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Abstract

This paper explores the relationship between micro-level innovation performance, changes in institutional frameworks and the mediating role of strategy embeddedness in the context of firms from emerging economies (known as latecomer firms). The paper is based on a multiple case-study design that draws on first-hand longitudinal evidence gathered during a three-year fieldwork campaign centered on 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, the following applied to firms that pursued proactive strategy embeddedness: (i) their innovation performance was significantly higher *over time* than firms that pursued active and/or reactive strategy embeddedness; (ii) they faced whatever discontinuities with progressively higher levels of innovation performance than firms that pursued an active and/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 growth, innovation and competitiveness, these achievements largely depend on the nature and dynamics of firms' own strategic choices and related innovation efforts. Policymaking should therefore involve coordinated efforts between government and firms. Based on a novel theoretical framework and rich empirical assessment, this paper contributes to advancing our understanding of factors affecting the innovation performance of latecomer firms, especially in natural-resource processing industries.

Key words: Catch-up; capability building; latecomer firms; natural resource-processing industries; Brazil.

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, known as latecomer firms as they (Bell, 2006): (i) emphasised the *dynamics* of the micro-level paths of capability accumulation; (ii) explored the role of learning mechanisms underlying those paths; and (iii) investigated the interactions of those capability building paths with the meso and macro-level institutional frameworks. After a period of absence of these kinds of studies, there has been, since the early-1990s, increasing research interest in producing *explanations* for the causes and consequences of the nature of capability-building paths taken by latecomer firms.

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 the technological gaps between them and firms in the industrialised world, achieve industrial growth and even technological and market leadership. He emphasised that the primary driving force for this development was 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 and involve their policy regimes, skill endowments and incentives (p. 169). Although Lall recognised the importance of micro-level factors and industry-specific institutions to firms' innovation performance, he did not explore much of these variables.

[1] Such investments refer largely to the *creation* and building of innovation capabilities.

Subsequent to the development of Lall's (1992) framework, a new generation of studies began to advance explanations, from both intra- and inter-firm perspectives, about the role of learning processes in influencing innovation performance in latecomer firms (e.g., Hobday, 1995; Kim, 1998; Dutrénit, 2000; Figueiredo, 2003; Marcelle, 2004; Dantas and Bell, 2009). However, our understanding of the *role of factors, other than learning*, on variability in terms of innovation performance across latecomer firms remains limited. This, in turn, constrains the quality of the recommendations generated by researchers to decision makers involved in actions on industrial innovation performance. Over the past few years, there have been efforts to explain how factors, other than learning, affect innovation performance in latecomer firms. However, these seem to have focused either on a narrow range of variables or to have been based on discrepant evidence, as briefly reviewed below.

In relation to studies based on micro/meso-level designs, some explore the correlation between firm-specific factors, such as age, size, ownership, and market orientation as well as 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 of 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. They cut across the East Asian catch-up story only *after* the shift from structures in which governments played the dominant role in funding and even performing R&D to one where firms played the dominant role.

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 terms of studies addressing latecomer firms' innovative performance from a macro-level perspective, since the early 2000s, following the decline of the Washington Consensus perspective, there has been a growing interest in understanding the role of institutions in influencing industrial innovation (e.g., Nelson and Sampat, 2001; Rodrik, 2004, 2006; Cimoli et al., 2009; Lee and Mathews, 2010). As argued in Rodrik (2004), institutions have been supporting many successful stories leading to industrial development. However, as pointed out in Nelson (2008, p. 1), in relation to concrete empirical analysis, "there remains a significant gap between aspirations and achievements". Such gaps are even wider in latecomer contexts, especially in terms of micro- and intra-industry standpoints.[2] There are, however, notable exceptions – e.g., Evans's (1995) 'public-private symbiosis' approach applied to the information technology (IT) industry in Brazil, India and Korea.[3] Indeed, there is a need for empirical analysis of the relationship between changing institutional frameworks and micro-level innovation performance, especially in the latecomer natural resource-rich settings.

[2] Nearly 20 years ago R Nelson made a call for researchers to take the interaction between firms and environmental factors more seriously for progress to be made in research on industrial leadership (see Nelson, 1996).

[3] Although industries and firms from *contemporary* latecomer economies are not addressed, Murmann (2003) develops a careful and insightful analysis of the role of institutions in explaining why Germany overtook Britain and the US in terms of technological leadership in the synthetic dye industry before World War I.

For instance, in the context of East Asia, where the bulk of our recent understanding about long-term technological development has been generated, there is a consensus of the important role played by macro-level institutions in the successful industrial innovation in that region (e.g., Amsden, 1989; Wade, 1990). One striking feature of this technological development process is that the successful micro-level paths of innovation capability building, most of them related to assembled-product industries, researched in the 1990s (e.g., Hobday, 1995; Kim, 1997; Mathews, 1999) and the 2000s (Mu and Lee, 2005; Choung et al., 2006) have evolved continually and smoothly across relatively stable and fairly *continuous* macro-level institutional frameworks. 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).[4] Consequently, these studies reveal little about the implications of discontinuous institutional frameworks for innovation performance in latecomer firms and industries.

As opposed to East Asian contexts, Latin American natural-resource-rich countries have experienced disruptions in their institutional frameworks, with apparently different kinds of impacts on their industrial-capability building. Some studies argue that the structural reforms of the early 1990s, which replaced the import-substituting industrialisation (ISI) regime with new conditions based on open economy and global competition, imposed a discontinuity to capability accumulation, perhaps at a lower level of capability than that set by the preceding ISI regime. They argue that such reforms have pushed Latin American economies into a 'low development trap', in which the growing relevance of natural resources industries in Argentina, Chile and Brazil is deemed as a 'negative' consequence of that macro-level discontinuity and an obstacle to deepening innovative capabilities (e.g., Katz, 2000; Reinhardt & Peres, 2000; Ocampo, 2001;

[4] Other studies have sought to tackle East Asian firms' *transition* into leading innovation (e.g., Amsden and Tschang, 2003; Hobday et al., 2004). However, these studies do not scrutinise *qualitative discontinuities* in firms' capability-building paths under discontinuous institutional environments.

Cimoli and Katz, 2003). It is evident that such reforms have caused serious disruptions to industries across Latin America. Considering that such studies were based on data that did not cover beyond the mid-1990s, during which time the bulk of those discontinuities occurred, it seems reasonable that their findings would lead to such conclusions. However, the same kind of argument has been held during the 2000s, as in Cimoli and Correa (2005), and more recently in Castaldi et al. (2009):

> "In terms of specialization patterns, following the trade reforms, many Latin American economies increased their share of production in (i) natural resources and natural resource processing industries (such as pulp and paper, iron and steel, vegetable oil, etc)…[…] The last couple of decades have been particularly disappointing. […] The end result is a widening *dualism* whereby an increasing share of the whole economy is composed of activities typically characterised by a low knowledge content and low opportunities for technological and organisational learning." (pp. 64-5).

This is a whimpering view of the industrial reality, which generates very little (if any) explanatory contribution.[5] First, by addressing such issues from a macro-level perspective, based on highly aggregated secondary data, these studies ignore intra-industry and micro-level variability and nuances of innovation performance across changing institutional frameworks. Second, they do not develop more sophisticated analytical frameworks to capture the dynamics of the industrial innovation process over time. Third, there is a common view on the 'Latin America experience', on the one hand, and on natural resources industries, on the other. The latter is reduced, without any effort of definition or distinction, to 'low-tech' sectors with low knowledge intensity. However, hidden behind their average 'low-medium tech' characteristics, such sectors include firms with considerable innovation capabilities and that undertake new-to-market and new-to-world types of innovation (von Tunzelmann and Acha, 2005; Smith, 2005).

[5] Such a view appears to revert to a 'Prebischian' and 'dependence theory' kind of approach. Just as there is in this argument an unconditional belief in the ISI regime, there is also, in an opposite research stream, a belief in the Washington Consensus-type of policy. Thus the research field is left with is a scarcity of comprehensive perspectives (Figueiredo, 2008).

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, as well as 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 a 'source of evidence' for strategy formulation, this paper considers the manner in which certain components of the institutional environment interact with the firm's innovation efforts. The second type of attribute resides within the firm. The first is the firm's innovation performance, which, different from most innovation studies, is proxied herein based on progressively higher levels of innovation-capability building. The second refers to the firm's strategy. Different from most studies, this paper emphasises a contextual or embeddedness approach to strategy. Specifically, the paper explores the role of *capability-building strategy embeddedness*, hereafter referred to as *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* is defined herein as the relationships between the firm's strategy-making process, related to innovation capability-building, and its institutional framework over time. It is operationalised in terms of levels: pro-active, active and reactive. The paper explores the role of strategy embeddedness in mediating variability in firms' innovative performance and changing institutional frameworks.

This set of relationships 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

This section presents the framework used in this paper to analyse the relationship between micro-level innovation performance, institutional frameworks and the mediating role of strategy embeddedness (Sections 2.1 to 2.3) and the operationalisation of such constructs (Section 2.4).

2.1 Innovation performance in latecomer firms

In this paper, firms' innovation performance reflects the accumulation of progressively higher levels of innovation capabilities. Firms' capabilities involve a stock of resources consisting of two broad dimensions: 'human resources' (e.g., 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*. Such innovation performance reflects the extent to which latecomer firms' catch up with or even overtake global technological leaders.

However, in latecomer parlance, the term 'catch-up' tends to suggest a single pathway, with different firms distributed along it, and a clearly defined 'frontier'[6]. 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[7]. In reality, the process of technological development of latecomers cannot be represented using

[6] Richard Nelson, 2008, personal communication.
[7] Martin Bell, 2008, personal communication.

the analogy of a race along a fixed track because of the possibility of successful overtaking by latecomers moving in new directions, and the emergence of radical discontinuities that open up opportunities for them (Perez and Soete, 1988; Lee and Lim, 2001; Figueiredo, 2010).

By such means, 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[8]. Rather than deeming the technological frontier an end-point or even a moving target, this paper considers it 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, 1988; Bell and Pavitt, 1993; Pavitt, 1998), leading to differences in the kinds of innovative activities they undertake or their innovation performance (e.g., 'new-to-the-firm' or 'new-to-the-world). Such innovation performance in latecomer firms may provide the resources for corporate growth through diversification (Amsden and Hikino, 1994), thus contributing to meeting the current challenges of industrial diversification (Hausmann and Rodrik, 2006), global competition and sustainability.

2.2 Firms' innovation performance and institutional frameworks

This section begins by clarifying the meaning of 'institutions'. Over the past two decades, there have been remarkable contributions from economics (North, 1990; Rodrik, 2004, 2006), institutional theory in sociology and organisation theory (Powell and DiMaggio, 1991; Scott, 2001) and innovation studies (Nelson and Sampat, 2001) on the role of institutions with respect to the

[8] Martin Bell, 2008, personal communication.

innovative and competitive performance of firms and industries. Such a view has also been held in the research body about innovation capabilities in latecomer firms (e.g., Bell, et al., 1982; Lall, 1992; Bell and Pavitt, 1993).

According to 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'. Although, by definition, 'institutions' denote stability, they are subject to change processes, both incremental and discontinuous (Scott, 2001). Institutional frameworks can be addressed from different perspectives such as broad policy regimes (e.g., North, 1990; Lall, 1992; Rodrik, 2004, 2006; Cimoli et al., 2009), industry-level frameworks (Murmann, 2003), public-private relationships (Evans, 1995) and knowledge related institutes and organisations (e.g., Malerba and Mani, 2009; Lundval et al., 2009).

Building on these concepts and on insights from previous empirical research (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 and knowledge-related bodies that shape and are shaped by firms' innovation-related strategic choices. Differently from North's (1990) view of firms as 'players in the game' but in line with Murmann (2003), this paper considers that firms and industries can also shape institutional frameworks as they pursue leading innovative performance. Following Scott (2001) this paper views institutional frameworks as dynamic (Scott, 2001). In addition, firms differ in the manner in which they respond to industrial policy and government expectations (Hillman and Hitt, 1999) with different consequences for their technological behaviour (Bell et al., 1982) and competitive performance (Gulati, 1998).

2.3 Strategy embeddedness: mediating the interaction between firms' innovative performance and institutional frameworks

Influential approaches to firms' competitive performance – e.g., the 'Chandlerian view', the 'transaction cost view', the 'industry-view' and the 'resource-based view' – examine firms from an acontextual angle and consider 'institutional frameworks' to be 'background conditions' (Peng, 2002; Murmann, 2003; Peng et al., 2008).

These 'atomist-type' of approaches have generated many relevant contributions, but they provide only partial explanations about firms' competitive performance (Baum and Button, 1996). It is well known, but not always operationalised in existing studies, that managers do not react or adapt automatically to intractable contingencies imposed by the environment. They can proactively make 'strategic choices' about what will be relevant, what will be constraints and pursue their course of actions (Child, 1972; Astley, 1984; Baum and Button, 1997). Such a view is recognised in works addressing technology and innovation strategy (e.g., Goodman and Lawless, 1994; Dodgson et al., 2008). As noted by Granovetter (1985) firms do not behave or decide as atoms outside of 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 an institutional embeddednesss approach to firm strategy (Baum and Dutton, 1996; Hoskinsson et al, 2000). This view is in line with 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). Indeed, firms rarely work alone in the process of building their strategic assets but rather in interaction with other actors of the environment in which they operate (Gulati, 1998). In their pursuit of knowledge to achieve distinguished competitive performance, firms become embedded 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). As suggested in Nelson and Sampat (2001), such embeddedness may help firms to understand better the intricacies of their institutional frameworks. It may also help firms to cross discontinuities in their institutional frameworks.

These approaches need to be tempered by the intricacies of the *process* of innovation-related strategies within firms. As noted in Pavitt (1990), technology and innovation strategies involve many organisational areas, different types of expertise, battles, political debate and advocacy within the firm. 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 the firm's entrepreneurs (Teece, 2007), the firm's dominant group (Kim, 1997), as they can be stimulated or constrained by the leadership's behaviour (Figueiredo, 2001).

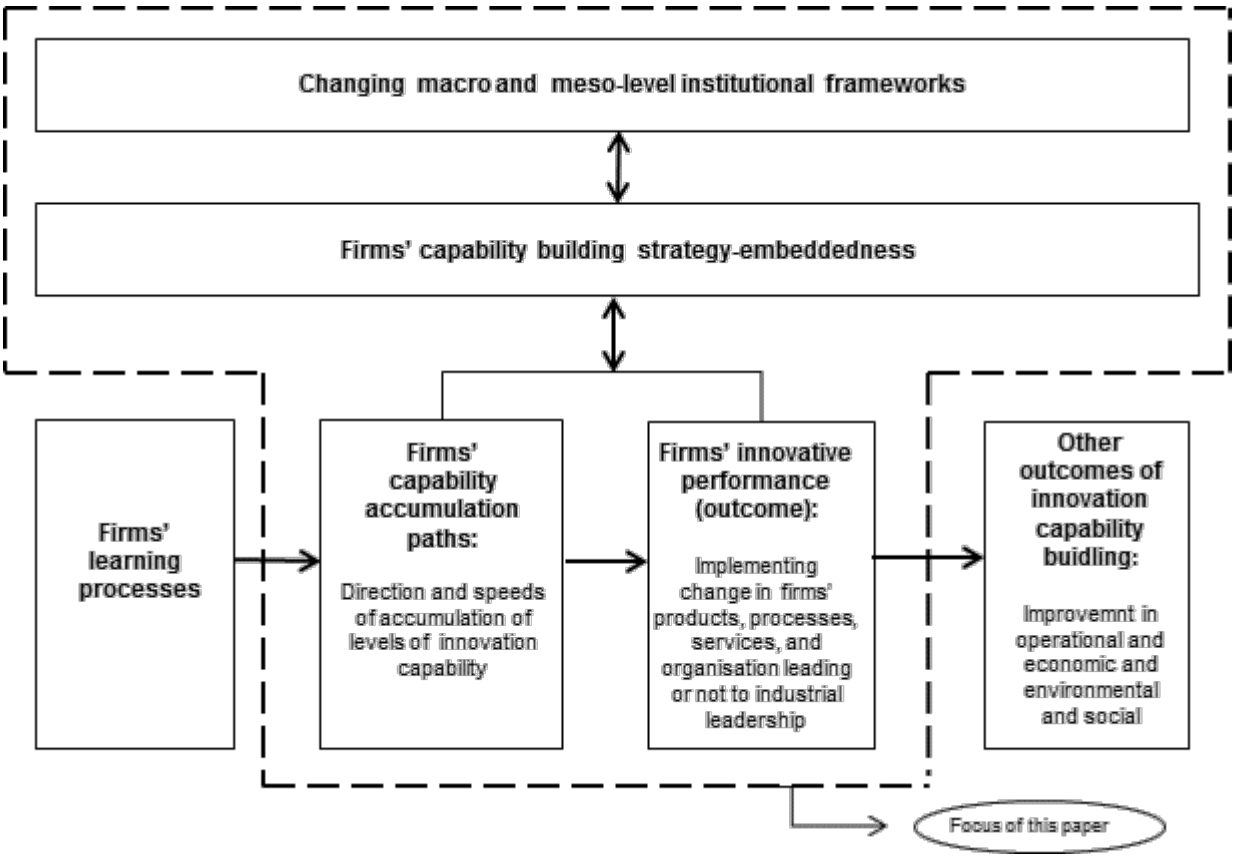
To examine the role of the firm's strategy in mediating the interaction between changes in the firm's institutional frameworks and its innovation performance, this paper focuses on the *capability-building strategy embeddedness* of firms, or *strategy embeddedness*. *Strategy embeddedness* is defined herein as the relationships between the firm's strategy-making process, related to innovation capability building, and its institutional framework over time. 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 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 paper's analytical framework



2.4 Operationalising the constructs

2.4.1 Firms' innovation performance

There are different proxies to examine firms' innovative performance such as the introduction of inventions into the market (Freeman and Soete, 1997) or R&D intensity and expenditures and patent counts/citations (Hagedoorn and Cloodt, 2003). However, these indicators capture only a fraction of the innovative activities in latecomer firms (Lall, 1992; Bell and Pavitt, 1993; Bell, 2006), especially for pulp and paper industries (Laestadius, 1998). This paper adopts a nuanced view of innovation that involves increasing *degrees* of novelty and complexity in terms of processes, products and organisation, 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 ranging from 'basic' to 'world leading', consistent with the Oslo Manual. Such a 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 identify 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, ranging from 'basic' to 'world leading'; the second column provides some illustrative examples of these levels of capability.[9]

Although this framework emphasises capabilities that are internal to the firm, it also recognises that a substantial part of a firm's innovation capability lies in other organisations (e.g., research institutes, universities). Consequently, the building of innovation capability is not necessarily confined to firm boundaries, but may involve several interdependencies. For the firm to develop such interactions, it has to build up substantial in-house expertise (Mowery, 1983) or absorptive capacity (Cohen and Levinthal, 1990) and demand for local R&D outputs (Bell and Pavitt, 1993).

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

Levels of innovative performance	*Illustrative examples of these levels of innovation performance*

[9] The original framework applied during fieldwork and analysis involved three individually tailored matrixes for forestry, pulp and paper. The application of this framework in this study was achieved after approximately six months of work, and involved several consultations with experts in forestry and pulp and paper industries for validation.

World leading (frontier pushing)	Undertaking cutting-edge innovation that provides the firm with a world-leading technological and market position in forestry, pulp or paper (e.g., R&D for the introduction of new-to-the-world forestry development processes along new technological trajectories based on R&D in genomics and proteomics; playing leading roles in world-leading research networks; development of new production processes based on R&D and engineering; intellectual property system).
Advanced	Closing 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 (e.g., R&D projects for the introduction of new feedstock processes implemented by innovation leaders; forest management based on sophisticated international certification (e.g. FSC);R&D for the introduction of new production processes following leaders)
Intermediate	Implementation of 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 (e.g. development of resources for forest installation, attendance and recovering and alternative processes and resources for disease and pests control; engineering efforts to adapt and improve production processes and equipment systems;
Basic	Implementation of basic levels of innovations which are novel to the firm and allow the firm to sustain a competitive performance in a regional market (e.g. implementation of resources for forest and agricultural installation, attendance and recovering; quality tests and features evaluation for seed and seedling production).

2.4.2 Firms' strategy embeddedness

In line with previous research (Dacin et al., 1999; Figueiredo, 2011) this paper considers that firms' levels of strategy embeddedness, as part of firms' strategic-asset building efforts, vary. Thus, building on Goodman and Lawless (1994) and Scott-Kemmis and Chitravas, (2007) strategy embeddedness is herein operationalised in terms of three levels: pro-active, active and reactive (Table 2). Additionally, the typology identifies macro- and meso levels institutional frameworks. 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

	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 level.
		Sector-level policies, plans and incentives that underpin particular kinds of policy

Components and players of institutional frameworks	Meso-level	regime. Sector-level organisational structures and pressure groups (e.g. industry associations) 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, and so forth.

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 pursue and 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 pursue and hold a position of innovation 'followers'.
	Reactive	Low or absent awareness of the role of innovation capability in the firm's competitive performance. Arm's length and/or indifferent to interactions with components of the meso- and macro level institutional frameworks. Firms tend to hold a position of very 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 papermaking, is obtained from trees such as pine (long-fibre or softwood) or eucalyptus (short-fibre or hardwood).

Planted forests are renewable resources for diverse 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., to decrease the 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 achieved subsequently, based on second-generation clones derived from eucalyptus hybridisation (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.[10] This 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 for growth and adaptability to tropical conditions and wood with higher pulp yield (Grattapaglia and Kirst, 2008). This technological development contributed to the achievement by Brazil of an internationally leading position in that field (see Table 3).

[10] For details of that breakthrough innovation see Figueiredo (2010). For technical details see Grattapaglia and Kirst (2008).

Table 3. 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.

The technological advance achieved by Brazilian firms was reflected in the commercial performance (or market catch-up, Lee and Lim, 2001) achieved by Brazil. Table 4 shows that 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. Furthermore, from 2001 to 2009, the export value of Brazil's pulp and paper exports grew, respectively, 10.7% and 23.8% annually on average, whereas the annual growth rates of Norscan countries were 0.18% (pulp) and 2.1% (paper) during that period.[11]

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

Table 4. Evolution of pulp/paper exports: Norscan countries *vs.* Brazil and other developing economies (000 tonnes)

PULP

	1970	Growth rate (1961-70)	1980	Growth rate (1971-80)	1990	Growth rate (1981-90)	2000	Growth rate (1991-2000)	2009	Growth rate (2001-2009)	Growth rate (1970-2009)
Canada	4,762	40.9	7,009	4.2	7,652	1.8	11,652	3.5	6,757	− 5.3	0.9
Finland	1,805	30.9	1,7612	3.6	1,363	− 1.2	1,681	2.8	1,456	− 1.7	− 0.5
Norway	912	7.5	406	− 6.0	479	1.5	408	− 0.9	387	− 2.8	− 2.2
Sweden	3,488	26.7	2,97	− 0.4	2,767	− 0.2	2,974	0.8	3,124	0.8	− 0.3
USA	2,062	103.1	2,828	9.1	4,783	6.4	5,583	0.9	6,496	1.8	3.0
Brazil	39	66.5	890	44.4	1,035	0.9	2,917	8.7	7,056	8.9	14.2
Chile	105	−5.61 (a)	415	16	581	6.8	1,835	12.3	4,061	7.2	9.8
China	42	26.6	45	− 3.7	101	8.8	47	5.2	99	11.3	2.2
Indonesia	0	0	0	0	130	0	1,352	29.9	2,621	4.94	17.1 (b)

(a) Period related to 1968-70; (b) Period related to 1990-2009

PAPER

	1970	Growth rate (1961-70)	1980	Growth rate (1971-80)	1990	Growth rate (1981-90)	2000	Growth rate (1991-2000)	2009	Growth rate (2001-2009)	Growth rate (1970-2009)
Canada	8,073	3.6	9,555	2.2	11,874	2.4	15,613	3.0	9,526	− 4.5	0.4
Finland	3,559	6.8	4,867	3.3	7,633	5.0	11,642	5.0	9,690	− 1.3	2.6
Norway	1,018	7.9	1,048	0.9	1,476	4.2	1,981	3.4	1,296	− 4.9	0.6
Sweden	2,939	8.7	4,626	5.1	6,613	3.8	9,031	3.9	9,867	1.8	3.2
USA	2,424	10.9	4,186	5.0	5,388	4.6	9,139	4.1	11,277	3.4	4.0
Brazil	1	39.0 (c)	198	59.9	840	10.7	585	− 6.2	2,591	16.0	22.3
Chile	96	12.4	87	1.01	131	8.0	313	10.7	586	6.0	4.7
China	122	8.9	193	4.0	1,364	22.7	3,686	7.4	4,850	4.8	9.9
Indonesia	0	0	7	0	166	39.9	2.717	25.1	3,574	4.9	24 (d)

Source: FAOSTAT, http://faostat.fao.org/

(c) Related to period 1962-70; (d) Period related to 1980- 2009

In 2009, Brazil ranked as the world's fourth-largest pulp producer (all types), first as a producer of hardwood pulp ('eucapulp'), and ninth-largest paper producer. One hundred percent of all pulp and paper produced in Brazil is derived from planted forests. Although the pulp and paper industries in Brazil consist of 222 firms, about 88% of the total output derives from about 10 large firms. From 2001 to 2005, the average share of the pulp and paper industries in Brazil's manufacturing value added (MVA) was 3.9%. Thus, over the past decades, Brazil has been holding a stronger leading market position in these industries, largely due to the innovation performance achieved by leading firms (Section 5).

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 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 more detailed investigation of the research questions than that afforded by other methods (Eisenhardt, 1989; Yin, 2003)

The cases to be studied were selected using the following criteria: (i) the firms account for nearly 85% of the pulp and paper output in Brazil; (ii) they are large exporters and domestic market suppliers; (iii) some of them are top players in the world market; and (iv) they illustrate different levels of innovative performance with varied strategies and diverse interactions with institutional frameworks. This process led to selection of 13 firms and their particular business lines: forestry, pulp and paper (Table 5). This number permitted the research implementation without amassing an unmanageable volume of information (Eisenhardt, 1989).

Table 5. The selected cases

Thirteen selected firms	Start-up year	Ownership	Cases		
			Forestry [7]	Pulp [9]	Paper [11]
1. Alpha	1978	Brazilian	✓	✓	None
2. Beta	1975	Foreigner	✓	✓	None
3.Gama	1960 (1990) [(a)]	Foreigner	None	✓	✓
4. Delta	1945	Brazilian	✓	✓	✓
5. Epsilon	1950 (1990) [(b)]	Brazilian	None	None	✓
6. Zeta-A	1954 (1990) [(c)]	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 [(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.

4.2 Evidence gathering and analysis processes

Following Jick (1979), Eisenhardt (1989), and Yin (2003), this study drew on a 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 to evidence. With their approval it was possible 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, retired staff and archival records). Open-ended interviews were conducted using an interview guide that was constructed in light of the study's typologies. Double and triple checks of specific events were made via e-mail and/or phone calls. The extensive use of

triangulation made it possible to gather evidence from a range of different sources to substantiate the results of the analysis.

Because the study sought to examine historical changes in the capability accumulation of the firms, special efforts were made to collect sufficient evidence to substantiate the reconstruction of the technological pathways taken by each firm. This was undertaken by scrutinising the firms' technological milestones, provided by different interviewees (including retired staff), internal presentations and records, annual reports and independent news reports. Even so, it is difficult to obtain a complete accuracy regarding past events. This is one of the limitations of this study. Nevertheless, the extensive use of triangulation allowed for gathering evidence from a range of different sources to substantiate the study.

After the main fieldwork, follow-up questionnaires were sent to target informants. Because most of them were aware of the study, a 95% response rate was achieved. The application of the questionnaire sought to expand the findings, and particularly, to systematise and code evidence of the issues examined herein over the period covered by the study. The questionnaire, in the form of a matrix, derived from the frameworks in Tables 1 and 2.

During the fieldwork, the researcher built up some associations between the firms' innovative activities and the ways in which they pursued their strategy embeddedness to improve their innovation performance across different institutional frameworks. Formal analyses involved the following techniques: (i) harmonisation and combination of the evidence from the interviews and observations with those 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). This was essential to reduce the sheer volume of information into a manageable size and to track main stages in the

study's constructs in a coherent manner; and (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).

Additionally, 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 tests and to enrich the empirical analysis. For instance, qualitative evidence from the application of the innovation performance typology (Table 1) was transformed into quantitative observations to allow the speed of capability accumulation to be calculated. The capability levels accumulated for these activities by each firm were then aggregated into a single index to represent the overall capability level of each firm in the three business lines (forestry, pulp and paper) over time. Evidence of the types of strategy embeddedness of firms (Table 2) was coded to test its association with innovation performance over time. Finally, the qualitative evidence described in Section 5.2, in the form of narratives, contributes to both strengthening the arguments and establishing causal relationships (Dougherty, 2002).

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) the 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).[12]

[12] Considering that the 1990s involved changes that were deep and far reaching in the Brazil's economy and industry, their implementation and assimilation by the industry took several years. As a result, the whole decade can be deemed as a transition from ISI regime into a regime based on open economy and globalised competition.

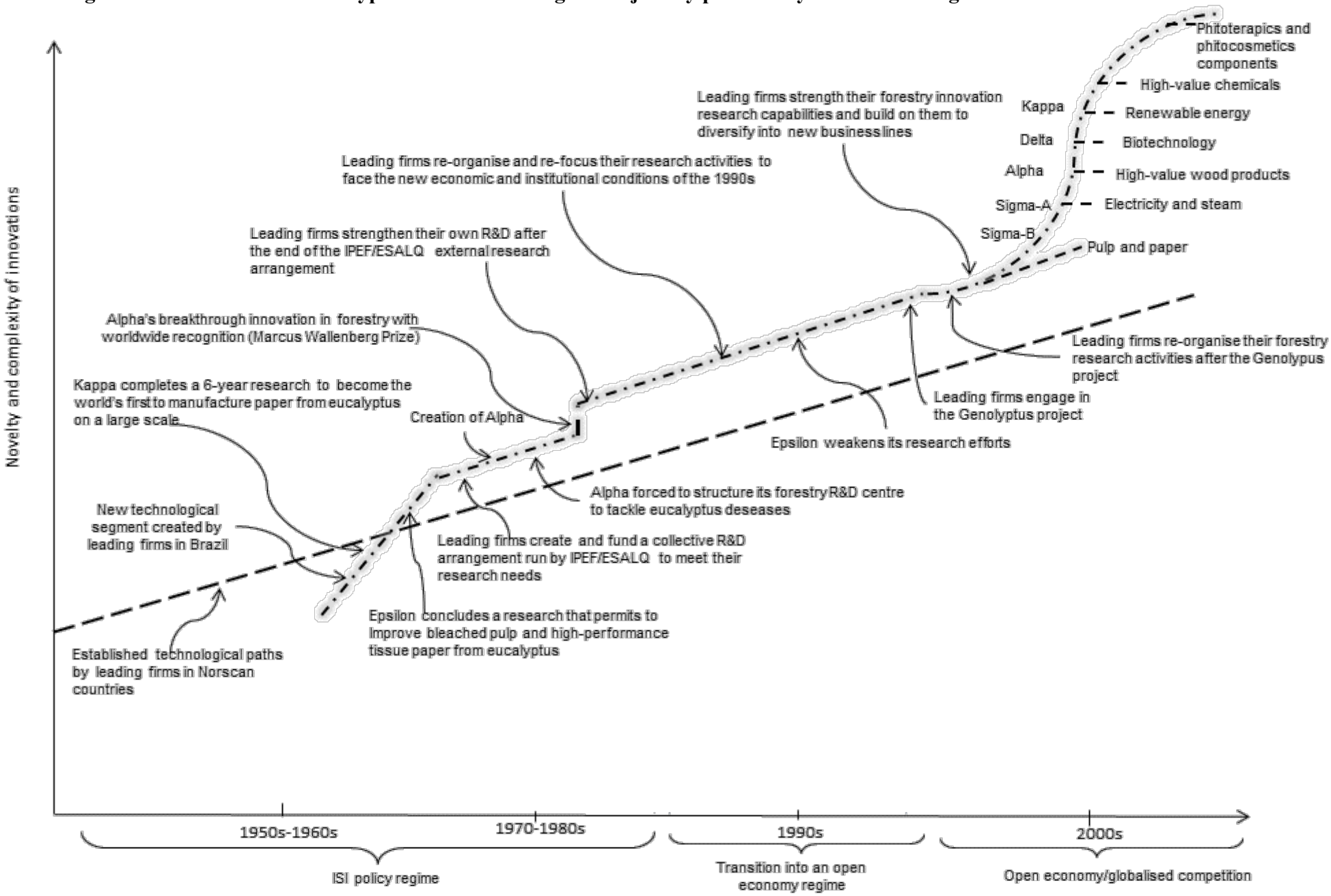
5.1 Firms' innovation performance and strategy embeddedness across different institutional frameworks: an overview

The findings indicate that since the 1950s leading firms from the forestry, pulp and paper industries in Brazil have engaged 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 but 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 to develop an 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. 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).[13] As illustrated in Figure 2, 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.

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

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



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 6 and Figures 3 to 5).

Table 6. Innovation performance of the case firms (2009)

Levels of innovation performance	Firms, business lines and the number of years taken 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.

Figure 3. Evolution of firms in terms of capability accumulation along the eucalyptus-based trajectory: forestry

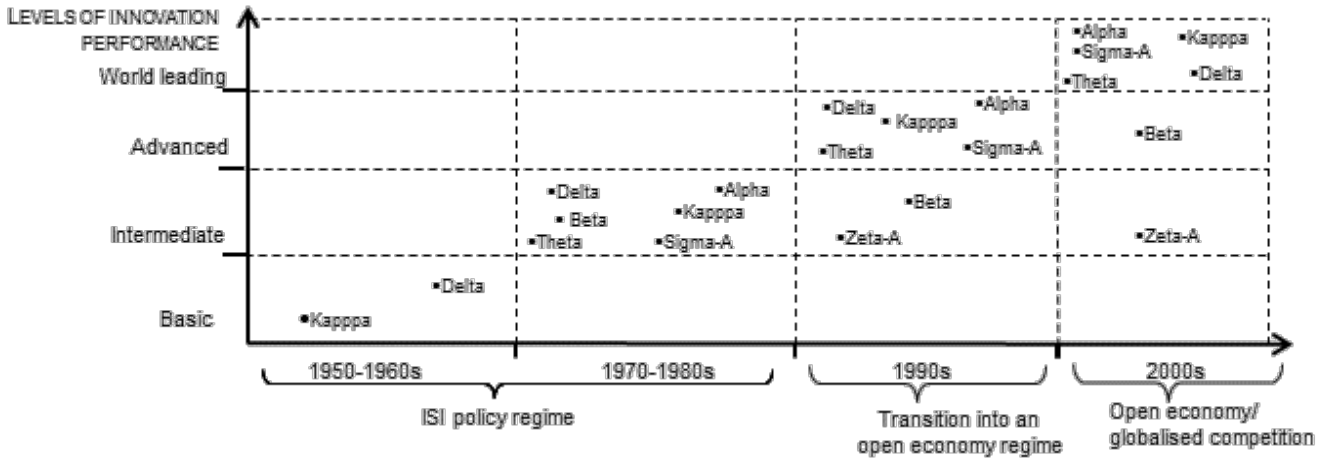


Figure 4. Evolution of firms in terms of capability accumulation along the eucalyptus-based trajectory: pulp

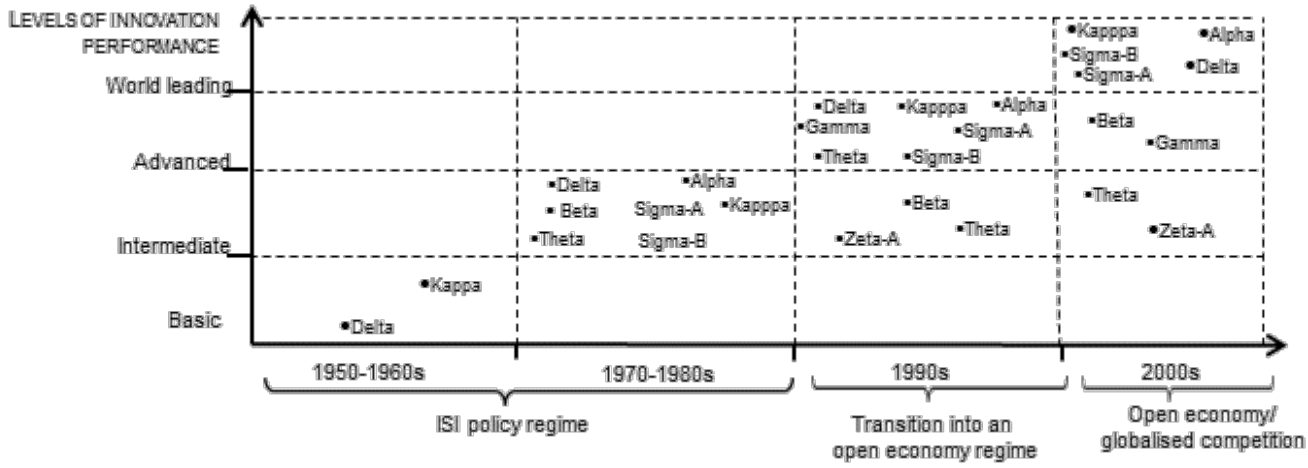
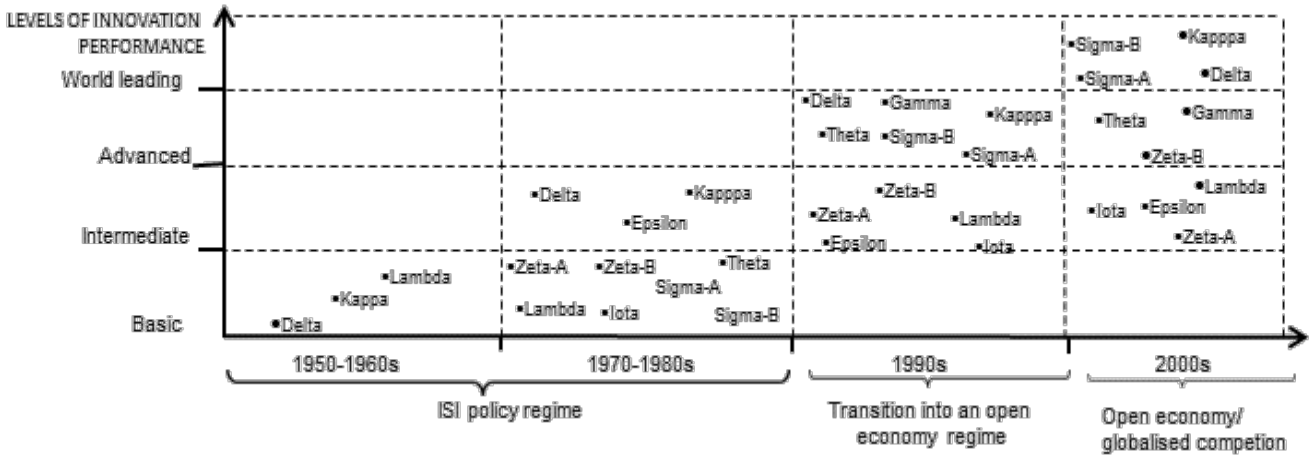


Figure 5. Evolution of firms in terms of capability accumulation along the eucalyptus-based trajectory: paper



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 strategy embeddedness that they pursued over time (Table 7). The results show that firms that obtained the highest innovation performance were those that pursued pro-active strategy embeddedness (Table 8). Specifically, Table 9 shows the results from the non-parametric Kruskal-Wallis test, which indicates a positive and significant association between the firms' levels of innovation performance and the prevailing types of strategy embeddedness that they pursued during the period of study: forestry (p<0.05), pulp (p<0.01), and paper (p<0.10). The following section provides a qualification to this evidence.

Table 7. Evolution of the innovation strategies 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 8. Types of strategies and levels of innovative performance in specific business lines

Business lines	Type of strategy	Level of innovative performance (mean)
Forestry	Pro-active	3
	Active	2.11
Pulp	Pro-active	3.18
	Active	2.23
Paper	Pro-active	2.67
	Active	2
	Reactive	1.43

Table 9. 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*

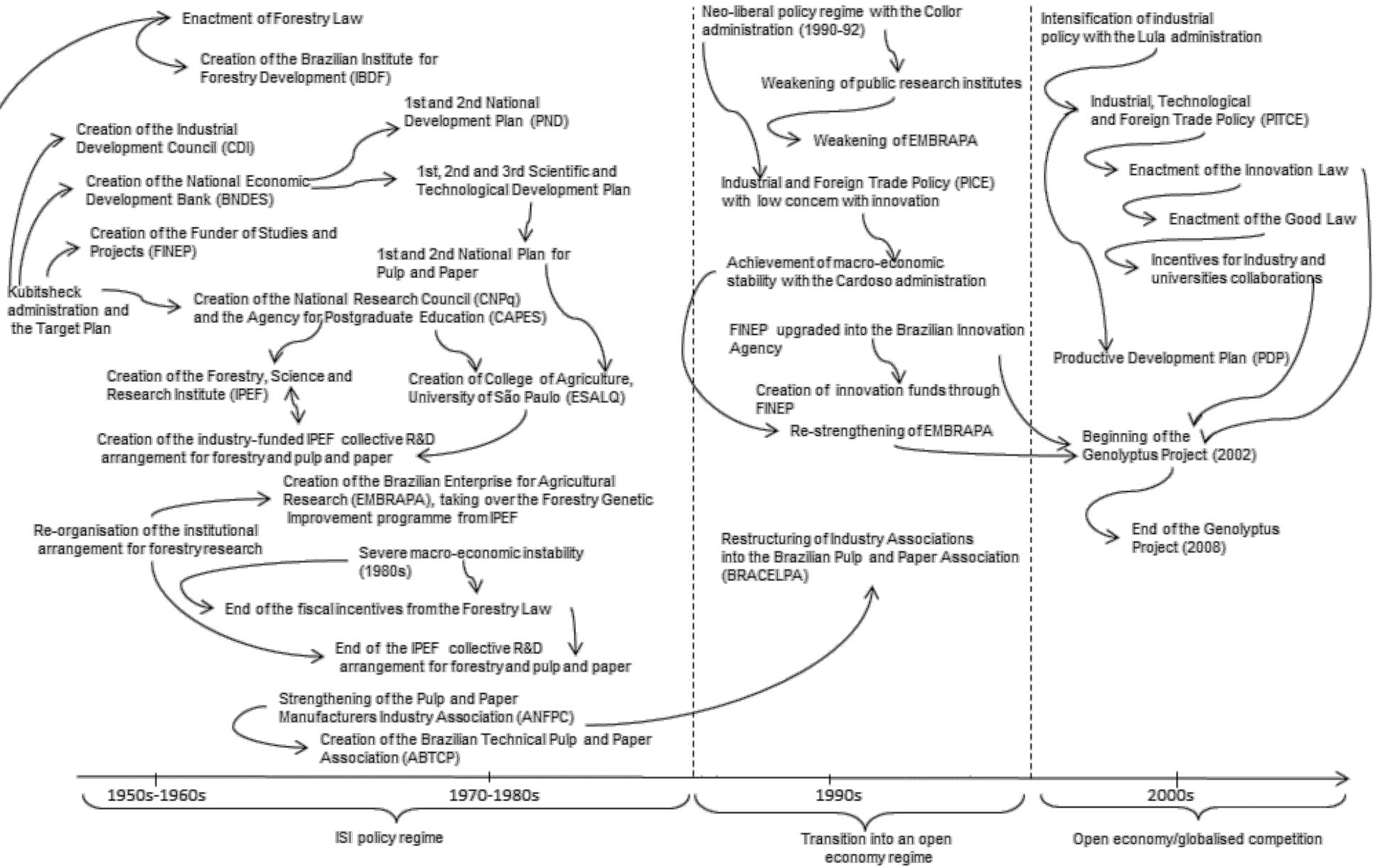
Notes: (*) Association significant at the 0.10 level; (**) Association significant at the 0.05 level (***) Association significant at the 0.01 level

5.2 Evolution of firms' innovation performance and strategy embeddedness across changing institutional frameworks[14]

Figure 6 provides a brief representation of the evolution of some of the main changes in the macro- and meso-level institutional frameworks over the periods examined in this section.

[14] This section does not intend to provide a clear-cut description of the evolution of these three constructs. In some parts, the description is blurred.

Figure 6. Representation of the evolution of some of the features of the institutional frameworks related to the forestry and pulp and paper industries in Brazil



5.2.1 The ISI policy regime: the 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 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)[15] became not only the main funder of industrial projects but also became responsible for Brazil's industrial policy. This framework involved the creation of state-owned enterprises and agencies to support the development agenda, e.g., the National Research Council (CNPq), the Agency for Post-graduate Training (CAPES) and later, the Funder of Studies and Projects (FINEP).[16]

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 (IBDF), created in 1967. 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 constraints on import 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

[15] 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.
[16] During the 2000s FINEP was upgraded into the Brazilian Innovation Agency.

Paper Manufacturers National Association (ANFPC), *provoked* the BNDES to assess the feasibility of the existing pulp and paper mills in Brazil.[17] This action reflected the pro-active strategy embeddedness of some firms to change industrial policy. Following that study, the BNDES and Industrial Development Council imposed new conditions for funding based on the increase of scale and of productivity of mills.

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 in 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 such as 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 which 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

[17] The ANFPC evolved from the National Papermakers Centre, created in 1925 to represent the interests of the paper industry among policymakers.

capability was a constraint for further innovative activities. Two important strategic actions taken by industrial entrepreneurs contributed decisively to overcoming this hurdle. First, firms such as 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 (IPEF), funded by the industry, but run by the public sector. Such collaboration arrangement permitted these firms to innovate successfully and lower the risks involved in this kind of path-creating innovation.[18]

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.[19] The initial idea to explore 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 structured its own research centre to tackle to such problems. By doing so, Alpha moved from vegetative propagation, based on seeds, to 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 to achieve technological and market leadership.[20] To facilitate its exports, Alpha negotiated with the federal government for permission to build its own harbour next to the mill.

[18] I thank one reviewer for suggesting me to refer to this point.
[19] This group involved visionary Brazilian entrepreneurs, among them one of the creators of Vale, a Brazilian mining company and a Norwegian businessman.
[20] The building of these research capabilities was also found in Scott-Kemmis (1988).

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 crisis. 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, which stimulated forestry research, forest-manufacturing integration and environment-related innovations. 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 such as Alpha, Delta, Kappa and Epsilon. It established new targets for the 1990s such as an increase of exports and stimuli to initial public offerings (IPOs). The start-up of operations of large mills of firms such as 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 to not engage 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 initiated its research activities, Alpha achieved worldwide recognition by being awarded the Marcus Wallenberg Prize from Sweden.[21] 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 such as Alpha, Kappa and Theta sought to reach export markets. However, as latecomers, they were confronted with an obvious hurdle: a lack of

[21] 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.

international market and technical credibility, especially related to 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 overcome these 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 the 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 several state-owned companies. As a result, several firms were swept away from the market, as they were unable to face international competition.

The BNDES began to emphasise financial and market mechanisms to allow the Brazilian economy to compete globally. To that end, in the early 1990s, BNDES implemented the Industrial and Foreign Trade Policy (PICE), which sought to stimulate the development of industrial capabilities. This policy sought to disseminate new management and production organisation techniques and the creation and upgrading of organisations for manufacturing

quality control. In parallel, however, through the mid-1990s, reflecting an exacerbation of neo-liberal policies, there was a severe financial and institutional weakening of public research institutes and universities: EMBRAPA and other organisations had their research programmes discontinued.

By the late 1990s, the Cardoso 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 modernisation and expansion of the technological infrastructure, the promotion of synergies between universities, research institutes and the industry to strengthen competitiveness.

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. While some firms stumbled, others restructured themselves and/or re-focused. Some sought to survive by securing production efficiency with basic innovation capabilities, whereas some firms deepened their innovation capabilities, despite the negative impacts on the public research facilities caused by the Collor administration.

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 a 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 remained stagnant at the intermediate level. By 2009 it was taken over by a Chilean firm.

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.[22] In contrast, Theta's strategic options emphasised innovation- capability deepening of the forestry business rather than pulp and even less paper (Table 7).[23]

Firms such as Lambda, Iota and Zeta-A pursued reactive 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. In contrast, firms such as 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 and new genetic material) in association with pulp and papermaking research (e.g., research on lignin biosynthesis and the patenting of the totally chlorine-free pulp (TFC) process and pollution control methods based on natural micro-organisms). Firms such as Alpha and Sigma-A created teams in their research centres and other units to discuss innovation

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

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

projects with large paper customers. Sigma-A implemented the 'Re-think Project' to encourage 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.[24] Industrial policy was based on a narrow selection of sectors. For example, the Industrial, Technological and Foreign Trade Policy (PITCE) was issued in 2004, and the Productive Development Plan (PDP) expanded its coverage to 24 sectors in 2007, targeting the strengthening of the international competitiveness of the pulp and paper industries. The Lula administration strengthened the innovation funds created during the Cardoso government. It went further to implement new policy instruments to promote innovation within firms and their links with universities and research institutes based on funding and fiscal incentives (e.g., the Innovation Law (2004) and the Good Law (2005).[25]

5.2.3.2 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 the following: (i) strengthening of their research activities, internally and in partnership with universities and research institutes; and (ii)

[24] The fact that 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 of a 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.
[25] These are, respectively, Law 10,973 of December 2004 and Law 11,196 of November 2005.

diversification into new business lines based on the previously accumulated innovation capabilities, especially in forestry.

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. They 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, papermaker Delta reviewed and re-organised its research centre to not only deepen its research into new genetic material but also to improve product and process development activities. Kappa, on the other hand, regained 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 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). 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.[26]

The end of Genolyptus, in 2008, somehow forced the participating firms to make strategic choices about 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 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 steps after Genolyptus.

In addition, 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 on renewable energy through the production of wood pallets for export markets.[27] Subsequently, Kappa acquired a British biotechnology firm with operations in the US, Israel, China and Southeast Asia. This was designed to facilitate the firm's entry into biofuels and the 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.[28]

[26] 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 such as Sigma-A, Sigma-B and Kappa.

[27] These are dehydrated and pressed particles of ground wood that are one of the most efficient methods of transporting biomass for energy over long distances.

[28] In several interviews managers defined these firms as 'forestry firms'. They pointed out that pulp and paper are no longer their only businesses.

6. Discussions of Findings

The purpose of this paper is to explore the relationship between micro-level innovation performance and changing institutional frameworks and the mediating role of strategy embeddedness. This set of relationships 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 capabilities 'levels'. 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*'. It was operationalised in terms of levels of interactions between the firms' innovation strategy process with components and players of their institutional frameworks over time, ranging from pro-active to active to reactive. 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, since the 1950s, firms have been engaged in a technological pathway that involved a *qualitative departure* from the established technological trajectory at an *early stage* in the capability development of Brazil's forestry and pulp and paper industry. This permitted the 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 and 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 in the 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 less rapidly (e.g., Delta, Kappa). In comparison, other firms achieved 'follower-type' of innovation performance level (e.g., Beta Gamma-pulp) or reached levels that were halfway 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. Additionally, the innovation performance achieved by firms such as Alpha, Kappa, Delta and Sigma-A have permitted them to engage in the diversification (although still incipient) of their business lines. By doing so, they are in a better position than other case firms to sustain their corporate growth (Amsden and Hikino, 1994) and meeting the current challenge diversification (Hausmann and Rodrik, 2006).

Fourth, by drawing on a micro-level design and on longitudinal fieldwork analysis, this study captures a dynamic, in-depth, nuanced and comprehensive view of the industrial reality, which

is not usually captured in studies based on highly aggregated designs. Consequently, the findings herein do not provide support for the views held in studies such as Ocampo (2001), Cimoli and Katz (2003), Cimoli and Correa (2005) and, especially, Castaldi et al. (2009) relative to the nature of the 'specialisation patterns' taken by Latin American economies after the reforms of the 1990s. Such statement deserves some qualifications.

First, obviously, this paper does not suggest any simplistic or radically opposing view that the reforms of the 1990s did not have negative impacts on the industrial innovation capability building in Brazil. Nor does the paper suggest that natural resource-processing industries, and especially the firms studied herein, are all characterised by high-level innovation capabilities. Second, at least in the context of this study, the findings indicate that the technological behaviour of the main firms of these highly relevant industries studied herein was characterised by a long-term process of building, accumulation, re-organisation (during the 1990s), renewing, deepening and diversification (although still incipient) of their innovation capabilities. Such process was associated with progressively higher levels of innovative performance and the achievement of leading commercial and technological positions in the global marketplace. Third, the variability in micro-level innovation performance found across the case firms as well as the world-leading innovation achievements attained by some of them are, in themselves, evidence that natural resource-processing industries are not the sort of industry to be encapsulated in one single category characterised by 'low knowledge content' and 'absence of technological learning', as suggested in Castaldi et al. (2009).

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

In light of the theoretical framework that was developed here, the study found that these firms pursued different levels of *strategy embeddedness* over time. Some firms pursued pro-active strategies (Alpha, Sigma-A, Sigma-B, Kappa and Delta), while others took active strategies (Gamma and Zeta-B), whereas others pursued arm's length strategies (Lambda and Zeta-A). Some began with pro-active strategies that ended up reactive (Epsilon), while others experienced a period of relative activeness during the 1990s (Kappa) but moved into pro-active strategy making during the 2000s. There were also variations across business lines of the same firm such as at 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, the following was determined for firms that pursued proactive strategy embeddedness: (i) their innovation performance was significantly higher *over time* than firms that pursed proactive embeddedness; (ii) they faced 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 taking advantage of technological and market opportunities than firms that relied on active and reactive types of strategy embeddedness.

These findings help to overcome 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 macro- and meso-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, this kind of longitudinal micro-level perspective is not captured by studies based on macro-level design and data derived from aggregated types 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 for studies that emphasise the role of institutional frameworks in industrial innovation in developing economies (Rodrik, 2004, 2006; Cimoli et al., 2009; Nelson, 1996; Nelson and Sampat, 2001; Iacavone and Crespi, 2010). However, the study herein goes further by demonstrating that although well-designed institutional frameworks are obviously necessary for the achievement of industrial innovation and leadership, a large part of achieving them will depend on the nature and dynamics of the firm's own strategic choices and related innovation efforts. Although this appears to be well known, the role of micro-level innovation efforts seems the ignored or underestimated in the design and implementation of industrial innovation policies.

7. Concluding Discussions

7.1 Contributions for theory and policy

7.1.1 Contribution for theory

Despite the emergence of Lall's framework circa 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 theory on the variability in innovation performance across latecomer firms. The paper also creates a basis for deepening 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., simply designing and supplying components of institutional frameworks (policies, incentives, laws and 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* policymaking processes with the strategic needs and choices related to innovation efforts of firms and their partners.

Fourth, one of 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 whether or not they are derived from existing technological trajectories.

7.2 Limitations and future research suggestions

This study has a number of limitations. It does not examine how the learning processes would interact with strategy embeddedness to mediate variability in firms' innovation performance within changing institutional frameworks. Nor does the paper captures the outcomes of firms' innovative performance. Future research might address these issues. This paper offers a powerful framework to scrutinise the manner, nuances and dynamics of firms' innovation performance. Such an approach might represent a powerful supplementary analysis to studies of firms' innovative performance that are based on innovation surveys and analysis of panel data. Furthermore, the framework for strategy embeddedness can be applied together with other micro-level factors (e.g., leadership and corporate behaviour) to examine their role in firms' innovation performance.

The research questions, theoretical framework and proxies can be examined using hypothesis testing in a large sample. This may yield more robust explanations of the *dynamics* of latecomer firms' innovation performance. Additionally, by drawing on the methodological contributions of this paper, in terms of proxies for innovative performance and strategy embeddedness, future research might examine those issues in other types of natural resources and natural resource-

processing industries and undertake cross-sector and even cross-country analyses. Future research might also examine triggers and mechanisms to achieve strategy embeddedness. Finally, future research might draw on this and other related studies to create a typology to distinguish among different kinds of innovative activities in natural resource-related industries.

7.3 Conclusion

This paper contributes to improving our understanding of variability in innovation performance across latecomer firms, especially in natural resource-processing industries. It does so by examining the dynamics of micro-level innovation performance improvement across changing meso/macro institutional frameworks and the mediating role of the strategy embededness over time. Although macro- and meso-level institutional frameworks are relevant for industrial growth, innovation and competitiveness, these will largely depend on the nature and dynamics of micro-level strategy processes related to innovation capability building.

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