantations with higher forest productivity, lower costs of harvesting and therefore less pressure on native forests.	New eucalyptus varieties resistant to drought and cold, through the Genolyptus project.
	The 'Monte Alegre Formula' based on meteorological data and occurrence of forest fires. This formula has been diffused to other firms and forestry-related organizations to estimate the risk of fire in forest areas.		
Theta	Forest biometrics process in pine planting with the development of mathematical models for prediction and control of timber production, which has allowed a more accurate assessment of available trees in the planting area and greater precision in the harvest planning.		Clonal planting of *Pinus taeda* on a commercial scale using somatic embryogenesis technique.
			Indoor garden for recombinant clones of eucalyptus dunnii, using controlled pollination in pots. Through dunnii eucalyptus species are recombined the best clones of the species, making the controlled pollination in pots in a greenhouse.
Kappa		New method for genetic transformation of eucalyptus. The project was undertaken with the University of Sao Paulo – ESALQ, obtaining the first transgenic eucalyptus although not applied to commercial production.	New eucalyptus varieties to implement 'energy forests'. These varieties has features designed to produce pellets with a high power burning and planting in very short cycle of two to three years in small areas.
Sigma		New genetic improvement processes through the eucalyptus clonal plantations and use of molecular markers, permitting the achievement of more accurate ways to select varieties of eucalyptus with higher productivity and resistance to pests and diseases.	New software to calculate the economic value of a eucalyptus clone, permitting the achievement of the best clone to a plantation site.

Table 6. Evolution of some technical indicators in forestry (1970-2009)

Performance indicators in forestry	Unit	1970	1975	1980	1985	1990	1995	2000	2002	2003	2004	2006	2009	Average annual rate of decrease/increase (%) (1970-2009)
Average annual increase	m^3/ha year	37	44	47	45	53	52	45	46	45	46	50	49	+0.7
Basic density of wood	Kg/m^3	473	473	473	488	488	488	485	489	494	496	493	506	+0.1
Average density	ton/m^3	0.47	0.47	0.47	0.49	0.49	0.49	0.49	0.49	0.49	0.5	0.49	0.51	+0.2
Average cut-off age	years	7.0	7.0	7.0	7.0	7.2	7.2	7.4	7.4	7.3	7.2	7.5	7.2	+0.07
Volume of wood per amount of pulp produced	m^3/ton pulp	4.25	4.17	3.97	3.86	3.71	3.71	3.83	3.81	3.81	3.94	3.93	3.84	–0.2
Planting density	Trees/ha	1,651	1,651	1,512	1,512	1,486	1,419	1,224	1,259	1,259	1,326	1,326	1,326	–0.5
Innovation capability index (aggregated for all case firms and forestry-related technological functions)[(a)]		1.5	2.1	2.8	3.2	3.8	4.0	4.8	5.1	5.5	5.8	5.9	6	+3.6

Source: Derived from the empirical study.

Note: (a) The forestry functions involve silviculture, harvesting, logistics and social-environmental forest management.

In addition, in the early 1990s, it was recognised that trees that yield more cellulose generate gains across the entire production chain in the form of savings from tree harvesting and transportation thus minimising the expansion of forests and reducing effluent waste (Assis, 2001; Grattapaglia, 2004; Grattapaglia and Kirst, 2008). Consequently, by realising that the 'pulp factory' is the tree (Grattapaglia and Kirst, 2008), pulp and paper firms have shifted the focus of their efforts from volume growth to wood quality. The objective is to reduce the amount of wood in cubic meters necessary for the production of one ton of pulp, that is, to decrease wood-specific consumption (WSC) (Grattapaglia and Kirst, 2008). During the 1980s, first-generation clonal forestry of eucalyptus reduced WSC by 20%. A further 20% reduction was subsequently achieved, based on second-generation clones derived from eucalyptus hybridisation (Ikemori et al., 2005, *cited by* Grattapaglia and Kirst, 2008). These achievements led to the planting of the first large-scale commercial stands of selected clones derived from hardwood cuttings. These and subsequent advances resulted in exceptional genetic gains in growth and adaptability to tropical conditions and wood with a higher pulp yield (Grattapaglia and Kirst, 2008). These leading firms' implementation of these innovations and their consistent improvement according to operational performance indicators have contributed to Brazil's attainment of an internationally leading position in this field (see Table 7).

Table 7. Some indicators reflecting Brazil's leading performance in forestry for pulp and paper

	Brazil	Chile	Indonesia	Canada	Sweden	Finland
Rotation of trees (hardwood: short fibre) – number of years	7 (eucalyptus)	10-12 (eucalyptus)	n.a.	n.a.	35-40 (birch)	
Rotation of trees (softwood – long fibre species)	15 (pinus spp)	25 (pinus radiate)	n.a.	45 [(a)] (oregon pinus)	70-80 (picea abies)	
Productivity of short fibre species – hardwood (m^3/hectare per year)	41 (eucalyptus)	25 (eucalyptus)	20 (acacia)	n.a.	6 (birch)	4 (birch)
Productivity in long-fibre species – softwood (m^3/hectare/year)	35 (pinus spp)	22 (pinus radiate)	n.a.	7[(b)] (oregon pinus)	4 (picea abies)	
Proportion of planted forest in the country's territory (percent)	0.6	2.9	4.4	n.a.	n.a.	
Forest area needed to produce one million tonnes of pulp/year	100,000 ha	n.a	n.a.	n.a.	720,000 ha.	

Sources: Elaborated on the basis of data from FAO/Bracelpa (2008). Note: (a) and (b) = Coastal area.

5.2.2 Implemented innovations and operational performance improvement in the pulp and paper cases

During the 1960s and 1970s, in addition to the development of capabilities to undertake innovative activities in forestry, namely, the original development of new eucalyptus varieties, which were more productive and more resistant to disease, the firms engaged in the development of capabilities to undertake process- and product-related innovations. Process innovations involved the development of modified process technology, which that was installed in a succession of new plants over three decades. In parallel with efforts to strengthen production capabilities, an immediate outcome of these capability building processes was in the consistent increase of the case firms' output from the 1980s to the 2000s (see Table 8).

Efforts to develop innovation capabilities, which were strong in the 1970s and proceeded into the following decades, with renewed, intensified efforts during the 1990s and 2000s, led to the implementation of significant innovations in pulp and paper activities in firms such as Alpha, Sigma-A and Sigma-B. Some of these innovations are briefly described in Table 9.

Table 8. Examples of implemented innovations in pulp and paper

Firms	1990s	2000s
Alpha	Tests for industrial wastewater involving: (i) fertilization of sea urchins submitted conditions of effluents; (ii) examination of mussels that are close to a terminal to discharge sewage into the sea. Toxicity of effluents is found through the quality of offspring.	Mapping carbon footprint and optimization of cooking additive technologies. Applied to different production units in the firm, these processes permits productivity increase and operating costs reduction.
	Novel variation to the TCF (Totally chlorine-free) process, using a much lower level of absorbable organic halogens (AOX).	Increase in the use of eucalyptus fibres in papermaking processes by: (i) offering the technology to be tested by different papermakers; (ii) developing new types of cellulose through environmentally friendly processes. Processes based on these new fibres permits make paper with less waste of electrical and thermal energy and reduction of specific consumption of fibre by increasing retention of mineral fillers.
Delta	Development and production of cardboard with a white layer for the Tetra-Pak packaging. This innovation allowed the firm Delta to become a leading supplier of the most important international packaging manufacturers.	'Card barrier' which allows the manufacture of packaging resistant to water, grease and steam without the use of plastic. This innovation allowed Delta to produce packaging for food applications with low environmental impact in its disposal.
		The chemi-thermomechanical (CTMP) pulping production process using hardwood, which leads to a more resistant to bending packaging..
		Production processes using multi-layers cardboard using CTMP pulping process.
Theta		New packaging for red fruits based on kraft paper with a high degree of security in the stack, an effective ventilation system which allows the accommodation of bowls of fruit inside. This package allows minimum handling of the fruit, since it is not necessary to remove the bowls of corrugated cardboard packaging for the perfect exposure of the fruit at the point of sale.
		Recyclable container for liquids of 200 litres which facilitates the individual handling. The product was developed with a system of corrugated packaging with special high-performance packaging and replacing other leads to reduction of logistics costs.
Kappa	Implementation of first automation and control system for recovery boiler, which allowed an effective reduction of emissions of particulate matter and sulphur-based components to the recovery boiler.	Special cardboards (e.g., anti-thermal and anti-freeze) to meet new customers' demands. By doing so, Kappa acquired new market share in the domestic market of special papers which was previously supplied by imported paper.
	Introduction of elemental chlorine free pulp bleaching process which permitted the firm Kappa to meet international standards and the reduction of environmental risks in bleaching stage.	Tissue paper to pharmaceutical industry, by which Kappa not only gained new market share in the domestic market but was able to supply this type of paper with a price lower than imported papers.
	Project to reduce water consumption, with locks and cooling cycle for re-use, leading to new standards in the industry regarding environmental suitable production process.	
	An alkaline correction process for an environmentally friendly papermaking process.	
	Cut size paper to laser and inkjet printing. These products were developed considering international specifications and quality on standards, allowing the firm to export these papers packed with the brand of customers.	
Sigma	New variation to the ECF (Elemental chlorine-free) process, using a much lower level of absorbable organic halogens (AOX).	Process and paper machine to produce carbonless paper on-machine, by which Sigma began to supply the domestic market with a paper cheaper than imported ones.
	An alkaline sizing process to generate greater brightness, colour stability and body (bulk) to the paper-basis used for making chemicals papers and coated papers, leading to an environmentally production process and permitted Sigma to supply special papers with better features than imported papers and also creating new market share.	Process to produce thermal papers to improving image stability and durability to be used in credit card receipts and invoice machines.

Table 9. Evolution of the case firms' output of pulp and paper

Pulp

Firms	1980	1990	2000	2009	Growth rates				
					1980-1990	1990-2000	2000-2009	1980-2009	Industry average Brazil 1980-2009
Alpha	361,280	501,182	1,301,240	3,491,271	3.3	10	11.5	8.1	4.8
Delta	327,415	796,022	1,468,297	1,458,730	9.2	6.3	-0.07	5.2	
Sigma	160,478	191,728	792,549	1,137,006	1.7	15.2	4	6.9	
Kappa	307,207	385,966	1,009,234	2,308,931	2.3	10	9.6	7.2	
Theta	91,276	141,859	194,681	216,663	4.5	3.2	1.1	3	

Paper

Firms	1980	1990	2000	2009	Growth rates				
					1980-1990	1990-2000	2000-2009	1980-2009	Industry average Brazil 1980-2009
Delta	387,209	1,017,628	1,485,411	1,600,372	10.1	3.8	0.8	5	3.6
Sigma A, B	147,301	522,568	522,408	365,515	13.4	-0.003	-3.8	3.1	
Kappa	218,155	740,054	722,398	1,081,268	12.9	-0.2	4.5	5.6	
Theta	167,331	285,197	286,660	308,676	5.4	0.05	0.8	2.1	

For example, Alpha restructured its research activities by merging the forestry and the industrial R&D centres. By doing so, Alpha sought to augment its forestry research capabilities in association with pulp and papermaking research (e.g., research on lignin biosynthesis and pollution control methods based on natural micro-organisms). By 1992, the firm Alpha had adopted the elementally chlorine-free (ECF) and the totally chlorine-free pulp (TCF). Alpha implemented these processes at the same time as leading firms in Canada and Scandinavia. However, Alpha went further creating a variant in the TCF process, characterised by a much lower level of absorbable organic halogens (AOX). This process became known as Alpha chlorine-free (ACF) and was patented in 1997. One year later, the firms Sigma-A and Sigma-B also created their own versions of the TCF process. By 1995, 10 of the 13 firms researched had already changed their processes to TCF.

The field interviews and consultations of archival records suggest that the implementation of these innovations resulted in considerable and consistent improvement in terms of process-related indicators in pulp and paper mills (Tables 10 and 11). Indeed, as shown in Tables 10 to 13 most performance indicators improve as the innovation capability indexes increase over time. This suggests an association between the accumulation of progressive higher levels of innovation capability and performance improvement.

Table 10. Evolution of some process performance indicators in the researched pulp mills

Process performance indicators in pulp		2000	2001	2002	2003	2004	2006	2009	Average annual rate of reduction/increase (%) (2000-2009)
Specific steam consumption	Steam ton/ pulp weight (ton)	4.92	5.4	4.9	4.9	4.5	4.4	3.6	–3.4
Specific electric energy consumption	KWh/ pulp weight (ton)	737	730	640.8	646.4	674.2	639.6	571	–2.8
Specific water consumption	m^3/ pulp weight (ton)	41.3	45.6	42.7	39.6	40.9	40.1	36.7	–1.3
Fiber losses	ton/day	13.1	16.7	15.5	11.1	8.8	9.5	10.9	–2
Innovation capability index (aggregated for all pulp case firms and technological functions)[(a)]		5.04	5.43	5.43	5.60	5.71	5.71	5.71	+1.4

Source: Derived from the empirical study. *Notes*: (a) The lower the better

Note: Process-related functions include project management, process and production organization, product-related activities and process-equipment related activities.

Table 11. Evolution of some process performance indicators in the researched paper mills [a]

Performance indicators in paper	Units	2000	2001	2002	2003	2004	2006	2009	Average annual rate of reduction/increase (2000-2009) (%)
Specific steam consumption [b]	Steam weight (ton)/ paper weight (ton)								
Printing and writing		3.1	2.9	2.8	2.7	2.6	2.5	2.4	–2.8
Packaging, wrapping & boxboard		1.9	2	3.5	3.2	2	1.9	1.9	0.00
Tissue		1.9	1.7	1.4	1.4	1.4	1.4	1.4	–3.3
Specific electrical energy consumption[b]	KWh/paper weight (ton)								
Printing and writing		627.5	614.3	591.9	576.1	572	554.5	547	–1.5
Packaging, wrapping & boxboard		457.5	465.2	655	725.8	486.3	432.8	391.9	–1.7
Tissue		412	473.5	439.2	458.1	447.1	398.2	229	–6.3
Specific water consumption [b]	m^3/ paper weight (ton)								
Printing and writing		28	26.2	24.6	20.8	19.2	18	17.1	–5.3
Packaging, wrapping & boxboard		31.6	32.5	32.6	33.5	23.2	19.3	20.1	–4.9
Tissue		34.8	33.1	31.8	30.6	28.9	25.8	23.3	–4.3
Innovation capability index (aggregated for all paper case firms and technological functions) [c]		4.65	5	5	5.2	5.6	5.6	5.6	+2.1

Source: Derived from the empirical study.
Notes: (a) Aggregated by specific paper segments (printing and writing; packaging, wrapping and boxboard; tissue paper); (b) The lower, the better; (c) Process and production organization, product-related activities and process-equipment related activities

The achievements illustrated in Tables 10 and 11 also reflect a change in these firms' energy matrix. In 1978, 65% of the mills' energy originated from oil, 24% from recovered black liquor[6] and 11% from biomass. In 2006, the composition of such an energy matrix was 62% recovered black liquor, 19% biomass, 10% oil and 9% natural gas. In some mills today, approximately 93% of fuels consumption derives from renewable sources.

With regard to environment-related indicators (Tables 12 and 13), within the pulp mills, for instance, industrial effluent output decreased by 3% annually on average during the period of 2000-2009, whereas SO_2 emission decreased by 3.4% annually, on average. In absolute terms, both indicators were below the limits delineated by the Brazilian Environment Authority (Conama) and by the European BAT.[7] Similarly, within the paper mills, the decrease in biochemical oxygen demand (BOD) varied from 2.6% to 9.9% annually, on average. In absolute terms, the levels were below the limits established by Conama. Other environment-related indicators also improved as the mills' capability levels increased during the examined period.

Table 12. Evolution of environment-related indicators of the researched pulp mills

Types of Effluents	Environment-related indicators	Units	2000	2003	2006	2009	Average annual rate of reduction/increase (2000-2009)	Limits defined by CONAMA [c]
Liquid	Industrial effluents output (a)	m3/pulp weight(ton)	46.7	42.9	38.7	35.3	–3	50-100
	COD Chemical oxygen demand) [a]	Kg/pulp weight(ton)	11.9	10	7.6	6.1	–7.1	10
	BOD (Biochemical oxygen demand) [a]	Kg/pulp weight(ton)	1.8	1.3	1.1	0.8	–8.6	2.5
	Total nitrogen [a]	Kg/pulp weight(ton)	0.2	0.1	n.a.	n.a.	–20.6	n.a.
Solid	Lime mud/ dregs/grits [b]	Kg/pulp weight(ton)	33.9	43.5	68	96.2	12.2	n.a.
	Total ashes [b]	Kg/pulp weight(ton)	11.7	15.5	29.1	38.5	14.1	n.a.
Air	SO_2(chemical recovery boiler) [a]	mg/Nm^3	8.8	24	7.1	6.4	–3.4	100
	NOX (chemical recovery boiler) [a]	mg/Nm^3	n.a	239.8	187.56	237.91	–0.1	470
	Particulate matter	mg/Nm^3	483.6	601.1	n.a.	n.a	7.5	n.a.
	Average TRS (Total reduced sulphur) [a]	ppm	1.64	0.82	2.13	2.42	4.4	n.a.
	Average SO_2 [a]	ppm	1.69	2.83	4.4	7.06	17.2	n.a.
	Average TRS (Lime kiln) [a]	ppm	17.16	42.93	16.6	17.21	0.03	n.a.
Innovation capability index (aggregated for all pulp firms and technological functions) [d]			5	5.6	5.7	5.9	1.86	

Source: Derived from the empirical study.
Note: (a) the lower, the better; (b) It varies according to production; (c) The National Environment Council of the Brazilian Ministry of Environment; (d) Process and production organisation, product-related activities and process-equipment related activities. n.a. = not available.

Table 13. Evolution of environment-related indicators of the researched paper mills[(a)]

Environment Indicators	Units	2000	2001	2002	2003	2004	2006	2009	Average annual rate of increase/ decrease 2000-2009 (%)	Limits defined by CONAMA [(c)]
Industrial effluents output	m^3/ paper weight (ton)									
Packaging. wrapping & boxboard [(b)]		28.4	28.4	25.1	37.4	38.8	38.2	39.7	3.7	50-100
Tissue [(b)]		90	80	80	46.1	43.4	34.1	31.7	–10.9	50-100
COD (Chemical oxygen demand)	Kg/ paper weight (ton)									
Packaging. wrapping & boxboard [(b)]		7.23	6.31	12.7	10.0	10.9	4.9	7.1	–0.2	10 [(a)]
Tissue [(b)]		14.5	18.0	13.6	13.6	15.9	9.3	9.2	–4.9	10 [(a)]
BOD (Biochemical oxygen demand)	Kg/ paper weight (ton)									
Packaging. wrapping & boxboard [(b)]		n.a.	n.a.	4.3	3.4	4.4	1.5	n.a.	–23.1	5
Tissue [(b)]		3.8	5.0	4.32	5.4	5.6	2.4	2.0	–6.8	5
Aggregated index of technological capability in the paper firms		4.7	5.0	5.0	5.3	5.6	5.6	5.7	2.17	

Source: Derived from the empirical study.
Notes: (a) Aggregated by specific paper segments (packaging, wrapping and boxboard; tissue paper); (b) The lower, the better.
(c) The National Environment Council of the Brazilian Ministry of Environment; n.a. = not available

These achievements reflect innovation activities with regard to the bleaching process associated with environmentally targeted efforts, since the 1980s, that involved research on lignin biosynthesis and the patenting of the TCF process. Because of these process innovations, less chemical products are needed to whiten the pulp used to produce paper. Consequently, mills' environmental impact was reduced, particularly in terms of diminished liquid effluents. Although in Brazil, pulp and paper industries have had consistently positive environmental impacts, in Chile, these industries have been notorious for having caused environmental disasters. For instance, in 2006, pollution caused by pulp mills in Valdívia is said to have caused the disappearance of black neck swans in the area. Populations of otters have been under threat in the River Itata, and the River Mataquito was contaminated by pulp mills. Although there are a few exceptions, such as the firm CMPC, the majority of the pulp and paper firms in Chile suffer severe attacks from the Chilean population because of their negative environmental impacts.

Additionally, pulp and paper firms realised that to secure competitive positions in the world market, they had to respond pro-actively to growing pressures from regulators and society with regard to environmental concerns beginning in the early 1990s (see Dalcomuni, 1997). Consequently, most of the researched firms exhibited intense efforts to accumulate environmental innovative capabilities in most of the researched firms.

5.2.3 Firms' diversification of output and spill overs

In light of the framework in Section 2, the evidence suggests that some firms have generated some type of diversification into new business lines based on the previously accumulated innovation capabilities, especially in forestry. In terms of diversification, some firms sought to draw on their accumulated innovation capabilities, especially in forestry, to diversify into new business lines. For example, in 2009, following a review of its strategic goals, Kappa opened a business line for renewable energy through the production of wood pallets for export markets. These pallets dehydrated and pressed particles of ground wood and are one of the most efficient methods of transporting biomass for energy over long distances. Subsequently, Kappa acquired a British biotechnology firm with operations in the US, Israel, China and Southeast Asia. This action was meant to facilitate the firm's entry into the arena of biofuels and the commercialisation of modified genes and to support its internationalisation strategy.

By the time of the fieldwork was underway, the firms Alpha, Kappa, Sigma-A and Sigma-B were advancing projects to move into bio-refineries to generate fuels, power, heat, and value-added chemicals derived from biomass. In addition, by the early 2000s and by drawing on its world-leading forestry capabilities, Delta intensified its efforts to enter the business of medicinal plants, phytotherapy and phytocosmetics. In 2001 Delta obtained custody certification of non-wood forest products. Efforts to diversify into these areas date to the late 1990s, when Delta was the world's first company to be granted Forest Stewardship Certification for the management of these types of plants. In several interviews, managers defined their firms as 'forestry firms'. The managers noted that pulp and paper are no longer their only businesses. During the fieldwork, we found evidence of several business initiatives in the municipalities where the case firms are located. Several of these initiatives emerged from the case firms or were stimulated by the case firms. We consider these initiatives as examples of spill-overs; there are examples that derived from the experiences of Alpha and Delta. In light of the framework in Section 2 and for the purposes of this paper, we have selected the following outstanding examples.

The first example refers to *Imetame Metalworking*. This initiative was created in 1980 by a mechanical turner and a welder who were two former Alpha professionals. Based on the determination of these two entrepreneurs, this firm began by providing metalworking services to Alpha. Over time, Imetame developed capabilities in engineering services. Today, Imetame has approximately 4,000 employees and operates in four major areas: (i) Fabrication: engineering projects involving pressure vessels, tanks, bins and steel structures based on carbon and stainless steel, as well as special materials such as titanium and low alloy steel; (ii) Maintenance: jobs involving pulp and paper (detaching and pressure parts in boilers) and in the metallurgy and mining sectors; (iii) Industrial erection: the firm has participated in major projects involving power and recovery boilers, stacking and drying machines, cooking plants, bleaching, evaporation and drying plants; (iv) Structure and logistics: the firm has its own fleet, which includes light vehicles, utility trucks, buses, trucks, muck trucks, boards and cranes. The firm has a large portfolio of clients including large local and multinational firms in the pulp and paper, oil and gas, steel, and capital goods industries and has been awarded several prizes from these firms. Consequently, today, Imetame's contracts with its 'mother' company represent only 8% of its revenue.[8]

The second example refers to *Inflor Consulting and Systems*. In 2001, a group of three young entrepreneurs and former employees of Alpha combined their skills to create a firm of forest management information systems. Initially supported by Alpha and with seven employees, they developed their first systems for implementation in Alpha's eucalyptus forests. They depended their technological capabilities to develop original information technology (IT) systems for integrated and sustainable forestry management. By 2004, they had already provided services to the largest pulp and paper firms in Brazil. By 2007, they possessed the capabilities to provide this type of service to firms in other sectors, such as the sugarcane ethanol sector, as well as other agricultural-related firms taking advantage of the opportunities available in natural resource industries in Brazil. Drawing on their strong knowledge of forest management, they developed technological partnerships with foreign firms in systems development, which allowed the firm to enter new markets. Since 2008, Inflor has been providing its services to customers in Chile, Uruguay, Europe and China, which appears to constitute firm steps into the internationalisation of its activities. Within 10 years, Inflor has become a leading firm in the development and implementation of IT systems for agribusiness management.[9]

The third example refers to the *wood cluster in and around the municipality of Telêmaco Borba*, the state of Paraná, in Southern Brazil, near the largest site of the firm Delta. During the mid-1990s, Delta led efforts to develop a wood cluster in the municipality of Telêmaco Borba. To that end, the firm established partnerships with the city council, the National Service of Industrial Apprenticeship (SENAI), the FATEB, a local technical university and the Wood Technological Centre (CETMAN), which specialised in technical training. These efforts led to the emergence of nearly 50 small and medium-sized firms in Telêmaco Borba, which generated approximately 1,500 jobs. Such efforts also led to the creation of the Centre of Utilisation of Residues. Building on these achievements, by the mid-2000s, Delta led new efforts to expand the wood cluster to other municipalities in the region. These efforts were conducted under the auspices of the Development Programme of Telêmaco Borba and Region based on the diversification and competitiveness of the local wood industry. To implement this programme, Delta developed partnerships with the Paraná state government, the Paraná's Federation of Industries and mayors of 14 municipalities in the region. These efforts have generated an expansion of the wood cluster to other municipalities in the region.

The fourth example refers to the *programme of forest partnerships* created as early as the early 1980s by such leading firms as Delta, Kappa, Alpha, and Sigma and, since its creation, intensified by these firms and followed by others. The programme benefits thousands of small rural owners and supply 20% of the wood used in pulp and paper production in Brazil. The programme of forest partnerships constitute the most important method that the industry uses to operate in these communities.Through this programme, firms in the pulp and paper industry generate jobs and income in 539 cities of the 18 Brazilian states in which the industry has operations and thus contributes to improving the quality of life in these regions' populations. These initiatives involve the great majority of forest-based companies, through the transfer of technology, the guarantee of the purchase of wood from these producers and encouragement of the development of other profitable agricultural activities associated with forest planting. The leading firms consider that this programme conciliates economic gains with environmental protection.

5.2.4 Evolution of some socio-economic indicators in the municipalities around the firms

In this section, we briefly examine the evolution of socio-economic indicators in the municipalities in which the case firms operate. Obviously, it is not possible to expect causal relationship between the development of firm-level technological capability and the improvement of socio-economic indicators regarding the municipalities in which the firms operate. Nevertheless, we examine such indicators for the following reasons. First, we are examining firms that belong to natural resource-related industries, such as the pulp and paper industries, which are generally and commonly labelled as having negative social and economic impacts on the communities around them. After all, there is evidence that firms in these sectors have negative impacts, as in the case of Chile.

Second, the case firms examined herein have achieved the development of a high-level technological capability which, in turn, has generated significant outcomes in terms of implemented innovations and operational and environmental outcomes, as well as output diversification and spill overs. Therefore, what about the municipalities in which these firms operate? After all, can we say that all of the firms' achievements are somehow 'reflected', or are they 'shared' to an extent with the communities around them? At the same time, the greater the size of each municipality the more difficult it is to identify firm influence. Even so, this type of examination is at least worth pursuing. For instance, this type of examination could reveal that, despite all of the firms' achievements, they operate in municipalities with negative socio-economic indicators. Here in, we consider the evolution of official indicators, such as income per capita, illiteracy rates, and the proportion of households with adequate sanitation. We combine these indicators with the social development index for the municipalities of Brazil, which is generated independently for most municipalities, by the Federation of Industry of the State of Rio de Janeiro (FIRJAN). This index combines three types of indicators (education, health, and employment and income) as a measure of social development.

Table 14 contains the evolution of specific socio-economic indicators based on official data. In absolute terms, income per capita was higher than the Brazil's average in all municipalities. On average, the annual growth rate of income per capita was 5.3% in the municipalities of Aracruz, Luis Antonio and Suzano, whereas in the municipalities of Três Barras and Telêmaco Borba, it increased to slightly above 10% during the period of 2000-2010, in line with Brazil's average of 10.5% during that period. An exception is the municipality of Luis Antonio, whre the income per capita decreased by 0.6% on average, during the 2000-2010 period, although, in absolute terms, this figure is nearly three times higher than Brazil's average.

Table 14. Evolution of specific socio-economic indicators in the municipalities of the case firms

Municipality	Related firm	Population (2010)	Income per capita (USD)			Illiteracy rate 15 to 24 years old (%)		Illiteracy rate 24 to 59 years old (%)		Proportion of households with adequate sanitation (%)	
			2000	2010	Annual growth rate	2000	2010	2000	2010	2000	2010
Aracruz	Alpha	81,832	9,527	14,359	4.6	2	1	10.4	5.9	64.6	77.4
Luis Antônio	Sigma B	11,286	31,217	29,404	-0.6	2.4	1.5	7.1	5.3	90.8	96.5
Jacareí	Sigma A	212,824	7,641	12,979	6.0	1.4	0.9	4.9	2.6	88.8	93.4
Suzano	Kappa	262,480	6,896	11,176	5.5	1.9	1.2	7.6	3.7	72.8	85.7
Três Barras	Theta	18,129	4,793	11,523	10.2	2.9	1.7	7.7	5.6	55.8	59.8
Telêmaco Borba	Delta	68,872	4,143	10,154	10.4	1.8	0.9	9.4	5.3	59.4	72.8
Brazil	-	190,755,800	3,936	9,670	10.5	4.9	2	9.8	6.4	47	56.8

(1) Proportion of permanent private households by type of sanitation – adequate.

(2) The Brazilian mean horizon of time is related to 1999-2009.

The last Brazilian mean of illiteracy rate related to individuals from 15 to 24 years old refers to 2009.

In terms of illiteracy rates, there was a systematic decrease in all municipalities among the 15 to 24 year-old category and the 24 to 59 year-old category. In both categories, the rates in all municipalities are lower than Brazil's average in 2000 and in 2010. A similar pattern of improvement can be observed in terms of the proportion of households with adequate sanitation: the proportion in each of the case municipalities was higher than Brazil's average in both 2000 and 2010. Table 15 shows the evolution of the social development index in these six municipalities. In general, there is continuous improvement in terms of this indicator in all municipalities in different years: 2000, 2005, and 2009. In all cases, especially in 2005 and 2008, the index for each municipality was above the national average, especially in municipalities such as Aracruz and Jacareí. Therefore, the pattern of improvement with regard to the indicator in Table 15 converges with that of Table 14.

Table 15. Evolution of the municipality development index

Municipality	Related firm	FIRJAN municipal development index		
		2000	2005	2009
Aracruz	Alpha	0.7	0.8	0.85
Luis Antônio	Sigma B	0.67	0.72	0.7
Jacareí	Sigma A	0.73	0.78	0.84
Suzano	Kappa	0.7	0.8	0.74
Três Barras	Theta	0.51	0.64	0.68
Telêmaco Borba	Delta	0.58	0.76	0.72
Brazil's average		0.52	0.59	0.65

Source: Federation of Industries of the State of Rio de Janeiro (FIRJAN).
Keys: Levels of human development for this index: Low (0 to 0.4), Regular (0.4001 to 0.6); Moderate (0,6001 to 0.8) and High (0.8001 to 1).

6. Discussions

By moving beyond most of the studies in the innovation related literature in the context of both advanced economies and, especially, emerging economies, this study sought to explore not the nature or the sources of the innovation capability building process but some of its consequences. This issue has received little attention in terms of the research tradition of innovation capabilities in the contexts of both advanced and emerging economies. In contrast to most existing studies, this paper has proxied innovation capabilities based on *levels* of novelty and the complexity of the technological and organisational activities that the firm is able to undertake over time. Another novelty of this study was the examination of such issues in latecomer natural resource-processing industries over time. Below, we discuss the findings that provide answers to the two research questions underpinning this paper.

Paths of innovation capability taken by the case firms

Regarding the first question, which related to the nature of the paths of innovation capability adopted by the case firms, the evidence reveal that the experience of leading firms in the Brazilian pulp and paper industry is an example of seizing an opportunity to undertake world-leading innovation and achieving international leadership. Until the mid-1960s, paper produced by the world's leading firms in the US, Canada and Scandinavia (the Norscan countries) derived from long-fibre pulp derived from conifers. These leading incumbents continued to develop along this technological trajectory, but as early as the 1960s, several paper producers in Brazil shifted to production based on short-fibre pulp derived from eucalyptus, a source of pulp with great potential in Brazil and compatible with Brazil's environmental conditions. This innovation required the development of modified process technology, which was installed in a succession of new plants over three decades.

In addition to this change, leading firms pursued the original development of new eucalyptus varieties, which were more productive and more resistant to disease. Specifically, the firms embraced a *different direction* of technological development than that of the global industry leaders. By doing so, these firms introduced a qualitatively different segment at the international technological frontier. The evidence presented in this paper related to this type of innovation capability accumulation contradicts common generalisations and arguments that consider natural resource-processing industries as being encapsulated in a single category and characterised by the absence of innovation opportunities, by 'low knowledge content' and by the 'absence of technological learning', as argued in Castaldi et al. (2009).

Outcomes that were generated as the case firms accumulated innovation capability

In relation to the second question, with relates to the types of outcomes that were generated as the case firms reached progressively higher levels of innovation capabilities, the study found four types of outcomes which, in different manners, were generated by the case firms. Some outcomes may be considered more tightly linked with the innovation capability building paths, whereas others are more loosely linked. However, it is important to mention that most outcomes do not simply spring automatically from the development of innovation capability *per se*.

The *first* type of outcome is implemented innovations, which are the most proximate to capability building. The study found several examples of innovations that were implemented by the case firms with different degrees of novelty, some of them at world-leading levels in the forestry (Table 5) and pulp and paper industries (Table 8). These firms have been able to achieve beyond the accumulation of innovative capabilities, transforming them into concrete innovations. Again, these findings contradict the common views of natural resource-processing industries, particularly the pulp and paper sector, as being absent of relevant innovative activities.

Second, the study found that as the firms moved into the accumulation of progressively higher levels of innovation capabilities, they also produced consistent and relevant improvements in terms of operational and environmental-related performance indicators. Although the study did not establish a rigorous causal analysis of the relationship between innovation capability and the improvement of these indicators, it is unlikely that those improvements in operational and environmental performance would have been achieved without the presence of strong production and innovation capability building. Specifically, in relation to improvement of environmental performance, the evidence suggests that, at least in the context of these Brazilian firms, the environmental concerns have moved beyond 'hype' and 'green-washing" into concrete achievements. These firms appear to treat environmental actions, not as stand-alone activities but as part of their technological capability-building efforts and competitive improvement in performance.

The *third* type of outcome found in the study consists of diversification and spill overs. As firms reached world-leading levels of innovation capabilities, they began to draw on these capabilities to take advantage of the new technological and business opportunities to introduce new business lines and industries. In addition, their technological activities have contributed to the stimulation of new firms and clusters around the firms.
Finally, the *fourth* type of outcomes found in the study is improvement in socio-economic indicators in the municipalities surrounding the case firms. On the one hand, by identifying concrete outcomes, this paper contradicts common and negative generalisations and expectations regarding the consequences of the technological activities of latecomer natural resource-processing industries. On the other hand, this paper contributes evidence to perspectives on the impacts of these technological activities. Although the evidence of these socio-economic indicators is incipient and their links with firms' capability building efforts are loose, they add some preliminary evidence at least in this exploratory level of investigation.

7. Conclusions, Implications and Limitations

The findings in this paper have contributed to expanding our understanding of the consequences of firm-level innovative activities. Specifically, by examining this issue in the context of latecomer firms, the findings have contributed to the furthering of our knowledge of the outcomes that may be generated when latecomer firms engage in a process of capability accumulation that permits them to undertake world-leading innovations and achieve international technological leadership positions. Thus, on the basis of the nature of the outcomes reported herein, we conclude that the pursuit of a technological capability building-path aimed towards world-leading innovation performance does pay off in terms of generating benefits for not only the innovative firms themselves but also to the industry and, consequently, the economy.

Therefore, corporate and government policies should *converge* on incentives to stimulate the firms' engagement in new technological trajectories to achieve world-leading innovative performance. The upstream diversification based on accumulated innovation capabilities, such as the experience of the forestry firms examined herein, appears to be an interesting focus for policy efforts. In addition, the findings suggest that the establishment of development goals, such as the improvement of environmental performance, without understanding and tackling the issue of firm-level innovative capability building, particularly with regard to the nature, direction and speed of innovative capability-building within firms, may not lead to concrete positive results. Otherwise, issues such as 'shared value' and 'environmental sustainability' risk being confined to opportunistic rhetoric.

Finally, this paper has several limitations. It does not examine *how* firms' capabilities were created and accumulated over time, that is, the underlying learning processes. In relation to outcomes, we recognise that we would need detailed evidence at the level of the individual firms. We would also need evidence on intermediate variables such as firms' strategies and leadership, to facilitate an explanation of the outcomes found. The paper could also have explored the role of policy context, regulation and markets in influencing the outcomes that were found. However, these limitations could be explored in future research.

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[1] Martin Bell, 2008, personal communication.

[2] DuPont initially entered the rayon industry by licensing technology from the original Alpha-phase innovators in Europe.

[3] See http://faostat.fao.org

[4] For details of this breakthrough innovation, see Figueiredo (2010). For technical details, see Grattapaglia and Kirst (2008).

[5] Established in 1980 in Sweden under the Marcus Wallenberg Foundation, this highly respected prize seeks to encourage and stimulate path-breaking scientific achievements that contribute significantly to a broadening of knowledge and to technical development within fields important to the forestry, pulp and paper industries.

[6] Black liquor is a byproduct of the Kraft process, which occurs during the production of paper pulp. Efficient mills seek to recover and burn much of the black liquor, generating steam and recovering the 'cooking chemicals'.

[7] BAT (best available techniques) refers to references of environment indicators established by the European Commission.

[8] For additional information, see www.imetame.com.br

[9] For additional information, see www.inflor.com.br