Paper to be presented at the DRUID 2011

on

INNOVATION, STRATEGY, and STRUCTURE -
Organizations, Institutions, Systems and Regions
at
Copenhagen Business School, Denmark, June 15-17, 2011

Variability in Micro-level Innovation Performance across Changing Institutional Frameworks: The Mediating of Role of Strategy Embeddedness

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Abstract

This paper explores variability across latecomer natural resource-processing firms in terms of innovation performance under changing institutional frameworks and the mediating role of strategy embeddedness. By drawing longitudinal evidence, gathered from extensive fieldwork, of 13 firms from the forestry, pulp and paper industries in Brazil (1950-2009) the study found that: (1) Although operating under the same macro and meso-level institutional frameworks the firms differed in terms of the manner and speed at which they achieved innovation performance along the new segment opened up in the existing technological trajectory; (2) Firms that pursued pro-active strategy embeddedness were able to cross the discontinuities emanated from the macro and meso-level institutional frameworks with increased innovation performance than firms that relied on active and arm?s length strategy embeddedness. This paper furthers our understanding of the role micro-level factors in mediating the interplay between micro-level performance and changing macro and meso-level institutional frameworks, especially in the context of firms from emerging economies. It also provides a basis to deepen the analysis of the nuances and dynamics of the relationship between these issues in order to explore the extent to which and how latecomer natural resource processing firms can attain internationally leading competitive positions.

Jelcodes:O32,O33

Variability in Micro-level Innovation Performance across Changing Institutional Frameworks: The Mediating of Role of Strategy Embeddedness

Abstract

This paper explores the relationship between micro-level innovation performance, changes in institutional frameworks and the mediating role of strategy embeddedness in latecomer firms. Based on longitudinal field evidence of 13 firms from the forestry, pulp and paper industries in Brazil (1950-2009) the results suggest that variability in the firms' innovation performance, proxied as capability levels, across changing institutional frameworks was mediated by degrees of strategy embeddedness. Specifically, for firms that pursued proactive strategy embeddedness: (i) their innovation performance was significantly higher *over time* than firms that pursued proactive embededdeness; (ii) they crossed whatever discontinuities with progressively higher levels of innovation performance than firms that pursued active or reactive strategy embeddedness; (iii) they sought to shape their institutional frameworks to overcome hurdles inherent to their latecomer condition and negotiate their transitions into world-leading technological and commercial positions. Although macro and meso-level institutional frameworks are necessary for industrial innovation its achievement depends, in large part, on the nature and dynamics of firms' own strategic choices and related innovation efforts. Innovation policymaking should therefore involve coordinated efforts of government and firms. Based on a novel theoretical framework and rich empirical assessment, this paper contributes to a greater clarity and better understanding of factors affecting innovation performance of latecomer firms, especially in natural-resource processing industries.

1. Introduction

During the mid-1970s a programme of studies led by Jorge Katz in Latin America gave rise to the research field of innovation capability building in firms from developing and emerging economies – latecomer firms, based on three dimensions (Bell, 2006): (i) they emphasised the *dynamics* of the micro-level paths of capability accumulation; (ii) they explored the role of learning mechanisms underlying those paths; (iii) they investigated the interactions of those capability building paths with the meso and macro-level institutional frameworks. After a period of absence of such kinds of study, since the early-1990s there has been increasing research interest in bringing *explanations* of the causes and consequences of the nature of capability building paths taken by latecomer firms. There is also a general interest in the different types of innovations emerging in these firms (see *The Economist*, 2010).

By the early 1990s Sanjaya Lall (Lall, 1992) provided us with an explanatory framework centred on the development of firm-level technological capabilities. As he noted, by accumulating their

innovation capabilities, latecomer firms could narrow their technological gaps with those firms in the industrialised world, achieve industrial growth and even leadership. He emphasised that the primary driving force for this were the investments undertaken by firms to accumulate their innovation capability.[1]

Lall viewed such capability building efforts as a response to external and internal stimuli. This led him to distinguish between firm-specific factors, which affect micro-level differences in capability development, and factors that are common to countries, involving their policy regimes, skill endowments, and incentives (p. 169). Although he recognised the importance of micro-level factors and industry-specific institutions to firms' innovation performance, he did not explore much of these variables.

Subsequently to Lall's framework, research about innovation capability in latecomer firms advanced the understanding of the role of learning processes in influencing inter-firm differences in terms innovation performance (e.g. Kim, 1998; Dutrénit, 2000; Figueiredo, 2003; Marcelle, 2004; Dantas and Bell, 2009). However, the investigation about the role of *factors, other than learning*, in affecting variability across latecomer firms in terms of innovation performance suffers from a dearth of empirical evidence. One of the problems is that existing studies have focused either on a narrow range of variables or have been based on discrepant evidence. Consequently, the understanding of innovation performance achievement in latecomer firms remains limited. And so do the recommendations for policymakers. Below I comment briefly on some of these limitations in studies addressing innovation performance in latecomer firms from micro/meso and macro-level perspectives.

[1] Such investments refer to the *creation* and building of innovation capabilities, that is, the mechanisms and processes for creating and acquiring knowledge, skills and other capability inputs for innovation.

Some studies explore the correlation between firm-specific factors, like age, size, ownership, and market orientation and innovation capabilities (e.g. Wignaraja, 2002; Rasiah, 2006; Quadros and Consoni, 2009). However, the variability found across firms in terms of innovation performance is poorly explained. Other studies explore a combination between firm-level and industry-level factors and their implications for firms' innovative or catch-up performance (Lee and Lim, 2001; Park and Lee, 2006). However, they shed limited light on the accumulation of capabilities at the *earlier* stages.

Another stream of work examines firms' performance in terms of 'intra-national' and 'global' catching-up (Jung and Lee, 2010; Iacovone and Crespi, 2010). However, their findings appear to be contradictory. Based on evidence from Korean and Japanese firms, Jung and Lee (2010) suggest that sector-level variables only affect international TFP catch-up, whereas firm-level variables, among them 'innovation capabilities', only determine intra-national catch-up. Based on evidence from Mexican firms, Iacavone and Crespi (2010) conclude that firms that make greater efforts to build their technological capabilities catch up much faster with the global frontier, while this effort does not really affect how fast they can catch up with the domestic frontier. The problem is that the design of these studies does not allow them to capture the role of other micro-level factors that may influence firms' innovative performance. Considering that innovation capability building depends on deliberate efforts. These can be conditioned by the nature of the firm's innovation-related strategy (Scott-Kemmis and Chitravas, 2007).

In relation to studies addressing latecomer firms' innovative performance from a macro-level perspective, since the early 2000s, following the worn-out of the Washington Consensus perspective, there has been a growing interest in understanding the role of institutions in influencing industrial innovation (e.g. Rodrik, 2004, 2006; Cimoli et al., 2009; Lee and Mathews, 2010). As argued in Rodrik (2004), institutions have been underpinning many

successful stories leading to industrial development, especially in natural resources-rich countries.

However, as pointed out in Nelson (2008, p. 1), in relation to concrete empirical analysis, 'there remains a significant gap between aspirations and achievements', especially from a micro and intra-industry level standpoint, although there are notable exceptions (e.g. Evans, 1995; Murmann, 2003).[2] The scarcity of empirical analyses leads to a limited understanding of the implications of changes in institutional frameworks for firms' innovation performance. Such limitations are found in important studies in Asia and Latin America.

With respect studies from Asian contexts, where most of our understanding about long-term technological behaviour in industrial firms has been generated, most of the recent studies on innovation capability building have been characterised by micro-level *continuity* under relatively stable and fairly *continuous* macro-level institutional frameworks (e.g. Amsden, 1989; Hobday, 1995; Kim, 1997; Mathews, 1999). Such perspective also appears in recent studies (e.g. Hobday et al., 2004; Mu and Lee, 2005; Choung et al., 2006). Even after the Asian crisis in 1997 several Korean industries were returning to their development mode based on technological innovation as a result of industrial policy measures and firms' innovative efforts (e.g. Woo and Sul, 2000).

Differently from such Asian contexts, Latin American natural resources-rich countries have experienced disruptions in their institutional frameworks with apparently different kinds of impacts on their industrial capability building. At the same time, firms seem to have generated different kinds of responses to such macro-level discontinuities in terms of innovative efforts across Latin American countries and industries. Such kinds of variability are far from being captured by existing analyses.

[2] Nearly 20 years ago R Nelson made a call for researchers to take more seriously the interaction between firms and environmental factors in order for us to make progress in research on industrial leadership (see Nelson, 1995).

For instance, some studies argue that the structural reforms of the early 1990s, which replaced the import substituting industrialization (ISI) regime by new conditions based on open economy and globalised competition, imposed a discontinuity on capability accumulation, perhaps at a lower level of capability than that set by the preceding ISI regime, and have pushed Latin American economies into a 'low development trap' (see Katz, 2000; Reinhardt & Peres, 2000; Ocampo, 2001; Narula, 2002). In addition, as argued, the growing relevance of natural resources industries in Argentina, Chile and Brazil is deemed as a 'negative' consequence of that macro-level discontinuity and a kind of obstacle to deepening innovative capabilities (Ocampo, 2001, Cimoli and Katz, 2003; Cimoli and Correa, 2005). More recently, a similar kind of perspective appears in Castaldi et al. (2009).

I agree with these studies that a Washington Consensus-type of policy suffers from serious limitations in terms of promoting industrial capability building. However, the problem with these studies is that, by addressing such issues from a macro-level perspective and based on highly aggregated secondary data, they miss out intra-industry and micro levels variability, dynamics and nuances of innovation performance across changing institutional frameworks. By so doing they also provide a common view on the 'Latin America experience'. Additionally, their view on natural resources industries are commonly generalised as 'low tech' sectors with low knowledge intensity. However, hidden behind their average 'low-medium tech' characteristics, such sectors include firms with considerable innovative capabilities that undertake new-to-market and new-to-world types of innovation (von Tunzelmann and Acha, 2005; Smith, 2005).

In sum, nearly 20 years after Lall's framework, explanations about variability across latecomer firms in terms of innovation performance are still limited. The review undertaken above suggests that research should urgently be directed to the understanding of the interaction between firms'

innovation performance and changes in their institutional environments and the role of micro-level attributes in mediating that interaction. This is precisely the intention of this paper.

The first type of attribute refers to the changing institutions at the meso and macro levels. Instead of considering the firm's institutional environment as 'given', 'background conditions' or 'source of evidence' for strategy formulation, this paper considers its role in firms' innovation performance. The second type of two firm-level attributes. The first is the firm's innovation performance which, differently from most innovation studies, is proxied here based on progressive higher levels of innovation capability building. The second refers to the firm's strategy. Differently from most studies, the paper emphasises a contextual or embeddedness approach to strategy. Specifically, the paper explores the role of *capability-building strategy embeddedness*, hereafter *strategy embeddedness*, in mediating the relationship between the changing meso and micro-level institutional frameworks and variability in firms' innovation performance over time. *Strategy embeddedness* of firms is defined herein in terms of levels of relationships between firms and their institutional frameworks, as part of the firm's strategy process to build up capabilities to improve their innovation performance *over time*.

This set of relationship is examined based on first-hand longitudinal evidence from 13 firms of the forestry, pulp and paper industries in Brazil (1950-2009). The remainder of this paper is structured as follows. Section 2 outlines the paper's analytical framework, while Sections 3 and 4 contains the empirical setting and research methods, respectively. Section 5 presents the empirical findings followed by discussions of findings in Section 6. Section 7 contains the paper's concluding discussions.

2. Analytical Framework

2.1 Innovation performance in latecomer firms

In this paper firms' innovation performance reflects the accumulation of progressive higher levels of innovation capabilities. Firms' capabilities involve a stock of resources consisting of two broad dimensions: 'human resources', skills, and knowledge bases and 'organisational' – e.g. different forms of internal and external arrangements (Lall, 1992; Bell and Pavitt, 1993; Kim, 1997, 1998; Dutrénit, 2000). Specifically, the manner and the speed at which firms' capability building paths proceed over time determine the types and levels of innovative activities that they are able to undertake, that is, the firm's *innovation performance*.

However, in the latecomer parlance the term 'catch-up' tends to suggest a single pathway, with different firms distributed along it, with a clearly defined 'frontier'[3]. Specifically, the notion of a frontier tends to be associated with that of all firms following the same specific technological path (towards the same end-point) as that previously followed by global technological leaders[4]. In reality, the process of technological development of latecomers cannot be represented using the analogy of a race along a fixed track. This is because of the possibility of successful overtaking by latecomers moving in new directions, and of the emergence of radical discontinuities that open up opportunities for them (Perez and Soete, 1988; Lim and Lee, 2001; Figueiredo, 2010).

Thus latecomer firms may accumulate capabilities by which they may pursue significantly new *directions* of innovation that depart from the trajectories previously mapped out by earlier innovators, thus opening up *qualitatively different segments* of the international innovation frontier[5]. Rather than deeming the technological frontier as an end-point or even a moving target,

[3] Richard Nelson, 2008, personal communication.
[4] Martin Bell, 2008, personal communication.
[5] Martin Bell, 2008, personal communication.

this paper considers it as a fluid area or horizon to be explored. Thus the notion of catch-up herein also encompasses so-called ‘overtaking’. Latecomer firms can explore such fluidity to create new segments in the technological frontier (Lee and Lim, 2001; Figueiredo, 2010)

However, firms differ in the manner and speed at which they engage in efforts to create their capabilities (Dosi, 1985; Bell and Pavitt, 1993; Pavitt, 1998), leading to differences in the kinds of innovative activities they undertake or their innovation performance. Such innovation performance improve indicators of technical, commercial and environmental performance, but also to meet the challenges of industrial diversification (Hausmann and Rodrik, 2006), globalised competition and sustainability.

2.2 Institutional frameworks and their impact on firms’ innovation performance

Over the past two decades this issue has received remarkable contributions from economics (North, 1990) and the institutional theory in sociology and organization theory (Powell and DiMaggio, 1991; Scott, 2001). As for North (1990) institutions ‘consist of both informal constraints and formal rules’. Nelson and Sampat’s (2001) notion of ‘social technology’ is in line with North’s (1990) ‘rules of the game’ or ‘institutional arrangements’. They suggest that institutions can have a significant impact on firms’ innovative and competitive performance. Such view has also been held in the research body about innovation capability in latecomer firms (e.g. Bell, et al., 1982; Lall, 1992; Bell and Pavitt, 1993). Although, by definition, ‘institutions’ denote stability, they are subject to change processes, both incremental and discontinuous (Scott, 2001).

Building on these and other concepts and on insights (e.g. Murmann, 2003; Evans, 1995) this paper defines ‘institutional frameworks’ as a set of norms in the form of laws, policies regulations, and incentive systems that may work as opportunities, but also as constraints to firms’ strategic choices. Institutional frameworks can be addressed from different perspectives like broad policy

regimes (e.g. North, 1990; Lall, 1992; Rodrik, 2004, 2006; Cimoli et al., 2009), industry-level frameworks (Murmann, 2003) and public-private relationships (Evans, 1995) and knowledge related institutes and organisations (e.g. Malerba and Mani, 2009; Lundval et al., 2009).

Following Scott (2001), this paper views institutional frameworks as dynamic Differently from North's (1990) view of firms as 'players in the game', but in line with Murmann (2003), this paper considers that institutional frameworks can also be shaped by firms and industries as they pursue leading innovative performance. In their pursuit of knowledge to achieve distinguished competitive performance, firms embed in a variety of interactions with different actors in their environment (McEvily and Zaheer, 1999). Such embeddedness denotes the notion that the achievement of firms' competitive performance can be facilitated by the attachments they create with several actors in their environment (Granovetter, 1985).

2.3 An embeddedness approach to firms' strategy

Strategy research has acknowledged the importance of the environment to firms' competitive performance. However, traditional views deem firms as solitary entities that operate under given environments to which intractable contingencies they need to *adapt* in order to be successful (Astley, 1984; Baum and Button, 1997). Such kind of perspective has been present, in different ways, in influential explanatory approaches to firms' competitive performance (Peng, 2002; Murmann, 2003): the 'Chandlerian firm', the 'transaction cost', the 'industry-view' and the 'resource-based view'.

These 'atomist-type' of approaches have generated many relevant contributions, but they provide only partial explanations about firms' competitive performance (Baum and Button, 1997). First, the functioning of a firm does not follow automatically from intractable contingencies imposed by the environment to which managers must react and adapt. Managers can proactively make

'strategic choices' about what will be relevant, what will be constraints and pursue their course of actions (Child, 1972; Astley, 1984). Such view is recognised in works addressing technology and innovation strategy (e.g. Goodman and Lawless, 1994; Dodgson et al., 2008). Second, as noted by Granovetter (1985) do not behave or decide as atoms outside a social context, but their attempts at purposive action are instead embedded in concrete ongoing systems.

Since the 1980s and, especially from the 1990s, there has been a growing awareness of the importance of a contextualised approach to the strategy concept leading to the emergence of an embeddedness strategy approach (Baum and Dutton, 1997; Hoskinsson, 2000). This reflects a growing consensus that institutions matter for firms' innovative and competitive performance (Powell and DiMaggio, 1991; Nelson and Sampat, 2001; Scott, 2001). Such view is in line with the Peng's (2002) 'institution-based view of business strategy' and the notion of embeddedness as a part of firms' strategic asset-seeking efforts (Dacin et al., 1999; Meyer et al., 2011).

However, these approaches need to be tempered by the intricacies of the *process* of innovation-related strategies within firms. As noted in Freeman (1974) and Pavitt (1990) technology and innovation strategies involve many organisational areas, different types of expertise and controversies and advocacy within the firm.

Innovation strategies strongly involve trial-and-error leading to rules of thumb and routines (Mintzberg, 1994). They emerge out of long trial-and-error processes (Pascale, 1984) and responses to crises (Mintzberg, 1994) and can be constrained by the firm's core rigidities (Leonard-Barton, 1995), resulting in truncated innovation performance (Druténit, 2000). They can also be persistently pursued firms' entrepreneurs (Teece, 2007), the firm's dominant group's innovation-drive (Kim, 1997) as they can be stimulated or constrained by the leadership's behaviour (Figueiredo, 2001).

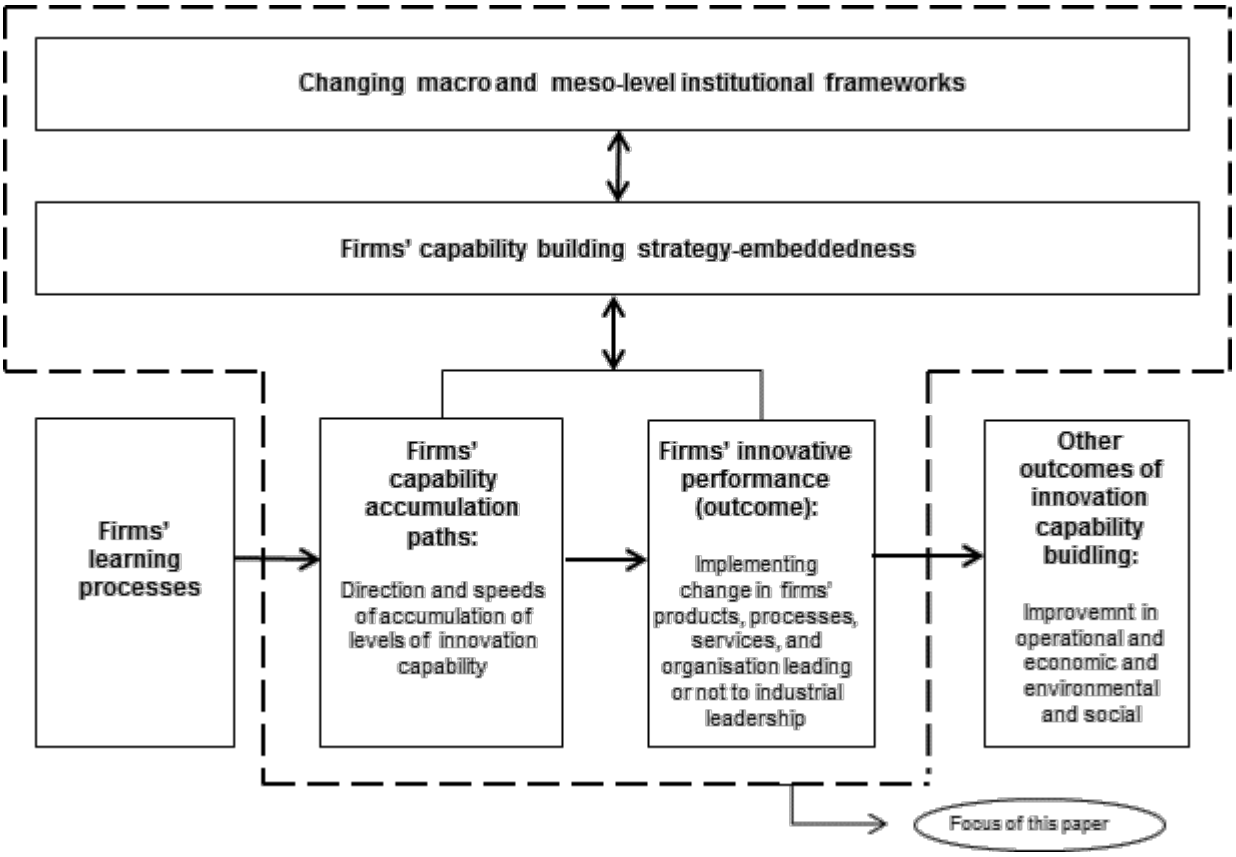
Therefore, in order to examine the role of the firm's strategy in mediating the interaction between changes in the firm's institutional frameworks and its innovation performance this paper focuses on the *capability-building strategy embeddedness* of firms or *strategy embeddedness*. *Strategy embeddedness* of firms is defined herein in terms of relationships between firms and their institutional framework, as part of the firm's strategy process to build up capabilities to achieve, sustain and deepen their innovation performance over time. By building on previous research, this paper considers that innovation strategies vary in terms of levels or degrees (Goodman and Lawless, 1994; Scott-Kemmis and Chitravas, 2007) and so does firms' embeddedness as part of firms' strategic asset seeking deliberate efforts (Dacin et al., 1999; Figueiredo, 2011). Consequently, *strategy embeddedness* is examined herein in terms of levels. This paper examines the relationship between these issues in a set of forestry and pulp and paper firms in Brazil over the period 1950-2009 by asking:

(1) To what extent did these firms differ in terms of the manner and speed at which they achieved innovation performance across changing institutional frameworks during the 1950-2009 period?

(2) What was the role of *capability-building strategy embeddedness* in mediating the interaction between the changing institutional frameworks and innovation performance of these firms' across that period?

The relationship between the issues addressed in the research question constitutes the analytical framework underpinning this paper as represented in Figure 1.

Figure 1. The study's analytical framework



2.4 Operationalising the constructs

2.4.1 Firms' innovation capabilities and innovative performance

This paper adopts a nuanced view of innovation that involves increasing *degrees* of novelty and complexity in terms of processes, products and organisation thus in line with the Oslo Manual (OECD, 2005). Consequently, this paper draws on a modified version of the Lall/Bell and Pavitt typology (Lall, 1992; Bell and Pavitt, 1995; Figueiredo, 2001): it identifies 'levels' of innovative capabilities running from 'basic' to 'world leading', consistent with the Oslo Manual. Such kind of typology has been used successfully in empirical studies, with slight variations in terminology (e.g. Figueiredo, 2003, 2010; Ariffin and Figueiredo, 2004; Hobday et al., 2004; Tsekouras, 2006; Iammarino et al., 2008; Dantas and Bell, 2009). Rather than identifying capabilities in terms of specific resources, they have identified levels of innovative *activity*, and then inferred that different levels of capability lie behind the patterns of *innovation performance*. Table 1

contains a condensed version of that framework. The first column shows four levels of innovative performance running from 'basic' to 'world leading'; the second column provides some illustrative examples of these levels of capability.

Table 1. Typology for assessing innovation performance in latecomer firms (condensed version)

Levels of innovative performance	*Illustrative examples of these levels of innovation performance*
World leading (frontier pushing)	Introduction of new-to-the-world innovations. R&D for the introduction of cutting edge seed development processes along new technological trajectories. This includes R&D in genomics and proteomics to introduce complex changes in the characteristics of cultivars.. Intellectual property system.
Advanced	Introduction of near-world-leading innovations. R&D projects for the introduction of new feedstock processes implemented by innovation leaders. R&D for the introduction of new production processes along existing trajectories.
Intermediate	Introduction of new to the local economy and/or new to the firm innovations. Development of resources for forest installation, attendance and recovering and alternative processes and resources for disease and pests control.
Basic	Introduction of new to the firm type of innovations. Implementation of resources for forest and agricultural installation, attendance and recovering. Quality tests and features evaluation for seed and seedling production. Forest management based on international certification (e.g. FSC).

2.4.2 Firms' capability-building strategy embeddedness

Strategy embeddedness is herein operationalized in terms three levels: pro-active, active and reactive or arm's length (Table 2). Additionally, the typology categorises institutional frameworks in terms of macro- and meso levels. The latter is opened up in two sub-levels. The second component of the meso-level institutional framework (knowledge-related institutes) is equivalent to what is examined in Malerba and Mani (2009) and Lundval et al. (2009) and will be addressed here only very superficially.

Table 2. Typology for assessing strategy embeddedness

Components and players of institutional frameworks	Macro-level	Complex macro regimes of interconnected segments of implemented public policy within which firms operate: a set of laws, policies, incentives and industrial development policies, plans and programmes at the national and industry levels.
	Meso-level	Sectoral level policies, plans and incentives that underpin particular kinds of policy regime. Sector-level organisational structures and pressure groups acting to influence government policy. Aspects of political and bureaucratic public-private interactions related to specific industrial sectors underpinning particular kind of policy regime.
		Knowledge-related institutes and organisations surrounding latecomer firms and concerned with education, training, standards, research.
		⇕
Levels of strategy-embeddeness	Pro-active	Very high awareness of the role of innovation capability in the firm's competitive performance. Pioneer and ambitious engagement in innovation activities. Initiative to provoke and interact with components of the meso and macro level institutional frameworks. Firms tend to hold a position of innovation 'leaders'.
	Active	High awareness of the role of innovation capability in the firm's competitive performance. Relatively conservative and/or follower approach to engagement in innovation activities. Follower approach to interacting with meso- and macro level components of the institutional frameworks. Firms tend to hold a position of innovation 'followers'.
	Reactive (arm's length)	Low or absent awareness of the role of innovation capability in the firm's competitive performance. Reactive and/or indifferent to interactions with components of the meso and macro level institutional frameworks. Firms tend to hold a position of slow innovation 'followers or laggards
		⇕
		Firms' innovation performance levels

3. Brazil's *Eucalyptus* forestry and pulp and paper: a leading competitive position

The pulp and paper industries are highly intensive in capital, processes and scale (Pavitt, 1984), while forestry itself is also increasingly science-based. The paper-making process involves the conversion of wood chips into pulp, which is processed to create paper. Pulp, the main raw material for paper-making, is obtained from trees such as pine (long-fibre or softwood) or eucalyptus (short-fibre or hardwood).

Planted forests are renewable resources for a diversity of industries based on raw materials from fibres and lignocelluloses, especially the pulp and paper industries. As explained in Assis (2001), Grattapaglia (2004) and Grattapaglia and Kirst (2008) since the early 1990s it has been realised 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. 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 to produce one ton of pulp, i.e., decreasing the wood specific consumption (WSC) (Grattapaglia and Kirst, 2008). During the 1980s, first-generation clonal forestry of eucalyptus reduced WSC by 20 percent. A further 20 percent reduction was achieved later based on second-generation clones derived from eucalyptus hybridization (Ikemori et al., 2005 and Assis et al., 2005 *apud* Grattapaglia and Kirst , 2008)

Historically, the world's main producers and innovators in the forestry, pulp and paper industries were the Norscan countries (Canada, US and Nordic countries Sweden, Finland and Norway). However, between the 1960s and 1970s a major breakthrough in eucalyptus-based forestry technology was achieved, especially in Brazil.[6] This led to the plantation of the first large-scale commercial stands of selected clones derived from hardwood cuttings. These and subsequent advances resulted in exceptional genetic gains for growth and adaptability to tropical conditions and wood with higher pulp yield (Grattapaglia and Kirst, 2008). Such technological development contributed to the achievement by Brazil of an international leading position in that field (see Table 3). One hundred percent of all pulp and paper produced in Brazil derives from planted forests.

[6] Figueiredo (2010) examines the emergence of that innovation in Brazil. For technical details see Grattapaglia and Kirst (2008) and related references.

Table 3. Some indicators 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.

Such technological advance achieved by Brazilian firms was reflected in the commercial performance (or market catch-up, Lee and Lim, 2001) achieved by Brazil. During the period 1970-2009 Brazil's exports of pulp and paper increased, respectively, by 14.2 and 21.3 percent annually on average, while the average growth rates of Norscan countries were 0.18 percent (pulp) and 2.1 percent (paper) during that period. Brazil also achieved a superior export growth rate of pulp and paper export in relation to other developing economies. Relatedly, during the 2001-2009 period the export value of Brazil's pulp and paper exports grew, respectively, 10.7 percent and 23.8 percent annually on average, whereas the annual growth rates of Norscan countries were 0.18 percent (pulp) and 2.1 percent (paper) during that period. [7] In 2009 Brazil ranked the world's 4th pulp producer (all types), 1st as a producer of hardwood pulp ('eucapulp'), and 9th paper producer.

4. Methods

4.1 Research design and cases selection

This paper derives from an empirical study based on a three-year fieldwork campaign (2006-08 with a follow-up in 2009) involving exploratory, pilot, and main fieldwork phases. In line with the

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

research questions and considering that they required an in-depth study with an analytical generalisation, this study was designed using long-term and first-hand evidence from multiple cases. The adoption of such a design permitted a detailed investigation of the processes involved than that afforded by other methods (Eisenhardt, 1989; Yin, 2003). Thirteen relevant firms and their particular business lines were selected (Table 4).

Table 4. The selected multiple cases

Thirteen selected firms	Start-up year	Ownership	Focal cases		
			Forestry [7]	Pulp [9]	Paper [11]
1. Alpha	1978	Brazilian	✓	✓	None
2. Beta	1975	Foreigner	✓	✓	None
3.Gama	1960 (1990)	Foreigner	None	✓	✓
4. Delta	1945	Brazilian	✓	✓	✓
5. Epsilon	1950 (1990)	Brazilian	None	None	✓
6. Zeta-A	1954 (1990)	Brazilian	✓	✓	✓
7. Zeta-B	1985	Brazilian	None	None	✓
8. Theta	1974	Foreigner	✓	✓	✓
9. Iota	1978	Brazilian	None	None	✓
10. Kappa	1941	Brazilian	✓	✓	✓
11. Lambda	1966	Brazilian	None	None	✓
12. Sigma-A	1988	Brazilian	✓	✓	✓
13. Sigma-B [(a)]	1988	Brazilian	None	✓	✓

Note: (a) Sigma-B does have forestry operations, but this business was not included in this study.

4.2 Evidence gathering and analysis processes

Following Jick (1979), Eisenhardt (1989), and Yin (2003), this study drew on triangulation methodology to achieve robust internal validity and reliability. It was based on a combination of extensive fieldwork and follow-up questionnaires. During the pilot and main fieldwork, the evidence collection involved 155 formal and 44 informal interviews (from one to three hours in length), direct observations, and several consultations of firms' and industry associations' archival records. Twelve interviews were conducted with local universities, research institutes, industry associations and government bodies to verify the nature of their relationships with the case firms.

The information gathering process began by contacting the chief executive of each firm to clarify the purpose of this research and to negotiate access for evidence gathering. With their approval it was possible to tap into various sources of information (e.g. industrial directors, managers, engineers, researchers, technicians, consultants, and archival records). Open-ended interviews were conducted using an interview guide that was constructed in the light of the study's typologies. The extensive use of triangulation made it possible to gather evidence from a range of different sources to substantiate the results of the analysis. After the main fieldwork, follow-up questionnaires were sent to target informants. Because most of them already knew the study, a 95 per cent response rate was achieved.

Formal analyses involved: (i) harmonisation and combination of the evidence from the interviews and observations with that from the follow-up questionnaires; (ii) tabulation of the frequency and types of observations *over time* and building systematic and successive 'cross-company display tables' based on a 'data reduction' procedure (Miles and Huberman, 1994). (iii) systematic matching of different pieces of evidence from the cases with the study's analytical frameworks (and Tables 1 and 2) to achieve solid construct validity (Campbell, 1975). Rather than reducing all qualitative data to quantitative observations, both types of evidence were used to form the study's dataset, to run some statistical testes and to enrich the empirical analysis.

5. Empirical Findings

Section 5.1 provides a brief overview of the association between the case firms' innovation performance and their strategy embeddedness across changing institutional frameworks (1950-2009). Based on qualitative evidence, Section 5.2 examines the evolution of that relationship during that period. The presentation of the evidence is organised mainly around three periods: (i) ISI policy regime (1950-1960s and 1970-1980s); (ii) the transition into an open economy regime (1990s) and (iii) the open economy and globalised competition regime (2000s).

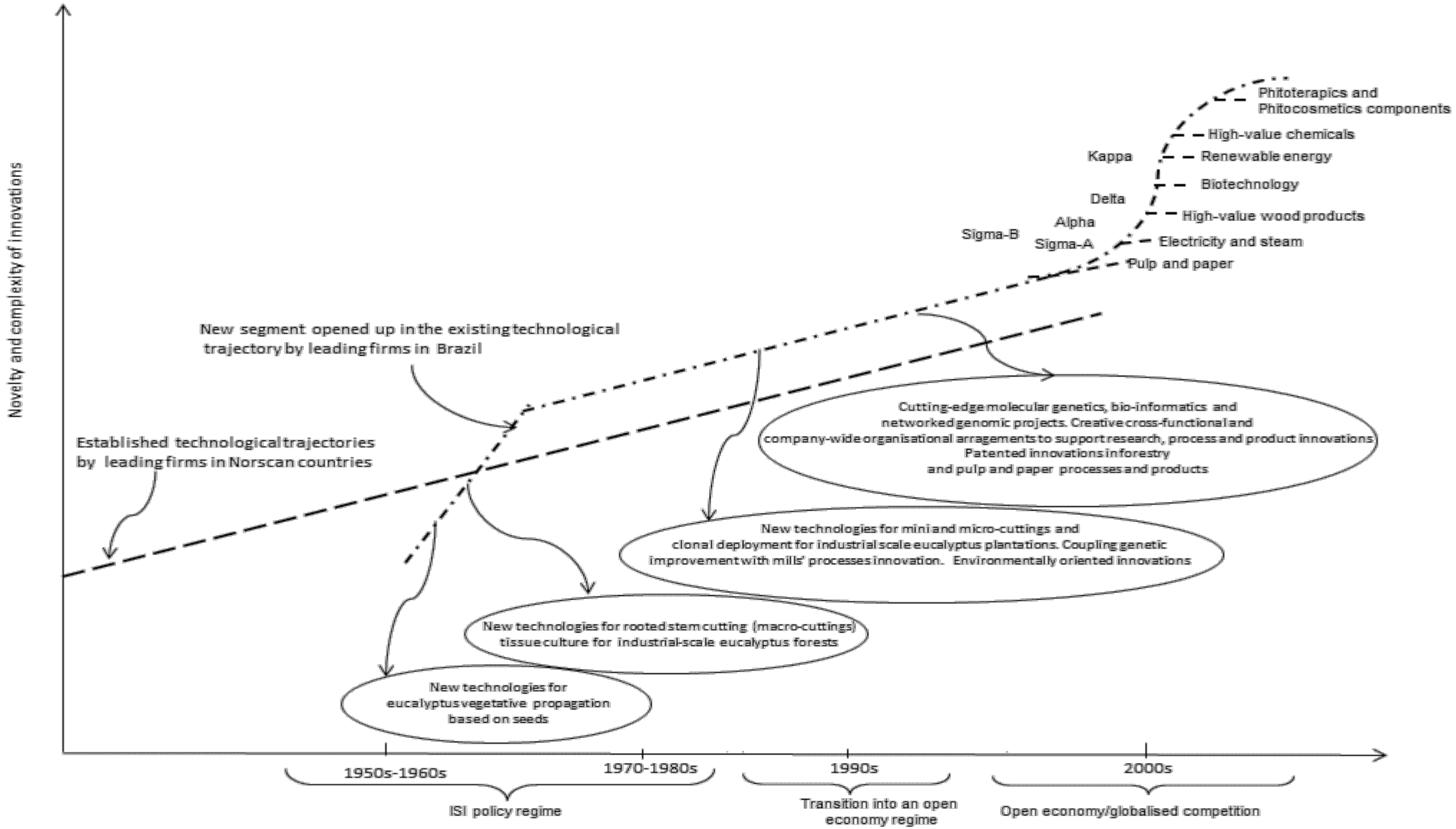
5.1 Firms' innovation performance and strategy embeddedness across different institutional frameworks

The findings indicate that leading firms from the forestry, pulp and paper industries in Brazil engaged since the 1950s in a kind of 'path-creating' capability accumulation. They 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 make pulp and paper from eucalyptus trees, and to engage in activities that firms in the Norscan countries were not engaged in. This meant that, relatively early on, they could not simply copy the recognised global leaders, and were instead forced to develop technologies more suited to their own somewhat different operations. They could not simply *imitate* because they were developing along a different trajectory. This involved the use of different raw materials (eucapulp), and in developing the effective means to do this: they had to innovate in their downstream pulp and papermaking processes because of the innovations developed in the upstream forestry.

Specifically, the firms took a *different direction* of technological development from those already pursued by the global industry leaders. By so doing, they opened up a qualitatively different segment at the international technological frontier. Such 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 capability (Figure 2).[8] From the mid-2000s those firms that had achieved world-leading innovation performance, especially in the forestry area, began to draw on their accumulated capabilities to diversify into different business lines.

[8] For details about these paths see Figueiredo (2010).

Figure 2. Evolution of the eucalyptus-based technological trajectory pursued by Brazil's leading firms



However, the process of innovation capability building of these firms *along the new technological segment* was characterised by a high degree of variability in terms of the *levels and speeds* of capability accumulation (Table 5).

Table 5. Accumulation of innovation capability along the eucalyptus-based technological trajectory (2009)

Levels of innovation performance	Firms and lines of business and number of years it took to attain each innovative performance level					
	Forestry		Pulp		Paper	
World leading	Sigma-A	23	Sigma-B	11	Sigma-B	18
	Alpha	31	Sigma-A	14	Sigma-A	19
	Delta	48	Alpha	22	Delta	54
	Theta	48	Delta	50	Kappa	54
	Kappa	51	Kappa	53		
Advanced	Beta	39	Gamma	14	Theta	33
			Beta	26	Gamma	14
					Zeta-B	18
Intermediate	Zeta-A	11	Zeta-A	11	Zeta-A	19
			Theta	31	Epsilon	14
					Iota	22
					Lambda	37

Source: Derived from the empirical study.

In addition to these differences in innovation performance, the study also found differences across these firms and their business lines in terms of the type of strategies embeddedness that they pursued over time (Table 6). Table 8 shows the results from the non-parametric Kruskal-Wallis test that indicates a positive and significant association between the firms' levels of innovation performance and the prevailing types of strategy embeddedness they implemented during the period of study. The following section provides a qualification to this evidence.

Table 6. Evolution of the strategy embeddedness adopted in specific business lines of the case-study firms

Firms	1950-1960s			1970-1980s			1990s			2000s		
	Forestry	**Pulp**	**Paper**	**Forestry**	**Pulp**	**Paper**	**Forestry**	**Pulp**	**Paper**	**Forestry**	**Pulp**	**Paper**
Alpha				Pro-active	Pro-active		Pro-active	Pro-active		Pro-active	Pro-active	
Beta				Active	Active		Active	Active		Active	Active	
Gamma								Active	Active		Active	Active
Delta	Active	Active	Active	Active	Active	Active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active
Epsilon			Proactive			Proactive			Reactive			Reactive
Zeta-A							Reactive	Reactive	Reactive	Reactive	Reactive	Reactive
Zeta-B						Reactive			Active			Active
Theta				Pro-active	Active	Active	Pro-active	Active	Active	Pro-active	Active	Active
Iota						Reactive			Reactive			Reactive
Kappa	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Active	Active	Active	Pro-active	Pro-active	Pro-active
Lambda			Reactive			Reactive			Reactive			Reactive
Sigma-A				Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active	Pro-active
Sigma-B					Pro-active	Pro-active		Pro-active	Pro-active		Pro-active	Pro-active

Note: Blank cells mean ‘not applicable’ either because (i) the firm and/or the line of business had not started up during that time period or (ii) the firm does not operate that line of business.

Table 7. Kruskal-Wallis test for firms' innovation strategies and levels of innovation performance

	Innovation strategies *vs.* innovative performance levels		
	Forestry	Pulp	Paper
Chi-Square	4.758	6.879	5.917
df	1	1	2
p-value	0.029**	0.009***	0.052*

Notes: (*) Association significant at the 0.10 level; (**) Association significant at the 0.05 level (***) Association significant at the 0.01 level

5.2 Evolution of the case firms' innovation performance and strategy embeddedness across changing institutional frameworks

5.2.1 The ISI policy regime: the periods 1950-1960s and 1970-1980s

5.2.1.1 Main changes in the macro and meso-level institutional frameworks: 1950-1960s

Building on the second Vargas' government (1951-54), the Kubitschek's administration (1956-60) created the Targets Plan to accelerate Brazil's industrialisation process, by intensifying the ISI policy. Strong emphasis was given to basic industries and inputs, among them forestry and pulp and paper. Under this state-led large-scale industrialisation, the National Bank for Economic and Social Development (BNDES)[9], became not only the main funder of industrial projects. It also became responsible for the industrial policy in Brazil. Such framework involved the creation of state-owned enterprises and agencies to support the development agenda – e.g. the National Research Council (CNPq), the Coordination for Post-graduate Training (CAPES) and later, the Funder of Studies and Projects (FINEP).

[9] Created in 1952 as the BNDE (National Bank for Economic Development), it became Brazil's first institution dedicated to the long-term funding of infrastructure and industrial development.

Three important factors related to that government agenda, had implications for firms' expansion of their forestry activities and engagement in innovative activities. First, the enforcement of the Forestry Law (of 1966), which provided tax incentives for firms that developed planted forestry based on eucalyptus, contributed to the expansion of the forest bases needed for new pulp and paper mills. This policy was implemented by the Brazilian Institute for Forestry Development (known as IBDF), created in 1967. In order to obtain funding from BNDES firms had to have their own supply of wood derived from planted forests.

Second, considering that the pulp and paper industries in Brazil emerged spontaneously as a response to import constraints of raw materials (e.g. WW2, Korean War), from the early 1950s there was a proliferation of inefficient small-scale pulp and paper mills. By the late-1960s some industrial leaders (some of them from Kappa and Delta), through the Pulp and Paper Manufacturers National Association (ANFPC), *provoked* the BNDES to assess the feasibility of the existing pulp and paper mills in Brazil. Such action reflected a pro-active strategy embeddedness of some firms to change industrial policy. Following that study, the BNDES imposed new conditions for funding based on production performance an introduction of innovations. Third, the emergence of research facilities and suppliers of human capital proved essential for the technological advance of forestry and pulp and paper firms. Supported by CNPq and CAPES, the College of Agriculture of the São Paulo University (ESALQ) began to offer degree courses on forestry (from undergraduate to PhDs), as it expanded its post-graduate programmes and laboratories for pilot production of eucalyptus-based pulp and paper.

5.2.1.2 Firms' strategy embeddedness and innovation performance: 1950-1960s

Firms like Kappa and Delta responded positively to the incentives generated by the Forestry Law by expanding their planted forests. However, reflecting a proactive strategy Kappa engaged in research activities. As Brazil lacked proper research facilities, Kappa developed a partnership with the Florida University in the US to use its laboratories to test the use of eucalyptus for large-scale pulp and paper production. After six years of systematic research efforts, by the late 1960s Kappa was manufacturing paper from eucalyptus pulp on a large scale.

Similarly, the firm Epsilon, also pursuing a proactive strategy, intensified its innovative efforts that had begun in the 1940s: it engaged in research to obtain improved bleached pulp and high-performance tissue paper from eucalyptus. However, Brazil's weak forestry research capability was a constraint for further innovative activities. Two important strategic actions taken by industrial entrepreneurs contributed decisively to overcome this hurdle. First, firms like Kappa, Delta and Epsilon began to provoke and create research demands for government bodies (e.g. IBDF) and government-led education and research institutions (ESALQ). This led to the creation, in the mid-1960s, of an external/collective R&D arrangement at the Forestry Science and Research Institute (known as IPEF), funded by the industry, but run by the public sector.

Second, by the mid-1960s, the creation of Alpha by a group of 12 entrepreneurs represented a decisive thrust for the commercial success of the eucalyptus-based technological trajectory.[10] The initial idea of exploring timber evolved into the building of a large export pulp firm. To speed up the project, their strategy was to draw on eucalyptus seeds that had been developed earlier in Brazil. However, Alpha's eucalyptus plantations were marred by uncontrolled hybridisation and high variability in growth rates and diseases, reflecting the poor quality of seeds. Consequently, Alpha was forced to change its initial strategy and, as early as 1968, Alpha

[10] This group involved visionary Brazilian entrepreneurs, among them one of the creators of Vale, a Brazilian mining company and a Norwegian businessman.

structured its own research centre to tackle to such problems. By doing so, Alpha moved from vegetative propagation, based on seeds, into tree improvement and clonal programmes (Campinhos, 1999; Evans and Turnbull, 2004). Although some shareholders were sceptical about such research investments, Alpha's dominant group intensified its emphasis on research as to achieve technological and market leadership. To facilitate its exports, Alpha negotiated with the federal government a permission to build its own harbour, next to the mill.

5.2.1.3 Main changes in the macro and meso-level institutional frameworks: 1970-1980s

While the first National Development Plan (PND-I, 1972-74) focused on infrastructure projects, the PND-II (1974-79) emphasised the expansion of basic industries and inputs, among them pulp and paper, as a means of increasing exports to face up to the energy crises. Within that framework, a review by BNDES of Brazil's forestry and pulp and paper industries led to the First National Pulp and Paper Plan. It sought to stimulate and support production efficiency and forestry research. While such measures were well received by firms committed to innovative forestry activities (e.g. Alpha, Kappa, Delta), some firms responded indifferently or negatively to such measures.

The Second National Pulp and Paper Plan was issued in the late-1980s by a joint efforts between the BNDES and the Industrial Development Council with an active participation of industrial leaders through the ANFPC, reflecting the pro-active strategy embeddedness of firms like Alpha, Delta, Kappa and Epsilon. It established new targets for the 1990s: (i) expansion of forest areas and the mills' output; (ii) increase of exports; and (iii) stimuli to initial public offerings (IPOs). The start-up of operations of large mills of firms like Alpha and Beta in the 1970s and of Sigma-A and Sigma-B in the 1980s, consolidated not only Brazil's self-sufficiency in pulp and paper. It also demonstrated a successful outcome of the public-private symbiosis and bold efforts of

industrial entrepreneurs and government to develop and strengthen the eucalyptus-based technology for pulp and paper.

During the early 1980s, there was a change in the division of labour related to the institutional framework for forestry research. The state-owned Brazilian Enterprise for Agricultural Research (EMBRAPA), created in 1973, took up the responsibility for the National Programme of Forestry Research, including genetic improvement, while IPEF became dedicated to new research methods based on forestry handling and exploitation. Such changes in meso-level institutions with the macro-level weakening of the ISI policy and the severe economic crises of the 1980s, led to the discontinuity of the tax incentives for re-forestation and of firms' collective R&D arrangement for forestry research within ESALQ through IPEF.

5.2.1.4 Firms' strategy embeddedness and innovation performance: 1970-1980s

Some firms responded to such discontinuities by creating and/or expanding their internal R&D facilities. For example, in addition to its forestry research centre, which had been created in the late 1960s, in 1983 Alpha structured an R&D centre dedicated to industrial pulp and paper activities. Firms that had started up in the 1980s (e.g. Sigma-A and Sigma-B) and established firms (Delta, Beta and Theta) also structured their own forestry research centres. These firms began to interact with other local universities (e.g. the Federal University of Lavras (UFL) and the Federal University of Viçosa (UFV)). In contrast, other firms (e.g. Lambda and Iota) opted for not engaging in the creation or strengthening of their own research facilities.

Alpha's proactive strategy was reflected in its massive investments in forestry research. In the early 1980s Alpha introduced a breakthrough innovation based on mass production of clonally propagated planting stock. In 1984, nearly 17 years after having started its research activities, Alpha achieved worldwide recognition by being awarded the Marcus Wallenberg Prize from

Sweden.[11] Alpha's achievement of such world-leading innovation consolidated the new technological segment opened up by Brazil's forestry for pulp and paper firms in the international technological frontier.

Building on these achievements, firms like Alpha, Kappa and Theta sought to reach export markets. However, by being latecomers they were confronted by an obvious hurdle: lack the international market and technical and credibility, especially related to the eucalyptus pulp efficacy. To overcome this barrier, these firms took actions that reflected, according to the typology of this study, typical pro-active strategy embeddedness. They began to build up, re-organise and draw on meso-level institutions to help them to overcoming those hurdles. For example, the Pulp and Paper Technical Centre at the University of São Paulo was created to promote the eucalyptus fibre in the world market. To strengthen the industry's capacity for commercial and political lobbying the Pulp and Paper Manufacturers Association (ANFPC) and the Brazilian Association Pulp Exporters were merged into the Brazilian Pulp and Paper Association (BRACELPA). The Brazilian Technical Pulp and Paper Association (ABTCP) was strengthened to train human resources and to promote manufacturing technical advances.

5.2.2 The transition into an open economy regime: the 1990s period

5.2.2.1 Main changes in the macro and meso-level institutional frameworks

March 1990 marked the formal end of state-led industrialisation policy in Brazil. In line with measures adopted in other developing economies, the Collor administration implemented a substantial reduction of trade barriers, an abrupt opening-up of the economy to foreign competition with a greater attraction of FDI, de-regulation of the economy and privatisation of

[11] 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.

several state-owned companies. As a result, several firms were swept away from the economy as they were not able to face up to international competition.

The BNDES began to emphasise financial and market mechanisms to allow Brazilian economy to compete globally. To that end, in early 1990, BNDES implemented the Industrial and Foreign Trade Policy (PICE), which sought to stimulate the development of industrial capability. Such policy involved several programmes and fiscal and credit incentives: the Brazilian Programme of Quality and Productivity (PBQP) sought to disseminate new management and production organisation techniques (e.g. TQC/M, JIT) and the creation and upgrading of organisations for manufacturing quality control.

By the late 1990s, the Cardoso's administration (1995-2002) created a set of innovation funds to complement the traditional financial resources to support industrial innovation. This set of innovation funds generated a new management model for innovation policies in Brazil emphasising the modernization and expansion of S,T&I infrastructure, the promotion of synergies between universities, research institutes and the industry for technological development.

5.2.2.2 Firms' strategy embeddedness and innovation performance

During the early 1990s most firms were impacted by the new economic and institutional conditions. There were varied types of strategic choices and actions. Some of the case firms stumbled. Others restructured themselves and/or re-focused. Some sought to survive by securing production efficiency with basic innovation capabilities. Some firms choose to deepen their innovative capabilities.

For example, the papermaker Epsilon, which used to implement innovative strategies from the 1950s to the 1980s, stopped its innovation efforts during the 1990s, reflecting its reactive strategy (Table 7). On the one hand, this was the result of the macro-level imposed discontinuity in the policy regime which suddenly exposed the firm to fierce international paper competitors. On the other hand, from the early 1990s Epsilon also suffered from inconsistencies in its strategies and bad management. By the early 2000s its innovation performance was stuck around the intermediate level. By 2009 it was taken over by a Chilean group.

Differently, to overcome its serious financial and commercial difficulties during the early 1990s, Delta implemented a bold organisational restructuring. This included the elimination of some business areas, the introduction of a company-wide quality management programme, the re-structuring of its R&D centre, and the achievement of highly recognised international certifications (e.g. FSC) in 2000.[12] Differently, Theta's strategic options emphasised innovation capability deepening on the forestry business, rather than in pulp and even lesser in paper (Table 7).[13]

Firms like Lambda, Iota and Zeta-A pursed reactive types of strategies to guarantee their minimum competitive performance under the new economic and institutional environment. Their efforts focused on strengthening *production* capabilities and basic/intermediate innovation performance. Differently, firms like Alpha, Sigma-A and Sigma-B sought to deepen their innovation capabilities, especially their organisational dimension. For example, Alpha restructured its research activities by merging the forestry and the industrial R&D centres. By so doing, it sought to augment its forestry research capabilities (e.g. development of clonal forests, new genetic material) in association with pulp and papermaking research (e.g. research on lignin

[12] Created in 1993, the Forest Stewardship Council certifies forestry firms based on socio-environmental criteria: www.fsc.org

[13] Consequently, Theta's innovation performance in pulp and paper (Table 6) should be interpreted as the result of a strategic option, rather than failure.

biosynthesis and the patenting of the totally chlorine free pulp (TFC) process and pollution control methods based on natural micro-organisms). Firms like Alpha and Sigma-A created teams in their R&D units and other units to discuss production innovation with large paper customers. Sigma-A implemented the 'Re-think Project' to stimulate people to criticise existing routines and procedures to integrate different knowledge bases to speed up innovation.

5.2.3 The open economy and globalised competition regime: the period 2000s

5.2.3.1 Main changes in the macro and meso-level institutional frameworks

The Lula administration (2003-10) sought to re-establish the role of government policy in Brazil's industrial development. BNDES focused its support on expansions, mergers and internationalisation of large national firms – including forestry, pulp and paper – reflecting a 'picking-winners' kind of approach.[14] Industrial policy was based on a narrow selection of sectors. For example, the Industrial, Technological and Foreign Trade Policy (known as PITCE), issued in 2004, whereas the Productive Development Plan (PDP) expanded its coverage to 24 sectors, in 2007, targeting strengthening of the international competitiveness the pulp and paper sector.

The Lula administration strengthened the innovation funds created during the Cardoso's government. It went further to implement new policy instruments to promote innovation within firms and their links with universities and research institutes based on finding and fiscal incentives (e.g. the Innovation Law (2004) and the Good Law (2005).[15]

[14] The fact Alpha and Sigma-A were able to persuade BNDES to fund their merger in 2009 as a response to the global financial crisis, is in itself evidence public-private symbiosis between BNDES and the pro-active forestry and pulp and paper firms in Brazil since the 1950s. That merger created the world's largest eucapulp firm.

[15] These are, respectively, Law 10,973 of December 2004 and Law 11,196 of November 2005.

5.2.4.2 Firms' strategy embeddedness and innovation performance

The innovative activities of the case firms, especially those with active and pro-active strategy embeddedness were characterised by: (i) strengthening their research activities, internally and in partnership with universities and research institutes; (ii) diversification into new business lines based on the previously accumulated innovation capabilities, especially in forestry.

In terms of research activities, some firms sough to re-organise their research activities in the light of an even more a specialised and commercially oriented research activities. They also realised the importance of partnerships to achieve such 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, papermaker Delta reviewed and re-organised its research centre to deepen its research into new genetic material, but also to improve product and process development activities. Kappa, on the other hand, regains its innovation drive in 2006, after a period of unfocused strategy during the 1990s due to internal management problems. Its new top management emphasised research-based innovation, especially in forestry, as a key driver for 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 from the Ministry of Science and Technology, this large research project involved 13 firms (among them Alpha, Kappa, Beta, Gamma, Delta, Theta, Sigma-A and Sigma-B) and seven universities, under the coordination of the government enterprise EMBRAPA. Genolyptus gathered a large number of genomic information to further the understanding of the underlying variation of genes. Through this successful project, Brazil

became one of the few countries to undertake cutting-edge eucalyptus genomic research based on a nation-wide biotechnology network.[16]

The end of Genolyptus, in 2008, somehow forced the participating firms to make strategic choices about their 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 USA. In 2009 Kappa supplied a eucalyptus gene to be used in world-leading genomic research project led by a pool of leading research institutes. Alpha also implemented an intellectual property policy to intenfy patenting. However, firms like Beta and Theta pursued less ambitious steps after Genolyptus.

In addition, some firms sought to drawn 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 on renewable energy through the production of wood pallets for export markets.[17] Later, Kappa acquired a British biotechnology firm with operations in the US, Israel, China and Southeast Asia. This sought to facilitate the firms' entry into biofuels and commercialisation of modified genes and to support its internationalisation strategy. By the time of fieldwork, firms Alpha, Kappa and Sigma-A and Sigma-B were advancing projects to move into biorefineries to generate fuels, power, heat, and value-added chemicals from biomass.

[16] A previous initiative (2001-04) was the creation of an expressed sequence tag (EST) database through the ForEST project (Eucalyptus Genome Sequencing Project Consortium), funded by the Research Foundation of the State of São (FAPESP) involving firms like Sigma-A, Sigma-B, Kappa.

[17] These are dehydrated and pressed particles of ground wood that is one of the most efficient form to transport biomass for energy over long distance.

6. Discussions of Findings

The purpose of this paper was to explore the relationship between micro-level innovation performance and changing institutional frameworks and the mediating role of strategy embeddedness. This set of relationship was examined based on longitudinal and first-hand evidence from natural resource-processing firms, forestry and pulp and paper, in Brazil (1950-2009). In contrast to most existing studies, this paper has proxied innovation performance using the concept of 'levels' of capabilities. To examine the mediating role of strategy in the relationship between firms' innovation performance and institutions, the paper advanced the concept with '*capability-building strategy embeddedness'*, operationalized in terms of levels. The paper's main findings are discussed below.

6.1 Variability across firms in terms of innovation performance across changing institutional frameworks

In relation to the first question, on the extent to which the case firms differed in terms of the manner and speed at which they achieved innovation performance across changing institutional frameworks during the 1950-2009 period, the study reveals the following findings. First, all firms were engaged in technological pathway that involved a *qualitative departure* from the established technological trajectory at an *early stage* in the capability development in Brazil's forestry and pulp and paper industry since the 1950s. This permitted main Brazilian firms to overtake global technological leaders and to compete on even terms with them in world markets. Second, as these firms moved along that technological pathway they also moved through different institutional frameworks involving hurdles, discontinuities but also opportunities: raw material scarcity and import restrictions (1950s); incentives (e.g. government policies of the ISI period and the open economy phase since the 1990s); challenging discontinuities (interruption of large research projects led by public sector institutions – late-1980s), pressure for strategic

choices on internal research (e.g. end of Genolyptus in 2008) and abrupt macro-level disruptions (major break in the policy regime during the early 1990s).

Third, as shown in Section 5 there was a high degree of variation across the firms (and business lines) in terms of the manner and dynamics in which they achieved levels of innovation performance along this new technological pathway and across those changing institutional frameworks. Some achieved world-leading innovation at a relatively fast pace (e.g. Alpha, Sigma-A, Sigma-B), others achieved that innovation performance level but less rapidly (e.g. Delta, Kappa). Differently, other firms achieved near-the-world leading innovation performance level – 'followers' (e.g. Beta Gamma-pulp) or half-way back the innovation frontier (e.g. Zeta-A, Theta-pulp). Others had their innovation trajectories interrupted and even reversed (e.g. Epsilon). In sum, there was high degree of variability in the manner and speed at which they achieved their innovation performance involving qualitative transformations, truncations and reversals.

Through these findings this study moves beyond existing studies of innovation capability building in latecomer firms by addressing by the dynamics of micro-level innovation performance in association with changes in meso and macro-level institutional frameworks. The study examines these issues in natural resource-processing industries, which is an under-researched type of empirical setting. By so doing, the paper fills a void that remained in this research field since the 1980s. Additionally, by tacking these issues together the study moves beyond the studies undertaken in Asian contexts especially from the late-1980s thus contributing to expanding our empirical notion of varieties of catch-up experiences beyond those types of technological trajectories and industries.

Third, by drawing on micro-level design and on fieldwork longitudinal analysis this study captures rich evidence that is not captured in studies designed on the basis of aggregated analysis (e.g. Ocampo, 2001; Cimoli and Katz, 2003; Cimoli and Correa, 2005 and Castaldi et al., 2009). The empirical findings here do not support their arguments relative to the impacts of changes in the institutional frameworks on industrial innovation capability building; neither does the study support their view on natural resource-processing industries.

6.2 Role of strategy embeddedness in mediating the interaction between firms' innovation performance and changing institutional frameworks

The case firms pursued different levels of *strategy embeddededness* over time. Some firms pursued pro-active strategies (Alpha, Sigma-A, Sigma-B, Kappa, Delta), others took active strategies (Gamma, Zeta-B), whereas others pursued arm's length strategies (Lambda, Zeta-A). Other began as pro-active and ended up as reactive (Epsilon), while others experienced a period of active, during the 1990s (Kappa) but moved into pro-active strategies during the 2000s. There were also variations across business lines of the same firm like Theta (active in pulp and paper and proactive in forestry).

The results suggest that variability in the firms' innovation performance across changing institutional frameworks was mediated by degrees of strategy embeddedness. Specifically, for firms that pursued proactive strategy embeddedness: (i) their innovation performance was significantly higher *over time* than firms that pursed proactive embededdeness; (ii) they crossed whatever discontinuities with progressively higher levels of innovation performance than firms that pursued active or reactive strategy embeddedness; (iii) they sought to shape their institutional frameworks to overcome hurdles inherent to their latecomer condition and negotiate their transitions into world-leading technological and commercial positions. Thus proactiveness in strategy embeddedness seems to provide a kind of buffer to possible deleterious effects of

changing institutional frameworks on firms' innovation performance. Additionally, firms pursuing pro-active strategies were more capable of identifying and take advantage of technological and market opportunities than firms that relied on active and reactive types of strategy embeddedness.

These findings help overcoming some of the shortcomings of existing studies relative to the role of micro-level factors, other than learning, in explaining variability across latecomer firms in terms of innovation performance. Indeed, this study's rich findings about the role of strategy embeddedness in mediating the relationship between micro-level innovation performance and changes in meso and macro-level institutional frameworks throw fresh empirical content into the debate and analysis of catch-up and industrial leadership of latecomer firms. While the study advances the kind of empirical analysis undertaken in notable previous research (e.g. Evans, 1995; Murmann, 2003), it also contributes to shedding light on contradictory conclusions (e.g. Jung and Lee, 2010; Iacovone and Crespi, 2010). Again, such kind of longitudinal micro-level perspective is not captured by studies based on macro-level design and data derived from aggregated type of data (either country level data or data derived from innovation surveys). Thus the findings here add empirical texture and provide a nuanced and more realistic perspective on the intricate process of innovation capability building in latecomer firms, especially in under-researched natural resource-processing industries.

The findings nonetheless provide support to studies that emphasise the role of institutional frameworks in industrial innovation in developing economies (Rodrik, 2004, 2006; Cimoli et al., 2009; Nelson, 1995; Nelson and Sampat, 2001; Iacavone and Crespi, 2009). However, the study herein moves further by showing that although well-designed institutional frameworks are obviously necessary to the achievement of industrial innovation and leadership, a large part will

depend on the nature and dynamics of firms' own strategic choices and related innovation efforts.

7. Concluding Discussions

7.1 Contributions for theory and policy

7.1.1 Contribution for theory

Despite the emergence of Lall's framework about 20 years ago, this research field has not made substantial advances in terms of explanatory factors relative to innovation performance of latecomer firms. By drawing on insights from the literatures on innovation, strategic management and institutions, this study has developed a conceptual framework centred on *capability-building strategy embeddedness*. By applying this framework empirically this paper contributes to advancing out theorizing about the variability in innovation performance across latecomer firms. The paper also creates a basis to deepen the analysis of the dynamic interaction between micro and meso/macro-level factors and its implications for innovation performance improvement in latecomer firms, especially those that operate in natural resource-rich economies.

7.1.2 Implications for policy

Policymakers seeking to improve industrial innovation performance should consider, first, that far from adapting automatically to given contingencies in their environment, firms can pursue their own strategic choices related to their technological development paths. Consequently, their responses to given policy frameworks will vary. Second, policymakers should not take a one-way perspective on policymaking, i.e., by simply designing and supplying components institutional frameworks (policies, incentives, laws, rules) for the industry. Third, corporate managers can offer precious insights and inputs to improve institutional frameworks to promote and support industrial innovation. Policymakers should take their contributions more seriously

and seek to coordinate the policymaking processes with the strategic needs and choices related to innovation efforts of firms and their partners.

Fourth, one the mechanisms for such coordination would be the building of *targets for innovation performance* based on the achievement of progressively higher levels of innovative performance. However, such targeting should not only focus on the sustaining of innovation performance of firms and industries along *existing technological trajectories*. They should also target the achievement of progressively higher levels of innovative performance at the level of industries and firms along new technological segments derived or not from existing technological trajectories.

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