Micro-level patterns of technological upgrading intensity and their outcomes: What does evidence from natural resources-intensive industries in Brazil tell us?

Paulo N. Figueiredo

Brazilian School of Public and Business Administration (EBAPE)
at the Getulio Vargas Foundation (FGV)
Research Programme on Technological Learning and Industrial Innovation in Brazil at FGV EBAPE
paulo.figueiredo@fgv.br

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Capability failure or firms' low level innovative technological capability ➔ one of the reasons of slow growth in certain middle-income countries (Lee, 2013).

Therefore, intensity of technological upgrading, i.e., the accumulation of types and levels of technological capabilities to implement production innovative activities (Bell, 2009; Radosevic and Yoruk, 2016, 2018; Lacasa et al., 2018) ➔relevant to be scrutinised in countries 'trapped at the middle income level'.

Indeed, there has been considerable empirical research on technological upgrading/catch-up since the influential article by Lee and Lim (2001) (see reviews in Bell and Figueiredo, 2012; Miao et al., 2018).

Plus: New explanatory frameworks for technological catch-up (process, influencing factors and consequences) have emerged (see Lee and He, 2009; Choung et al., 2011; Lee and Malerba, 2017; Miao et al., 2018; Radosevic and Yoruk, 2018; Figueiredo and Cohen, 2019).

However, some issues have received less attention in the literature, which have prompted the emergence of recent studies which:

1. Move beyond the use of standard proxies proxies for innovative capability accumulation;

2. Move beyond the so-called ‘high-tech’ industries to emphasise the so-called ‘low tech’ industries;

3. Adopt a wider perspective on outcomes of innovation, including trade-offs of innovation and ‘negative’ outcomes;

4. Emphasise the micro-level (intra-industry, intra-firm)

5. Draw on primary empirical evidence (not oficial innovation surveys) and dynamic designs

Therefore,

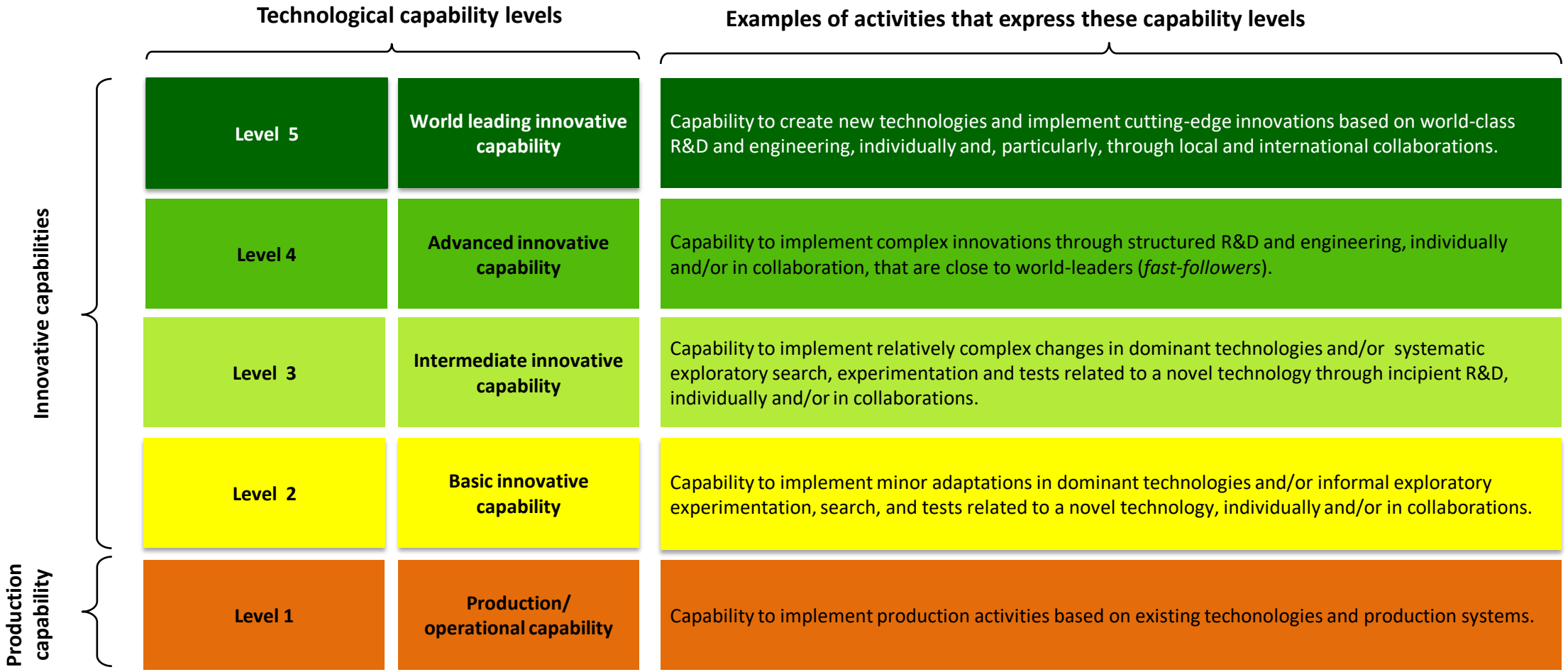
the purpose of this chapter is to review recent empirical evidence on the accumulation of innovative technological capability (technological upgrading intensity) from **three** natural resources-intensive industries in Brazil:

Forestry and pulp and paper

Sugarcane ethanol

Mining

Framework for examining technological upgrading intensity (as accumulation of levels of technological capability)



Sources: Adapted from Lall (1992); Bell and Pavitt (1995); Bell & Figueiredo (2012), Figueiredo (2001, 2011, 2017).

Going beyond the firm as unit of observation:

Innovative capabilities at the level of specific intra-firm technological areas/functions and their network of partnerships

Industry	Specific technological areas/functions within firms:
Forestry and pulp and paper	• Forestry (feedstock) • Pulp and paper making industrial processes
Sugarcane ethanol	• Feedstock • Agricultural processes • Industrial processes
Mining	• Exploration • Mining • Mineral processing

Mostly distributed across a network of partners – e.g.:

- suppliers
- lead users
- specialized engineering and consulting firms
- research institutes
- universities

A ‘framework’ of some outcomes of innovative technological capability accumulation

Implemented inventive activities	Number patentes and registred cultivars
Implemented innovative activities	Various types of innovative activities with differing degrees of complexity and novelty.
Operational and enviroment-related performance improvement	Various technical/operational and environmental-related performance parameters of specific industries – e.g. wood density, planting density, specific consumption electricity and water, fiber losses, liquid, solid and air effluents.
Labour productivity	Firms’ value of revenues by the number of direct production workers.
Export performance	Share of exports on firms’ revenue.
Patterns of corporate growth	(i) Horizontal integration (e.g. enlargement of existing facilities); (ii) Vertical integration (upstream/downstream); (iii) Diversification: (a) ‘direct’ diversification (e.g. biotechnology) (b) ‘indirect’ diversification (spin-offs and spill-overs, local suppliers development).
Social impacts	Skills development and job upgrade, contribution to local human developent index improvement
Trade-offs and negative outcomes	Controversial environmental and social issues; environmental damages and social conflicts.

Sources: Empirical evidence and related studies.

Natural resources-intensive industries

They respond for nearly 70% of Brazil's exports

Geographically specific and **knowledge idiosyncratic**: local environmental, ecological, and geological conditions – climate, soil, wood, biological conditions, diseases, genetic material.

Highly dependent on localised knowledge .

Not 'generic' or universal industries (Katz and Pietrobelli, 2018).

High potential for **path-creation technological catch-up**: they cannot imitate or import incumbents' technologies because of local conditions (Mazzoleni and Nelson, 2007; Figueiredo and Cohen, 2019).

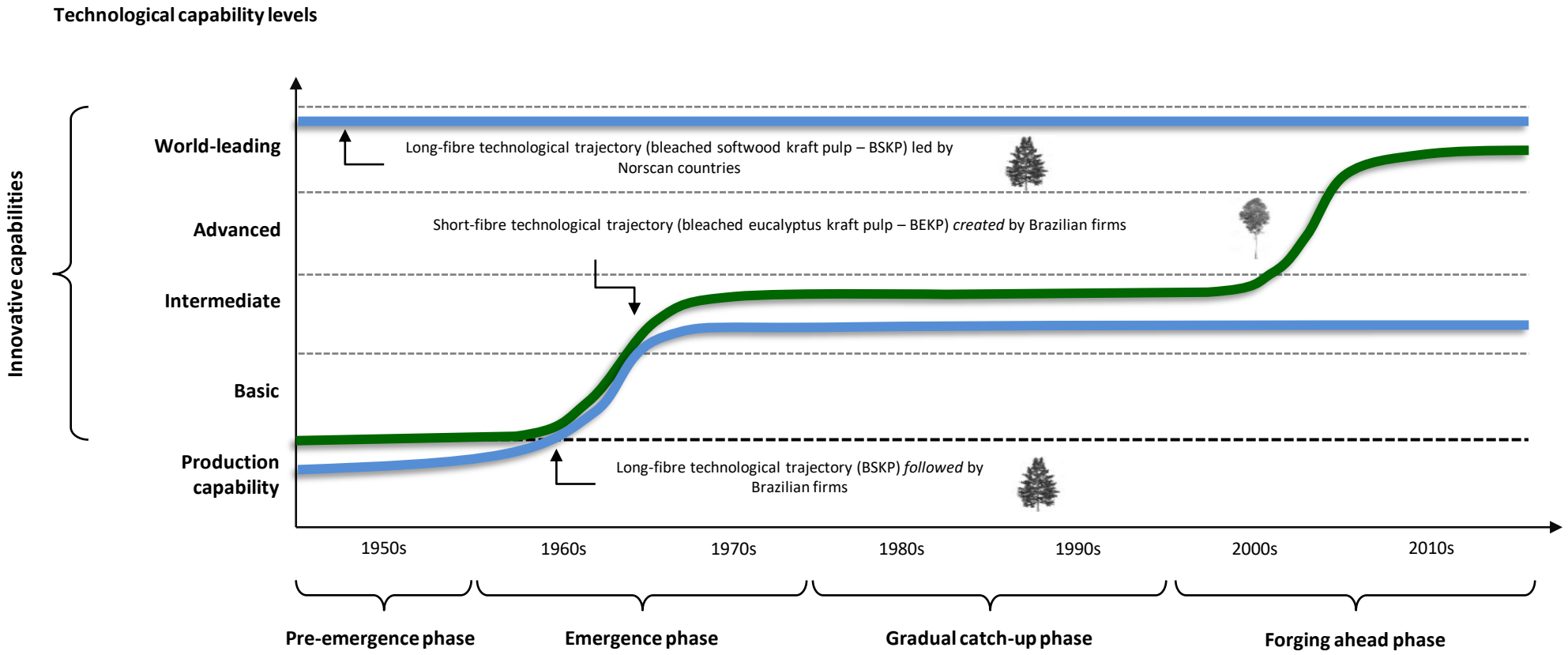
Forestry and pulp and paper industries

Brazil: world's largest eucalyptus pulp producer and exporter.

Brazil's **leading technological and commercial position** in the global pulp industry = recognised by the technical literature and latecomer innovation studies

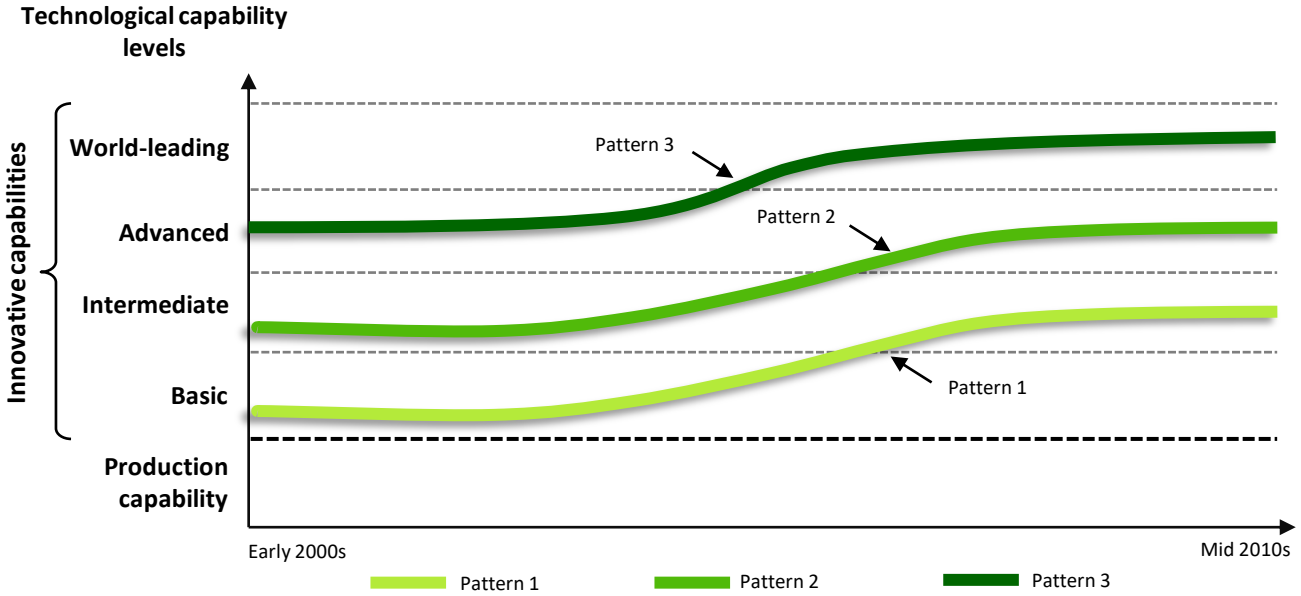
Fibria (former Aracruz/VCP), **Suzano**, **Klabin:** first- and second-world's largest eucalyptus pulp producers and exporters global pulp industry.

General pattern of innovative technological capability accumulation in Brazil's forestry and pulp and paper industry



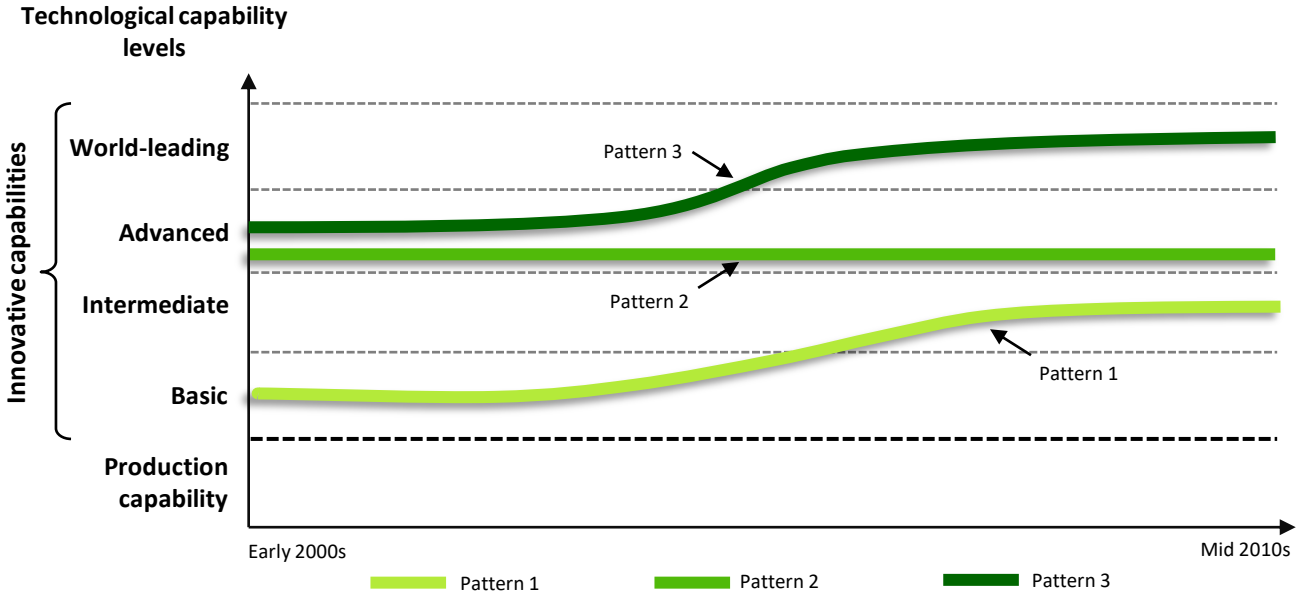
Source: Figueiredo (2016); Figueiredo and Cohen (2019)

Patterns of innovative capability accumulation within forestry technological area in Brazil



Source: Figueiredo et al. (2018).

Specific patterns of innovative capability accumulation within the pulp and paper processes technological area in Brazil



Source: Figueiredo et al. (2018).

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Some outcomes of patterns of innovative technological capability accumulation in Brazil's forestry and pulp and paper industry

Inventive activities

Innovative activities

Operational and environment related performance improvement

Patterns of corporate growth

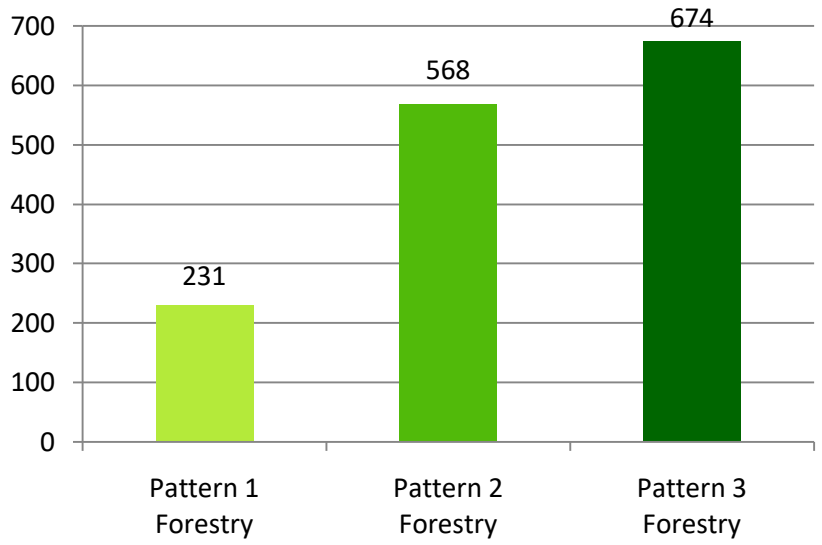
Diversification beyond pulp and paper

Labour productivity

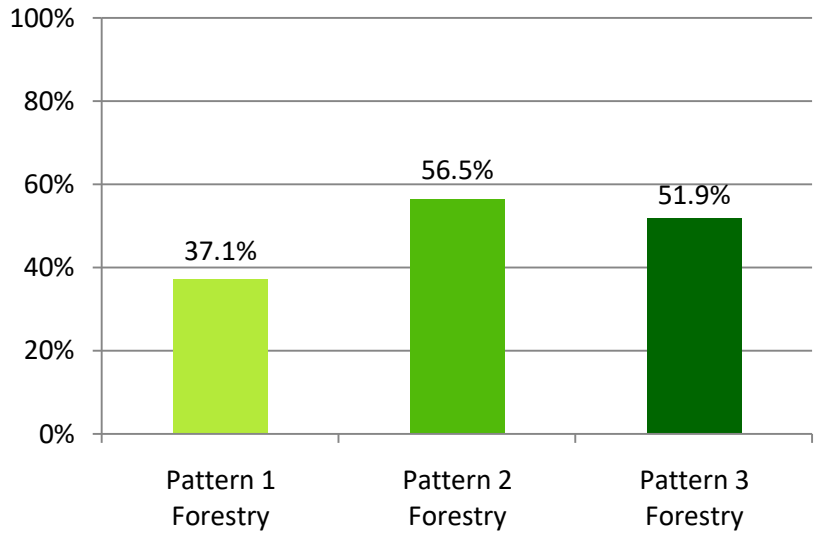
Export performance

Patterns of innovative technological capability and firm's competitive performance: Forestry industry: Forestry area

Labour productivity
(firms' revenue (BRL)/per number of workers)



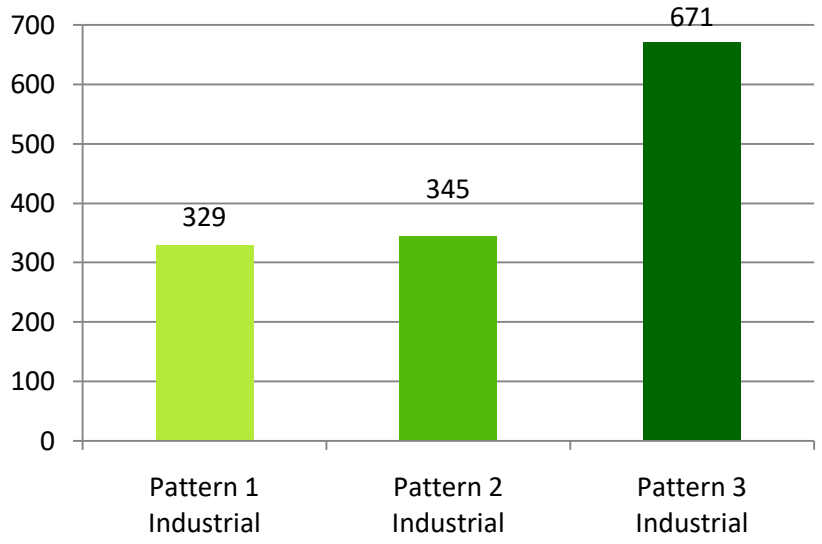
Export performance
(proportion of exports in firms' revenues)



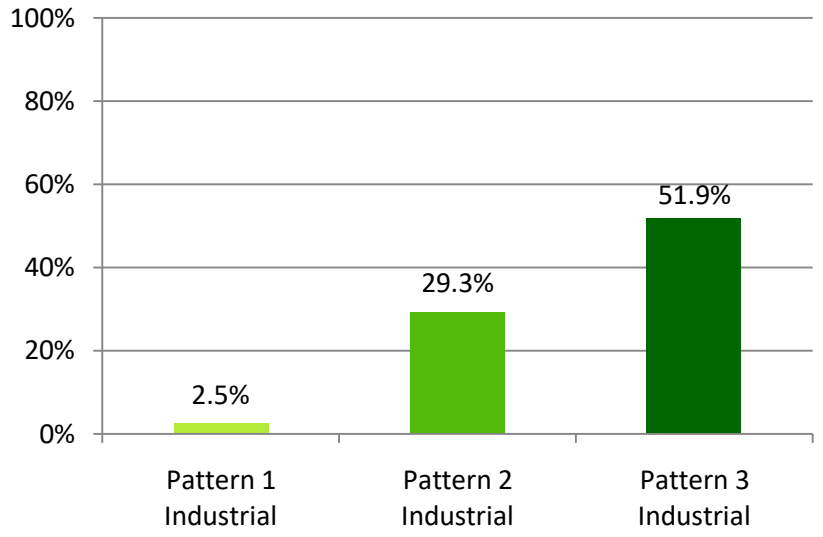
Source: Figueiredo et al. (2018).

Patterns of innovative technological capability and firm's competitive performance: Forestry industry: Industrial area

Labour productivity
(firms' revenue (BRL)/per number of workers)



Export performance
(proportion of exports in firms' revenues)



Source: Figueiredo et al. (2018).

Some trade-offs and ‘negative’ outcomes of technological development in Brazil’s forestry and pulp industry

Eucalyptus accused of being ‘water guzzlers’ and ‘green deserts’

Industrial eucalyptus forests accused of destryoing local biodiversity

Conflicts with indegenous peoples (indians and quilombolas) over land use (1970s through 1990s)

Governenment regulation + social pressures + consumers’ pressurers (demand) + international forest certification bodies and evaluation with impacts on firms’ value forced firms to:

Develop new technologies and practices forest management to mitigate environmenal damages and social conflicts.

Sugarcane ethanol industry

Brazil and USA: world's largest ethanol producers, though using different feedstok.

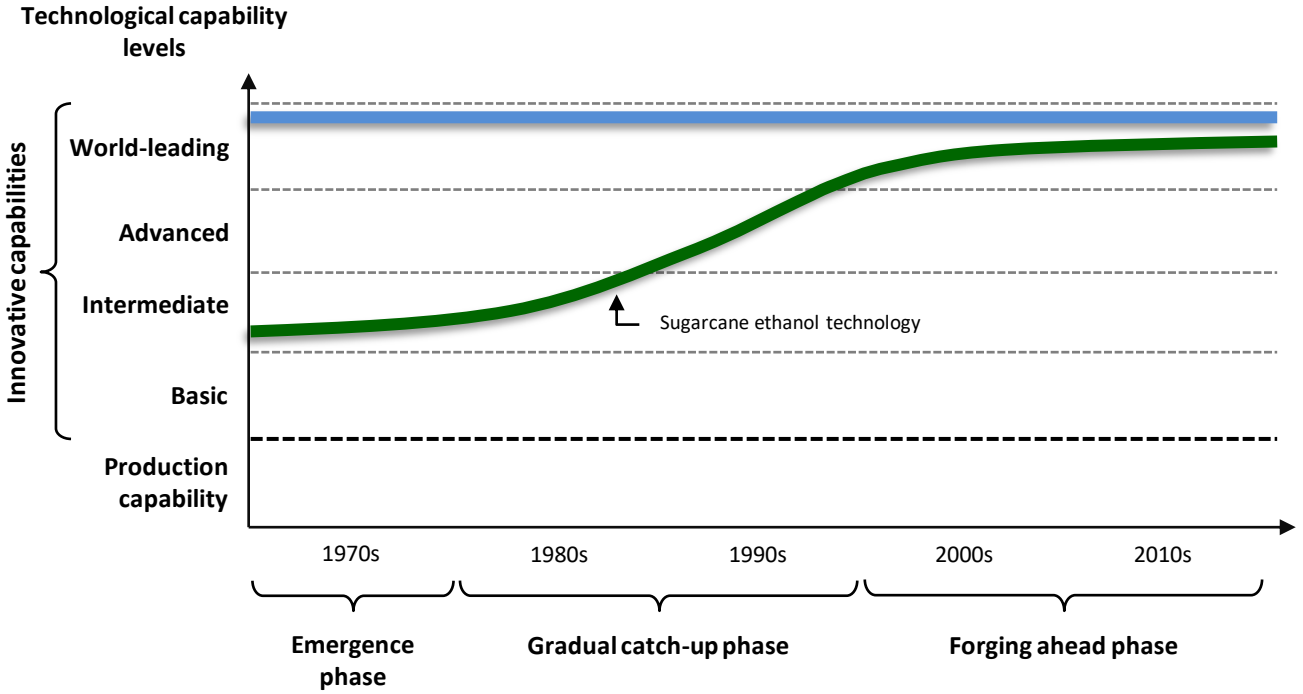
Brazil:

- World’s largest sugarcane ethanol producer.
- World’s 7th largest greenhouse gas (GHG) emitter.
- One of 5 countries with the greatest potential to reduce emissions by 2030

+

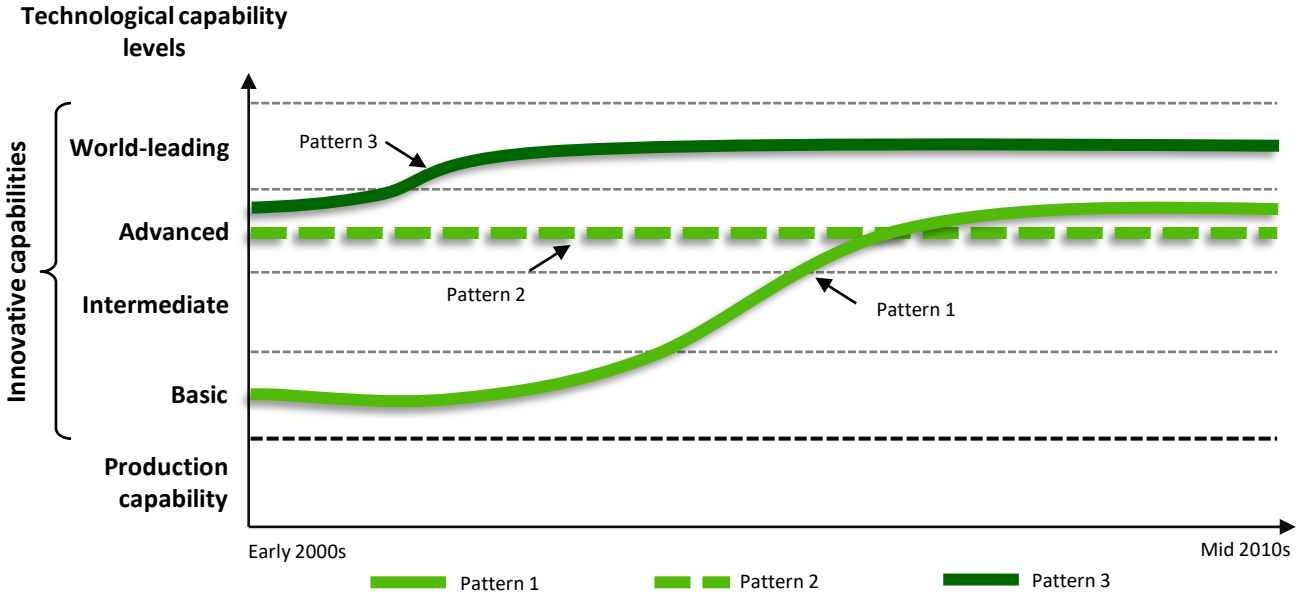
- Every litre of petrol replaced with sugarcane ethanol reduces emissions by 90%.
- arcane ethanol’s by-products ➔ sources for bioelectricity cogeneration.
- 2017: sugarcane mills met approximately 4% of Brazil’s electricity demand.

The general pattern of innovative technological capability accumulation in Brazil's sugarcane ethanol industry



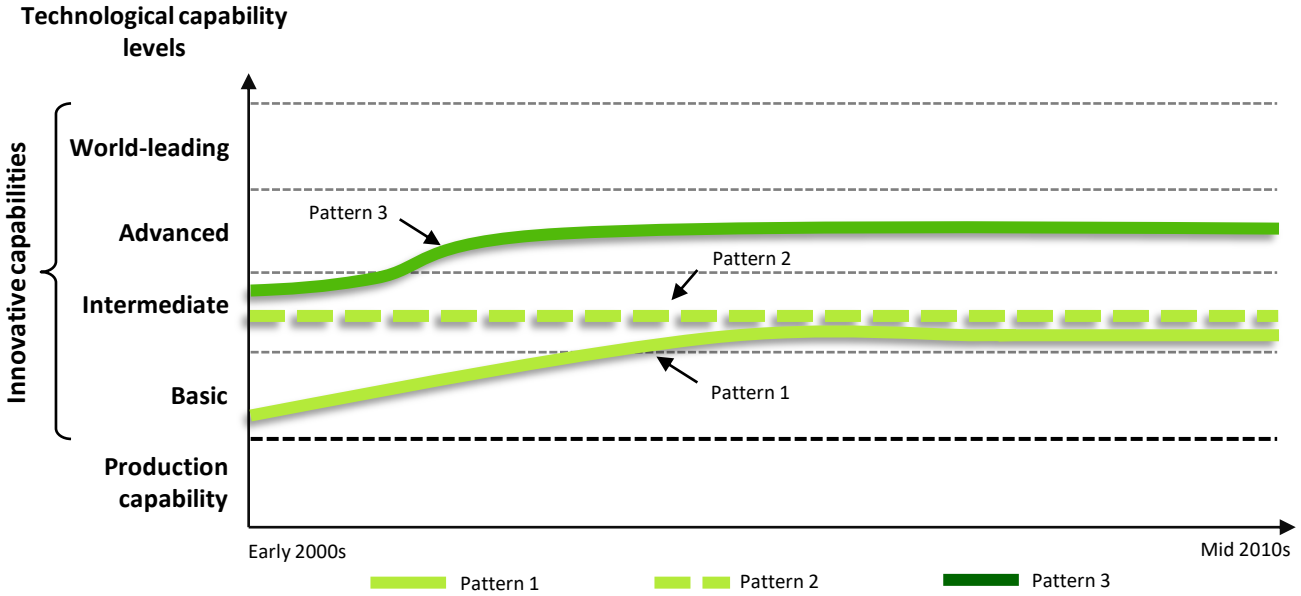
Sources: Gonzalez (2016); Figueiredo (2017).

Specific intra-industry patterns of innovative capability accumulation in the feedstock technological area



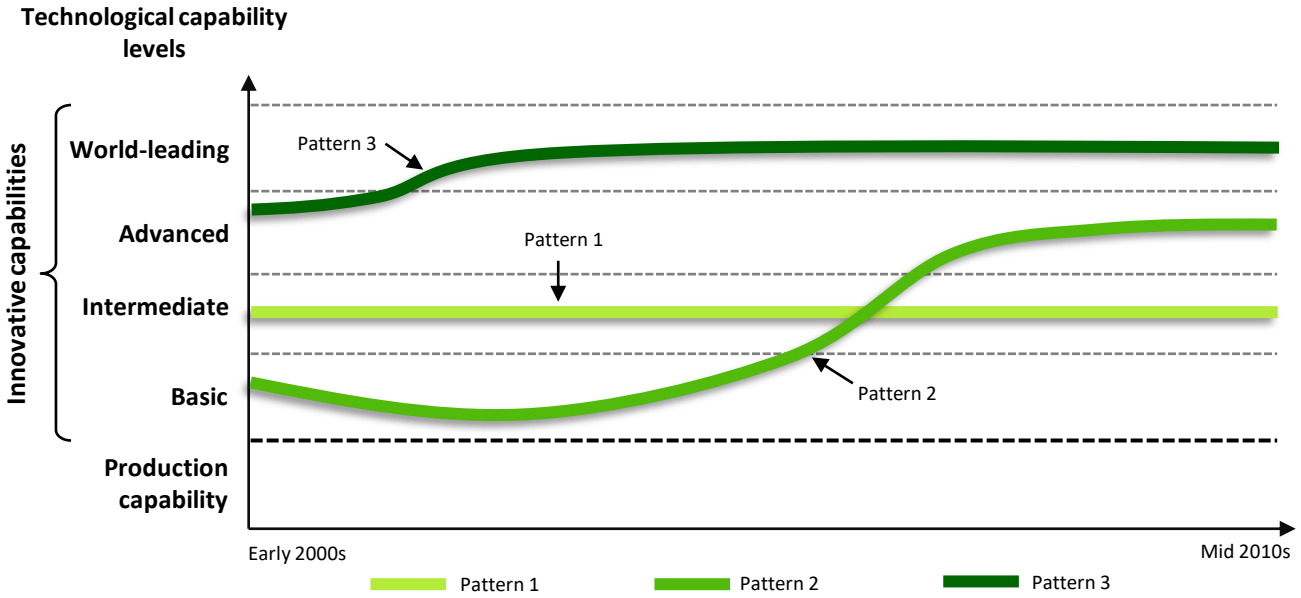
Source: Figueiredo et al. (2018).

Specific intra-industry patterns of innovative capability accumulation in agricultural processes technological area



Source: Figueiredo et al. (2018).

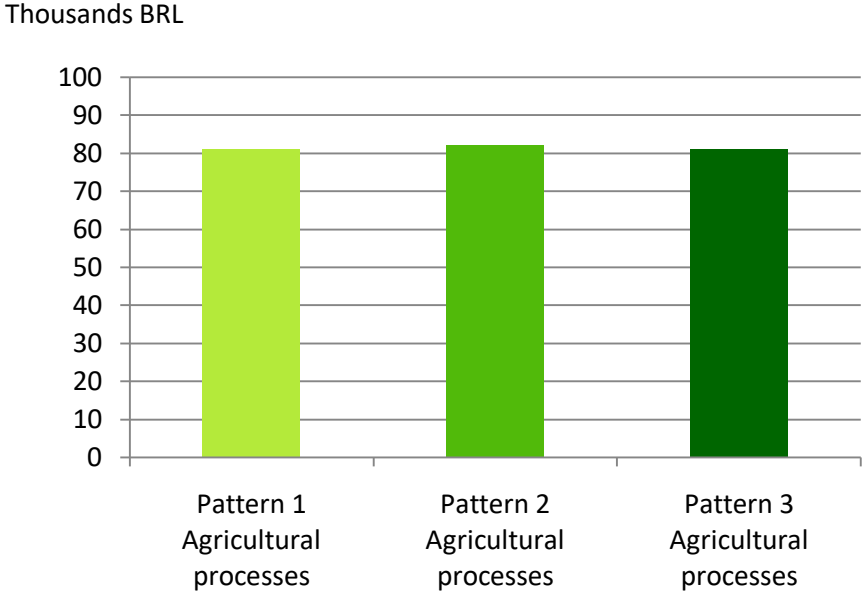
Specific intra-industry patterns of innovative capability accumulation in industrial processes technological area



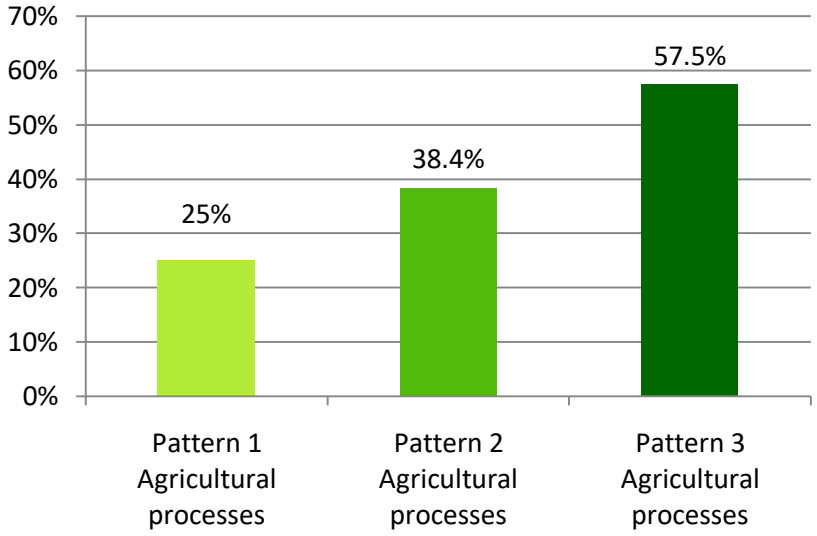
Source: Figueiredo et al. (2018).

Patterns of innovative technological capability and firm's competitive performance: Sugarcane ethanol industry: Agricultural processes

Labour productivity
(firms' revenue (BRL)/per number of workers)



Export performance
(proportion of exports in firms' revenues)



Source: Figueiredo et al. (2018).

Some trade-offs and 'negative' outcomes of technological development in Brazil's sugarcane etanol industry

Competition with food crops
(1970s and 1980s)

Environmental damage caused by production residue (vinasse)
(up to 1990s)

Development of new technology to transform vinasse into soil bio-fertilizer

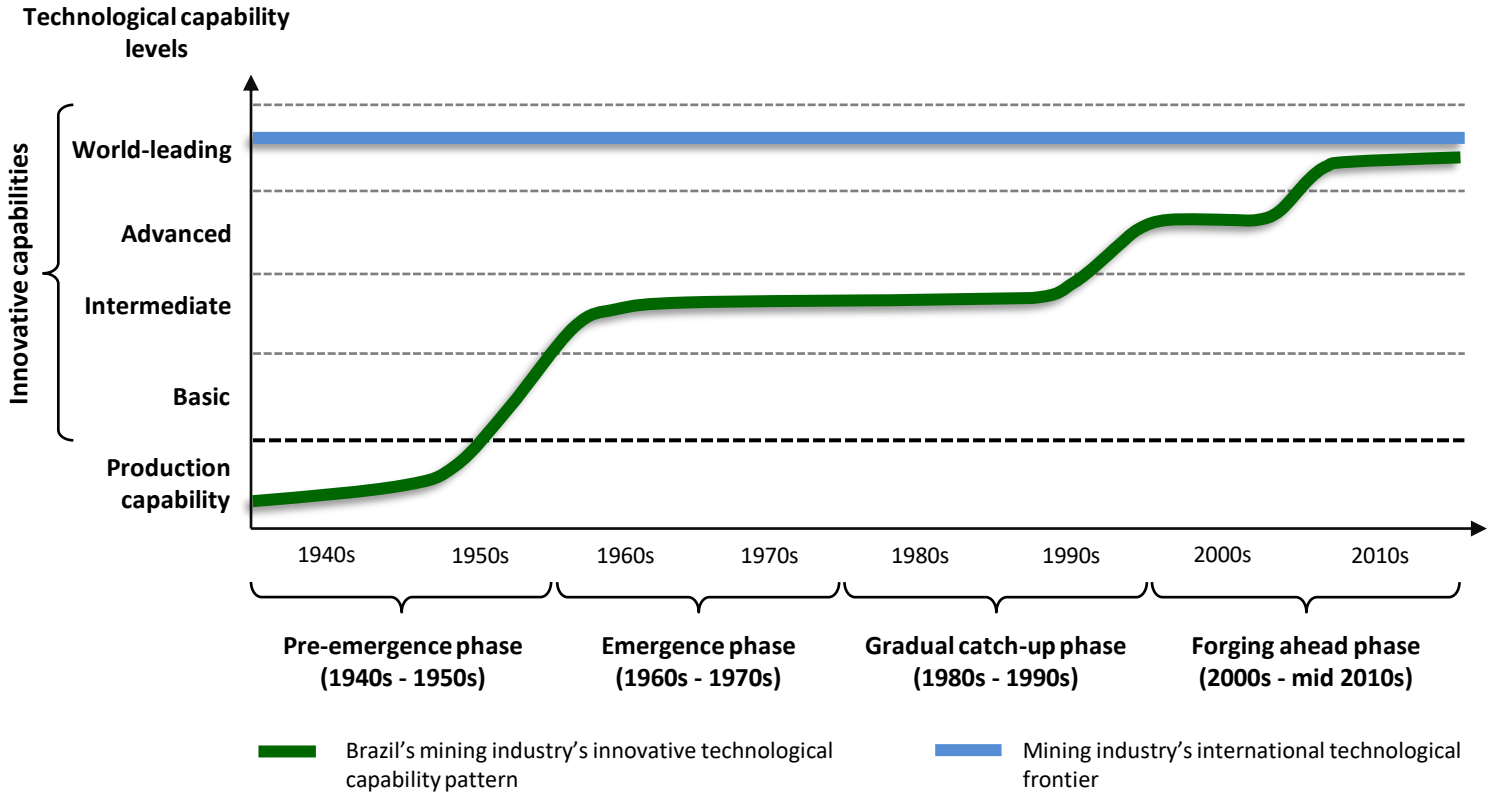
Mining industry

Brazil is one of the world's largest mineral producers and exporters, with a diversified mineral basis involving 72 minerals, with leading production of niobium and iron ore.

The bulk of this industry is dominated by large, local mining firms (Vale and Votorantim Metais), which also have strong international operations.

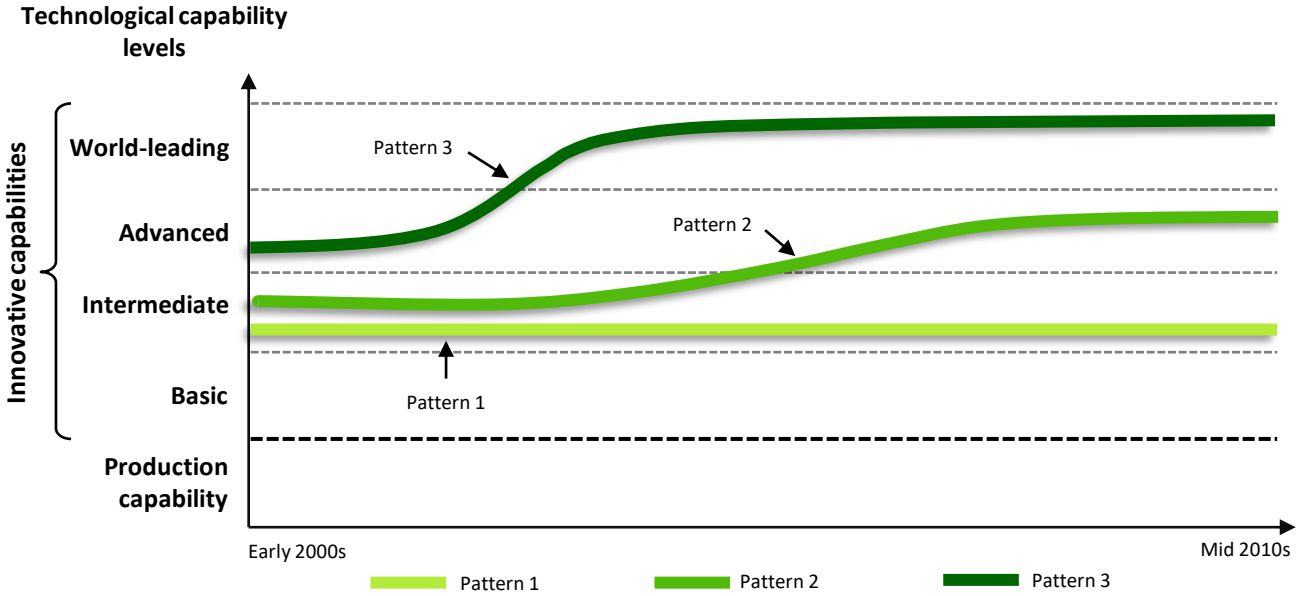
Vale is the world's largest iron ore, pellets, and nickel producer, operating in more than 30 countries.

General pattern of innovative technological capability accumulation in Brazil's mining industry



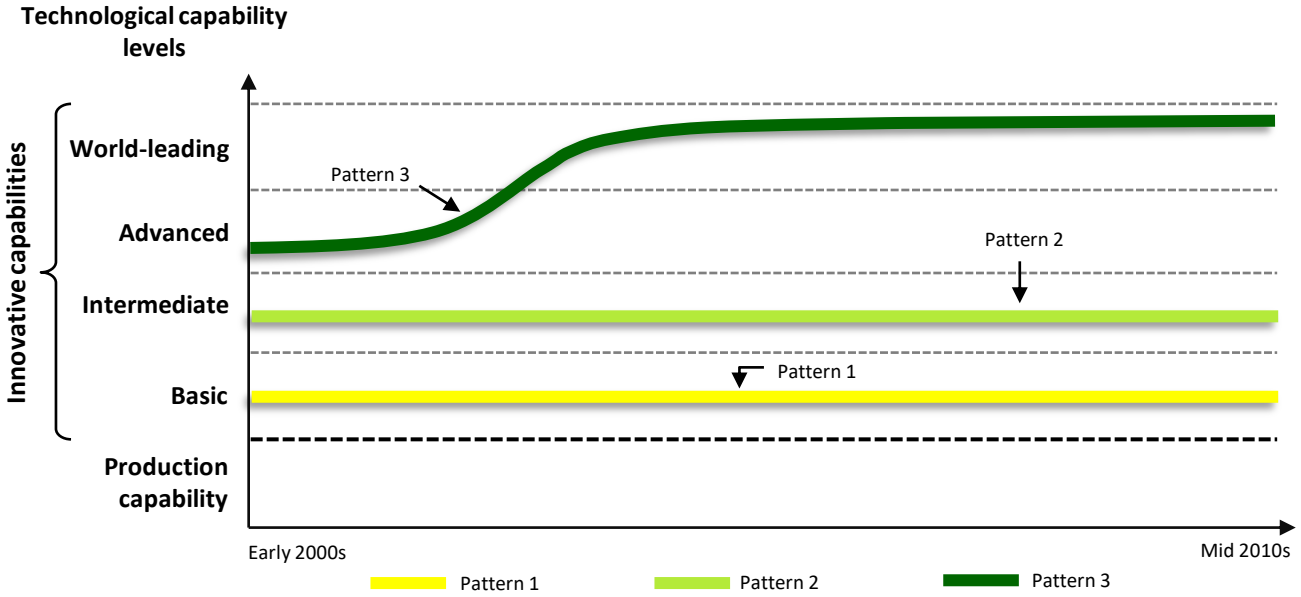
Sources: Piana (2016); Figueiredo and Piana (2018).

Specific intra-industry patterns of innovative capability accumulation in the exploration technological area in Brazil's mining industry



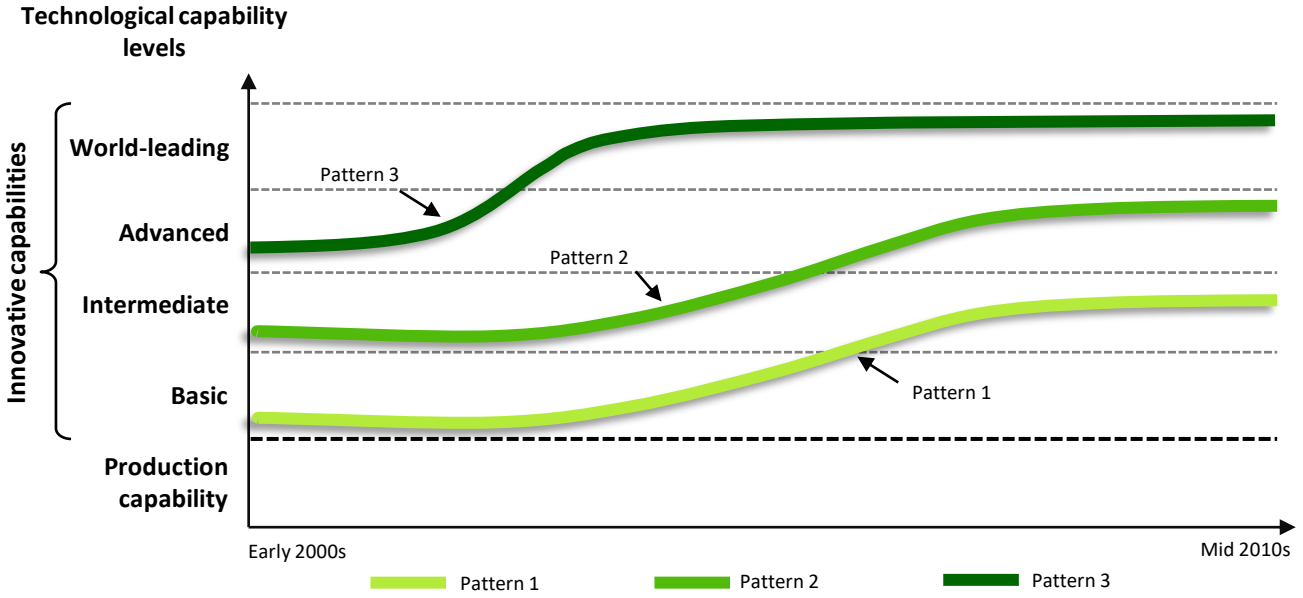
Source: Figueiredo et al. (2018).

Specific intra-industry patterns of innovative capability accumulation in the mining technological area in Brazil's mining industry



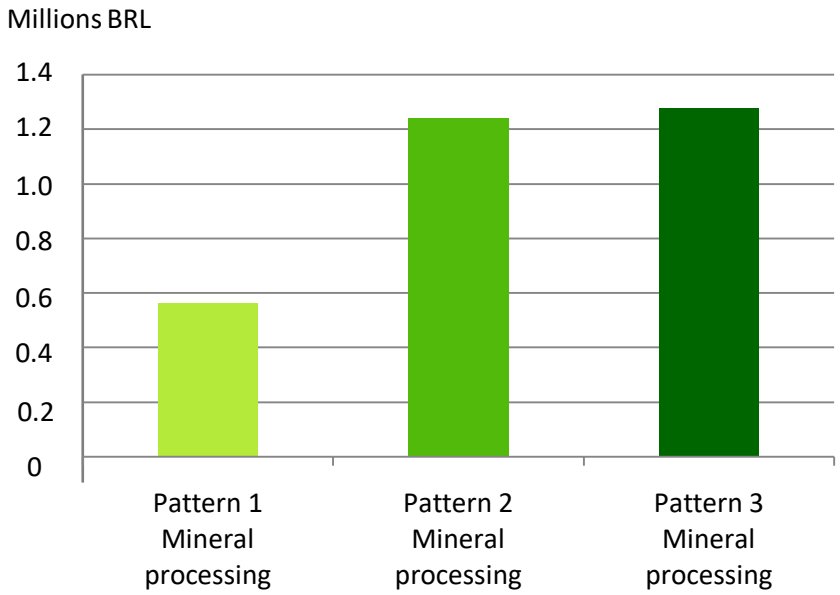
Source: Figueiredo et al. (2018).

Specific intra-industry patterns of innovative capability accumulation in the mineral processing technological area in Brazil's mining industry

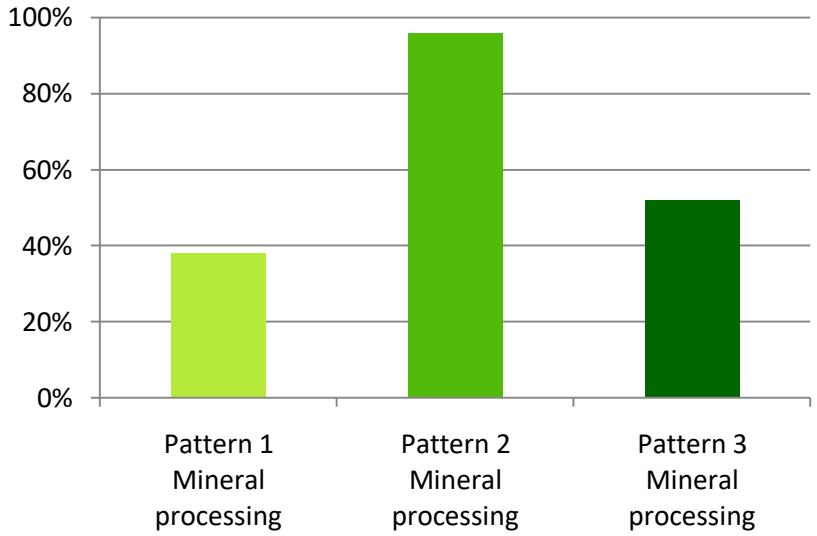


Patterns of innovative technological capability and firm's competitive performance: mining industry: Mineral processing

Labour productivity
(firms' revenue (BRL)/per number of workers)



Export performance
(proportion of exports in firms' revenues)



Some trade-offs and negative outcomes of technological development in Brazil's mining industry

Collapse of tailing dams in mining towns of **Mariana** (2015) and **Brumadinho** (2019), southeastern state of Minas Gerais

This is has been one of the most feared damages by mining firms with cases in USA, Canada, Mexico, Brazil, China and Israel.

Inception of tighter rules and new regulation (e.g. total ban on tailing dams)

Development of new technologies to monitor and/or replace tillage dams (Vale's S11D Project)

Some points for conclusions and recommendations

1. Reviews micro-level evidence that moves **beyond the firm** as the sole unit of observation to capture micro-level patterns of innovative technological capability accumulation at the level of specific areas within firms.
2. In relation to these micro-level patterns of innovative technological capability accumulation, they involve:

   i. **Path-creation mode** of technological catch-up process;
   ii. At upper innovative capability levels firms engage with **science-based innovative activities**, therefore contradicting the so-called 'low tech'/'commodity' classifications;
   iii. **Significant variation** within industries and across and within firms of the same industry;
   iv. **Variety of types and levels of innovative capabilities**, beyond R&D and patenting, including design and engineering.
   v. **Openness or intense inter-organizational collaboration** throughout the innovative capability accumulation process (e.g. with local SMEs – mining industry – and other types of partners.)
   vi. Firms that accumulate world-leading technological capability have engaged in **diversification into new technological areas** (e.g. bioenergy and biotechnology (forestry and pulp and paper), bio-products (sugarcane ethanol).
   vii. Some firms have sought to take advantage of **digital technologies to innovate** (AI, big data) and nano- and biotechnology (mining).

3. It contributes to **furthering our understanding about the intricacies, nuances, dynamics of the intensity of technological upgrading** in under-researched natural resources-intensive industries in the context of natural resource-rich emerging economy.

4. It draws on a **comprehensive proxy of innovative technological capability**, beyond standard proxies solely based on patenting and R&D expenditures: these could lead to **false negative conclusions**.

5. The evidence challenges standard classifications of industry (OECD-type of classification)

Finally:

6. Caveat: the evidence is fragmented, suggesting the need for more systematic investigation.

7. The evidence does NOT suggest a country's specialisation in natural resources-intensive industries.

It simply suggests that natural resources-intensive industries offer relevant opportunities for innovation and growth.

Path-creation technological catch-up in these industries seems relevant for **economic catch-up** in resource-rich developing economies.

Therefore, they should receive policy makers' greater attention especially in resource-rich developing economies such as Brazil.

Thank you.