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When Being Large Is Not an Advantage: How Innovation Impacts the Sustainability of Firm Performance in Natural Resource Industries

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Abstract: This paper provides an in-depth study of how incremental innovation, a ubiquitous factor, affects the sustainability of performance of small- and large-sized firms differently. Specifically, this work examines the sustainability of firm growth in natural resource industries. In these industries, innovation is mainly based on processes in the form of incremental changes, and the adoption of innovations has significant sunk costs. We argue that, before incremental process innovation, firm performance is directly proportional to firm size. However, in the presence of incremental innovation events, firm performance is inversely proportional to firm size since smaller firms pose higher strategic flexibility and can adopt innovations faster. Our empirical findings highlight the relevance of incremental innovation as an inflection point of firm performance, creating a competitive opportunity window for small firms and a sustainability threat for large firms.

Keywords: firm performance; Gibrat's law; growth; incremental innovation; natural resource industries; size; sustainability

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1. Introduction

Sustainable firm performance involves sustaining and expanding economic growth, shareholder value, prestige, corporate reputation, customer relationships, and the quality of products and services [1–4], contributing to a more equitable and wealthy world [5,6]. An important part of the extant management literature considers growth as one of the main indicators of firm performance [7–12]. One area of interest receiving particular attention has been the relationship between performance and size. Indeed, a significant number of studies focused on testing whether firm growth is a random phenomenon independent of firm size [13–16], as stated by Gibrat [17]. Evidence on Gibrat's Law, also known as Law of Proportionate Effect (LPE) or "random walk" [18], is still inconclusive. While several empirical studies suggest a negative relationship between firm size and growth [14,16,19–21], other studies have found a positive relationship [22–24], and still others report no significant relationship [23,25]. In a search for necessary mechanisms and contingent conditions for the sustainability of firm's performance, scholars have also asked whether innovation events can influence performance experienced by firms of different types [14,26–31]. However, most of the research considers heterogeneous industries, and consequently, they do not account for the structural differences of markets and their influence on the sustainability of firm performance. Our work extends current knowledge to an underexplored area of management: natural resource industries, contrasting the validity of Gibrat's Law and the impact of innovation on a firm's performance.

Although natural resource industries represent between 25% and 35% of global exports [32], and more than 50% of countries in the world are commodity-dependent [33], including developing countries in Latin America, Africa, Asia, and several developed countries such as Australia, Canada, and the Northern European countries, these industries have received limited attention to date. Consequently, they represent a rich area for inquiry [34]. Natural resource industries are defined as those whose primary purpose is to reproduce, explore, and utilize nature, converting natural resources into useful resource commodities [35]. That is, natural resource industries depart from other industries because their products are and remain a commodity, in some cases remaining unaltered for decades or centuries, favoring competition strategies based on cost optimization, in contrast to product differentiation strategies commonly found in other industries. Therefore, production technology in natural resource industries is equipment-intensive (e.g., oil, pulp and paper, or mining industries), with significant economies of scale, focused on efficiency. This quest for cost reduction and productivity has led to the use of advanced technology, increasing the automation of processes, and the reduction of production buffers by manufacturing integration [36], with incremental process innovation as the most common form of process improvement [37].

Due to the existence of capital-intensive and highly integrated manufacturing processes, and the fact that most innovations emanate from suppliers, innovation adoption and competitive dynamics in natural resource industries diverge from those of differentiated product industries [38], offering a unique setting for analysis. For instance, in industries with product differentiation and rapid environmental changes, resources and processes rapidly become obsolete [39,40] as radical changes diminish the value of extant knowledge and render organizational structures, processes, and capabilities obsolete [41,42]. Thus, small, adaptable organizations with flexible technical and financial approaches have an edge on facing the diversity and uncertainty of performance requirements for disruptive innovations, and industry leaders may become laggards because they have difficulty managing disruptive changes [43–45]. However, in a context of undifferentiated products, a stable environment, and the absence of radical innovation, does incremental process innovation affect the sustainability of firm performance? More specifically, how does firm size influence the successful adoption of innovations? Do small firms have an advantage? Answering these research questions is paramount in light of the importance of natural resource industries in worldwide economic activity.

In doing so, we examine the last significant incremental innovation in the pulp and paper industry in the US from 1978 to 1987. (Significant incremental innovations are incremental innovations that are observable and cause a significant, measurable impact on firm performance [46]. Henceforth, we focus our attention on significant incremental innovation. Therefore, when using the term incremental innovation, we will refer to significant incremental innovation, even if it is not explicitly stated). We argue that, in natural resource industries, and contrary to previous research [47,48], just after an incremental innovation event, small firms grow faster than larger firms since they are nimble enough to adopt the innovation more rapidly. Large firms get no advantage of having superior resources and higher market share as incremental innovations come mostly from suppliers' spillover knowledge and affect process efficiencies while products remain unaltered. Additionally, large firms need more time to adjust the high level of fixed assets to any innovation. Interestingly, in the time-window previous to process innovation, larger firms benefit from the isolation mechanisms that provide a competitive advantage [49] in mature industries by growing faster. Therefore, incremental innovations pose an inflection point in terms of firm performance in an industry, creating a competitive opportunity space for small firms and a sustainability threat for large firms. These results contradict Gibrat's Law [17], which claims that firm growth is a random variable independent of firm size.

The main contributions of this paper are as follows. First, we identify incremental innovation as a central force in shaping the sustainability of performance: large firms undergo positive growth before incremental innovation and negative after the innovation, whereas small firms experience the opposite effect. Thus, our study untangles the contradictory results obtained by scholars when assessing the relationship between performance (growth) and firm size [20,50], recognizing incremental innovation as a distinctive environmental factor that shall be considered in the analysis. Second, given that incremental innovation is the norm and not the exception, understanding the environmental factors that influence the structural properties of the industry is of critical importance, not only for advancing theory on competitive dynamics but predominantly for practitioners when formulating and developing strategies to deal with a changing environment. In particular, in natural resource industries, where incremental process innovation is pervasive and product differentiation is almost non-existent, economies of scale or preemption of resources do not provide a safety shield for larger firms. This is because innovations create an opportunity for smaller, more flexible competitors to adopt innovations faster and to improve their efficiency much earlier than larger firms, and, as a consequence, to achieve higher growth, providing a temporary performance advantage. Finally, our manuscript contributes to the literature on competitive strategy in natural resources. We respond to a recent call for filling the knowledge gap by increasing investigation regarding needs in the field [34], providing empirical evidence from the pulp and paper industry.

The rest of the paper is organized as follows: We first develop the theoretical framework that supports our claim, building on the literature of firm growth and incremental process innovation. We then discuss our empirical strategy and report results. We conclude by discussing the study's implications as well as its limitations.

2. Theoretical Framework and Hypotheses Development

2.1. Performance as Firm Growth: The Relationship between Size and Performance

Only through sustainable performance are organizations able to grow and progress. Although firms possess multiple dimensions and measurements of sustainable firm performance [51], firm growth is an essential sign and a key performance measure of a competitive and viable firm. Scholars in the management field have long studied sustainable firm growth in financial terms [2], social and business value creation [4], production [28], sales, employment, or net assets [52], among others. Specifically, the relationship between size and firm growth has been the subject of a large body of theoretical and empirical research [28,52–59]. One of the first and most significant contributions in this field is Gibrat's Law [17], which states that the growth rate of an individual firm in a specific period is independent of the firm's growth in previous periods. Consequently, there will be no convergence process within industries, and thus, no predictable differences in growth will exist. Instead, growth is regarded as a pure stochastic phenomenon resulting from the cumulative effects of many factors acting randomly. This implies that the chances of growth or shrinkage of individual firms depend on many factors, including the quality of firm management, efficient organizational structure, the economic environment of the firm, product diversification, successful innovation, level of profitability, technological opportunities, etc. Still, growth from these factors cannot be predicted ex-ante since they are distributed randomly across firms [60]. Gibrat's Law has been a cornerstone in firm performance literature because of its ability to provide a compelling explanation of the observed heterogeneity in firm size within industries [57,61].

However, a large number of studies on the dynamics of firm size and performance have shown inconsistent conclusions. Early studies based on small samples of well-established, mature, and large firms tended to confirm the Law [53,62,63], in harmony with the prevailing dynamic growth pattern observable in most industrial sectors at that time. Later studies [52,56,57,64–67], using databases and more sophisticated statistical techniques, challenged the validity of previous results. Most of them concluded that Gibrat's Law fails to hold because firm growth rates and variance tend to fall with size. Scholars agree that Gibrat's Law is better suited to describing the growth process of relatively large and mature firms that have reached a minimum efficiency scale, not for the whole size distribution in which smaller firms operate just below this threshold [68,69].

More recent studies move from employing data and econometric corrections for explaining the varying results to a new strand of analysis where the basic Gibrat's model is modified to validate Gibrat's Law. One example is Lotti [20], who uncovered a convergence towards Gibrat's behavior and reconciled the different results described above by considering the role of market selection and learning in reshaping a given population of firms through time. Fotopoulos and Giotopoulos [15] found that medium, large, and old Greek manufacturing firms exhibit growth patterns consistent with Gibrat's Law. Daunfeldt and Elert [50] revealed that the more disaggregated the data analyzed, the more likely Gibrat's Law was to be confirmed. Additional studies move beyond Gibrat's Law to empirical studies of performance sustainability that incorporate firm-specific and environmental factors [59,70,71]. Our research expands this latter strand of research by proposing a characterization of firm growth dynamics wherein the sustainability of firm performance depends not only on current and past firm size but also on environmental shifts caused by innovation.

2.2. Innovation and Firm Growth in Natural Resource Industries

Innovation is a determinant of firm growth that has received much attention [28,69,71–73]. Most studies suggest that small firms in innovative industries perform better than large firms. Those results are consistent with both Schumpeter's early work [74], in which he argued that it was the entrepreneur who was the critical driver of innovation, and in industrial organization literature, in which smaller firms are considered to be more willing to challenge the status quo, and therefore, are more innovative [75,76].

However, the relationship between innovation and performance varies along the industry life cycle. Under the classical pattern of the relationship between innovation and a product's stage of development proposed by Utterback and Abernathy [37], in mature industries, production processes become predominant over time. Large firms benefit from economies of scale and scope, implying that small firms are likely to exhibit lower performance [77,78]. Thus, while small firms may be able to occupy a niche, their expansion may be constrained by structural properties of the industry, such as high capital intensity.

Natural resource industries are mature markets based on commodities, offering scarce options for product differentiation and product innovation, so the path to growth that small firms have is severely curtailed [29]. Moreover, in natural resource industries, in-house innovation requires vast amounts of capital, while potential benefits are marginal, so suppliers often develop innovative strategies [79,80], as they have greater incentives to develop a solution for multiple customers. Additionally, the diffusion of process technology permeates all firms in the industry [81], and consequently, the state-of-the-art technology systems and equipment are available to small and large firms alike. In this context, technological knowledge and innovation capabilities are not likely to be a key feature affecting the sustainability of performance [82].

Similarly, other factors that determine the rate of innovation adoption and performance identified in the strategy literature, such as organizational routines [83], capabilities and internal resources [84,85], customer demand [45,86], network effects [87], and information contagion [88], are not considered in natural resource industries because there is little chance to offer differentiated products to customers. Thus, with some exceptions [89], the primary option to effectively compete in natural resource industries is to adopt incremental innovations and increase productivity strategically. In the next section, we uncover how incremental innovation alters firm performance.

2.3. The Effect of Incremental Innovation

Much of the literature on innovation and management focuses on radical, disruptive innovation [45,90–92]. Incremental innovation, by contrast, has received less attention, with few exceptions [47,48,93–95]. Contrary to the idea of radical and disruptive innovations, incremental innovation is a common and dominant form of innovation based on minor system refinements and extensions of established processes and designs [96,97]. Moreover, incremental innovation has significant effects [93,98], enhancing product and process performance and lowering costs, thus enabling capturing the value generated by radical innovations. Incremental changes are not only the most common form of innovation characterized by long and stable periods of incremental innovations [99,100], but the cumulative effect of numerous incremental innovations also accounts for the majority of technical progress in the industry [101,102].

Incremental innovations are defined as conscious, pre-defined concepts of creating and capturing continuous value, and are the most common form of innovation [103]. Synonyms of incremental innovation are technology regime [96], competence enhancing breakthroughs [99], sustaining technologies [104], and evolutionary change [105]. Disruptive and incremental innovations are intimately connected; they represent the two phases of the innovation cycle. The cycle starts with an era of ferment, characterized by high uncertainty, with numerous innovations trying to build demand. The era of ferment ends with the emergence of a dominant design, a single architecture that establishes dominance in a product class [106,107] and enables firms to design standardized and optimized parts and processes for volume and efficiency [106,108], creating learning economies and dramatic decreases in product and process costs. Once a dominant design is adopted, customers must incur switching costs, economies of scale are the determinant to gain efficiency, and future innovations consist of incremental improvements [101,103]. The focus of competition shifts from higher product performance to lower cost via standard operating procedures, mainly through incremental process innovation. The era of incremental innovation persists until it is ended by another disruptive innovation [99,106,109].

During periods of incremental innovation, firms use existing know-how as a platform for adopting small changes [99]; in contrast to adaptation processes observed in radical innovations, firms do not need to abandon existing know-how and acquire an entirely new set of capabilities [45,97,99,110]. In other words, incremental innovation primarily affects the efficiency of existing processes and not the array of new products and processes [111], as in radical and disruptive innovations. Thus, in the presence of incremental change, there is no dilemma in choosing the older or the new technology since advances always increase the innovation and efficiency of the existing technological order. According to this argument, the market leaders, the firms that possess the know-how and resources, usually larger firms, are most likely to build on that expertise [112] and have better performance. Larger firms are better able to acquire new knowledge, cope with incremental change [48,95,113], and are more likely to invest in incremental innovation [114,115]. It is worth noting that, additionally to the advantages large firms possess in the specific setting of incremental innovation, in a broader context, they do tend to have many competitive advantages over smaller firms just by their size, based on the possession of relevant resources and capabilities such as more extensive market connections, better access to capital markets, and more significant internal funds [116,117]. The larger firms also have the advantage of industry competitive isolating mechanisms as described by industrial organization literature, such as economies of scale and entry and exit barriers [118]. As a consequence, large firms may experience better performance than small firms. In this sense, we argue that large firms present better performance sustainability than small firms before an incremental innovation (Hypothesis 1):

Hypothesis 1 (H1). *In natural resource industries, large firms have better performance than small firms before an incremental innovation.*

However, even if the skills, knowledge, and routines embedded in the organization that contribute to accountability and reliability are not completely rendered obsolete in the presence of incremental innovation [41,86,97,119], the physical assets associated with irreversible investment decisions in the form of exogenous sunk costs [120] may become outdated and inefficient, or just undermine the value of existing product lines [121], inhibiting adaptation. Natural resource firms, especially, face the dilemma of adopting incremental innovation in new processing technologies embracing more efficient processes at a high cost or staying with the current technology, eliminating the need for asset reconfiguration and capability adaptation activity. Furthermore, incumbent firms may suffer strategic myopia caused by the influence of complementary assets in perceiving the most promising technological direction [122], creating temporary strategic inertia. Therefore, smaller firms can enjoy higher strategic, technical, and financial flexibility due to lower assets and costs of output adjustment, even if their relative percentage of marginal costs are higher than those of larger firms [123,124]. They can also adopt incremental innovations faster and therefore, present higher performance. As such, we claim that small firms present better performance sustainability than large firms after an incremental innovation (Hypothesis 2):

Hypothesis 2 (H2). *In natural resource industries, small firms have better performance than large firms after an incremental innovation.*

The apparent contradiction of these two divergent theories, one supporting the know-how and resources of larger firms as the key drivers for performance, and the other theory supporting the flexibility of smaller firms, is explained by taking as a reference an event of significant incremental innovations. We argue that before a significant incremental innovation, larger firms grow faster, taking advantage of their know-how and resources since the efficiency of their assets has not been affected. However, after a significant incremental innovation occurs, larger firms, due to the high integration of processes, may delay process adaptation at risk of process obsolescence and, therefore, efficiency loss and economic decay. By contrast, smaller firms can exploit their flexibility and adapt faster to the change, consequently generating higher growth rates.

3. Data and Research Methodology

3.1. Data: The Pulp and Paper Industry

For investigating the sustainability of firm performance and the forces behind it in an incremental innovation era, we chose the pulp and paper industry (P&P) in the United States during the period 1978–1987, around an incremental process innovation event: the development of integrated process control systems based on microprocessor technology. The P&P industry is based on three primary activities: cultivating forest resources, producing pulp (by extracting cellulose fibers), and producing paper and board products. Pulp is the primary raw material for paper production. Papermaking involves removing cellulose from the lignin matrix in wood and forming those fibers into a web of paper. Formally, pulping is the process by which the cellulose fiber is extracted from the wood, and papermaking is the process that transforms the pulp into paper. Several characteristics favor the selection of this empirical setting.

Paper is among the most capital-intensive manufacturing industries [125]. Producing pulp and paper competitively requires significant scale economies and, thus, large amounts of invested capital in physical assets, which are usually associated with irreversible investment decisions. This level of capital expenditure needed in these processes makes the pulp and paper industry an excellent context for studying the effect of incremental innovation on performance sustainability.

Pulp and paper are homogeneous products, characteristic of a natural resource industry where incremental process innovation is predominant in the search for process efficiency. Economies of scale are achieved through high sunk costs, as it is one of the world's largest and most capital-intensive sectors when measured as average investment per employee [126]. Currently, its global annual revenue exceeds USD 500 billion on more than 300 million tons of products, a third of which is attributable to the United States, the ninth-largest manufacturing sector.

The P&P industry exhibits persistently high heterogeneity in size, with firms varying from small, single-product firms with less than 2000 tons/year capacity, to very large and diversified firms with an annual production capacity of more than 12 million tons (more than 6000 times larger than the smallest firm). However, the P&P industry has undergone a transformation that has changed its size distribution and increased its concentration at the global level [127,128]. While in 1978, the top 20 firms produced 25% of total output, in 2000, this had risen to almost 40%. In the US, the world's largest P&P producer and consumer, the number of firms has decreased from 300 in 1970 to 234 in 2000, while average production capacity has increased from 187,000 to 434,000 tons.

Consumption in the P&P industry grows linearly [129], but productivity increases exponentially through continuous incremental process innovations. These technological changes enabled meaningful increases in production scale and productivity. Still, since the state-of-the-art of paper machines have become increasingly prominent, firms have incurred irreversible investments, resulting in substantial jumps in capacity [128] at increasingly high sunk costs, thus decreasing technological and financial flexibility.

A Significant Incremental Innovation in the Paper and Pulp Industry

The primary disruptive innovations that took place in the P&P industry were the invention of the first paper-making process in the first century AD in China, the creation of the first paper machine at the end of the 18th century, and the introduction of wood as raw material in substitution of other natural fiber products such as rags, straw, waste paper, and manila stock [130] at the end of the 19th century. Therefore, most of the evolution of the industry has been based on incremental process innovations, such as improving the effective utilization of wood fiber, installing more energy-efficient processes, and raising the unit size of the paper and board machine. When it was no longer feasible to augment the width of the machine, the increasing production could be achieved only by improving the P&P machines' operating speed [131–133]. This improvement in machine speed was possible thanks to technological advances. In 1945–1955, instrumentation techniques and process indicators were developed. The first process computers were adopted in the 1960s, and in the 1970s, analogical differential drives were replaced by electric drives [82]. The most significant increase in machine speed occurred in the mid-1980s, with the development of integrated process control systems based on microprocessor technology (see Figure 1). The paper machine operation speed technology frontier represented in Figure 1 shows a discontinuity in 1982 due to the introduction of an incremental innovation: the integration of production control systems based on microprocessors. The structural discontinuity in 1982 was verified using a Chow test. The period under study, 1978–1987, considers five years before and five years after the innovation. Thus, the evolution of the P&P industry in the 1980s provides an optimal setting for testing our hypotheses.

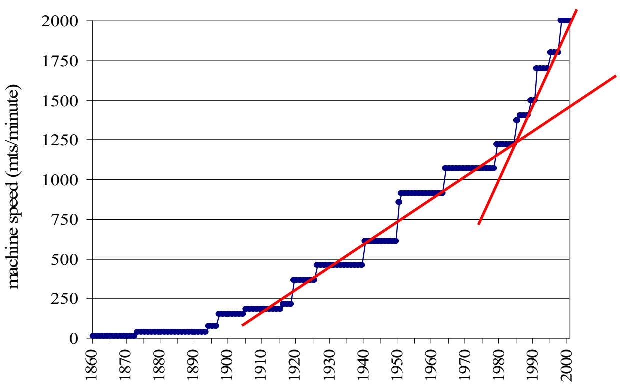

Figure 1. Paper Machine Operation Speed Technology Frontier, 1860–2000. Source: Author's elaboration from Beloit Paper Machine List. The red lines' cross point indicates a significant change in paper machine operation speed, i.e., a significant incremental innovation.

3.2. Sample Design and Data Collection

We obtained our primary firm-level panel data for the US P&P industry from three sources. The first database was gathered from the Forest Products Laboratory (FPL) housed at the US Department of Agriculture in Madison, Wisconsin, in collaboration with the University of Wisconsin–Madison. This dataset contains estimates of the annual production capacity for all mill locations in the U.S., in which 13 principal paper, paperboard, and market pulp products were produced during our sample period. We complemented missing information from a second source containing company reports from the 100 largest U.S. P&P firms, published annually by Scandinavian Pulp & Paper Reports (https://www.fisheri.com, accessed on 7 March 2011). With the information gathered from these two sources, we built an unbalanced panel with 2801 firm-year observations for the 567 firms in the database. The third firm-level source included corporate and financial data from public P&P companies obtained from Compustat, also called S&P Capital IQ, a comprehensive market and corporate financial database covering mainly publicly traded companies worldwide. From Compustat, we collected 449 data files from 79 (large only) firms. The sampling process is summarized as follows: First, we identified the incremental innovation in the P&P industry (see Figure 1). It took place in 1982, with the integration of production control systems based on microprocessors in paper machine technology Second, we collected data from the mentioned data sources five years before and after the incremental innovation.

Aggregated economic data, gross domestic product growth (GDP), was obtained from the Maddison-Project dataset (Extracted on 21 October 2021 from https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2020) described in Bolt and van Zanden [134]. Data on paper machine speed are based on the Beloit Paper Machine List (Extracted on 15 April 2019 from http://www.facetspro.com) containing the technical specifications of 968 machines manufactured by Beloit between 1862 and 1999. Beloit Corporation, previously Beloit Iron Works, was one of the world's leading manufacturers of paper technology until it went bankrupt in 1999. Most of these innovations were developed by suppliers since the pay-off required to justify inside innovation is large while potential benefits are marginal.

3.2.1. Dependent Variable

We measure firm performance as firm growth. Firm growth is an essential performance measure of a competitive and sustainable firm [2,4,12,69]. Given the need for more agreement in the management literature about the measures that would unequivocally quantify and evaluate firm growth, we selected three different indicators: production capacity growth [28], sales growth [26], and number of employees growth [135]. All of them will serve to have three different performance measurements and test the effects of incremental innovation on firm performance sustainability in three different panel data. In the first panel data, we use three-year firm production capacity growth as the dependent variable, indicating a firm's multiple-year capacity for growth. We define three-year growth as the three-year difference of the natural logarithm of total firm production capacity. In the second and third panel data, we use as dependent variables the three-year difference in firm sales and the three-year difference in the natural logarithm of total number of employees, respectively. Production Capacity is extracted from the FPL database, whereas sales and number of employees are extracted from Compustat.

3.2.2. Main Covariates

We use two variables for determining growth: size and age, lagged three periods, accounting for the setup time needed in natural resources industries from the decision to invest, to the adequate time when investments are implemented. We have, for each company, the number of years of existence (age) and the firm size. Size is measured through three different variables: production capacity, sales, and number of employees [26,28,135].

Firm age is an important covariate variable explaining firm growth [64,136]. Recent studies confirm a causal relationship between age and firm performance through intermediating mechanisms such as routinization, accumulated learning, reputation, and organizational rigidity [13,137]. We define age as the difference between the current year and the firm's entry into the industry.

3.2.3. Control Variables

The level of diversification may influence the adoption of innovation in different manners. Chen [138] argues that firms with broader product lines are more sensitive to new opportunities and, for instance, to adopt various innovations. Opposing Chen, some scholars suggest that diversification creates information overload and loss of strategic control, so managers become shortsighted and risk-averse, reducing their incentives to adopt innovations. As a result of this factor, we control for the number of mutually exclusive products firms compete in (Diversification). We address product Diversification by counting the number of products in which the company competes.

Because rivalry levels affect competition and firm performance, we used a normalized Herfindahl index (Norm. Herfindahl) to capture the possible impact of industry concentration on firm growth. Additionally, the variable machine speed growth (M. Speed Growth) is designed to capture the potential impact of exogenous technological change in the P&P industry. It is computed as the triannual paper machine speed growth in 1970–2000 (we use triannual machine speed growth since technology jumps are discrete and last an average of 2–3 years in our sample).

Macroeconomic conditions also affect competitive and selection pressures since they alter resource munificence. Expansionary periods augment resource munificence, diminishing selection pressures, while recessions have the opposite effect. Therefore, we include the variable gross domestic product growth (GDP growth) as an additional control variable. GDP growth is computed as the annual growth rate of GDP per capita based on purchasing power parity in the United States. We expect this variable to be positively associated with growth.

We also control for the potential impact of the financial debt with the variable Leverage obtained from the Compustat database.

Finally, in the secondand third panel data, we introduce the dummy variable After Innovation, indicating those periods immediately after an innovation. This variable captures the effect of the innovation immediately after the event occurs. All control variables are lagged three periods, considering the implementation time of incremental innovation.

We summarize all the variables of the research model in Table 1.

Table 1. Sources of Information and Variable Descriptions.

Variable Name	Variable Type	Source of Information
Production Capacity Growth	Dependent	The Forest Products Laboratory (FPL) and Scandinavian Pulp & Paper Reports
Sales Growth	Dependent	Compustat
Employees Growth	Dependent	Compustat
Production Capacity	Main Covariate	The Forest Products Laboratory (FPL) and Scandinavian Pulp & Paper Reports
Sales	Main Covariate	Compustat
Number of Employees	Main Covariate	Compustat
Age	Main Covariate	The Forest Products Laboratory (FPL) and Scandinavian Pulp & Paper Reports
Diversification	Control	The Forest Products Laboratory (FPL) and Scandinavian Pulp & Paper Reports
Norm. Herfindahl index	Control	The Forest Products Laboratory (FPL) and Scandinavian Pulp & Paper Reports, Compustat
Machine Speed Growth	Control	Beloit Paper Machine List
GDP Growth	Control	Maddison-Project dataset

Table 1. *Cont.*

Variable Name	Variable Type	Source of Information
Leverage	Control	Compustat
After Innovation	Control	Calculated: value of 1 if the observation occurs after 1982, 0 otherwise

3.2.4. Summary Statistics

Tables 2–4 show descriptive statistics for the variables, one for each different size measure. The tables are computed using panel data for firms with three or more size observations during the sample period (1978–1987).

Table 2. Size variable: Production Capacity, gathered from FPL & Scandinavian P&P database.

Variables	N	Mean	SD	Min	Max	Correlations					
						(a)	(b)	(c)	(d)	(e)	(f)
(a) Production Capacity Growth	2327	0.0593	0.258	−1.989	1.952	1					
(b) Production Capacity	2327	4.308	1.672	0.642	8.709	0.157 ***	1				
(c) Age	2327	3.617	1.034	1.386	5.056	−0.0993 ***	0.0320 ***	1			
(d) Diversification	2327	1.851	1.694	1	12	0.112 ***	0.627 ***	0.135 ***	1		
(e) Norm. Herfindahl	2327	0.0186	0.00119	0.0164	0.0207	−0.0354 ***	0.118 ***	−0.0666 ***	−0.0139	1	
(f) M. Speed Growth	2327	0.0845	0.0701	0	0.150	−0.0268 **	0.0358 ***	−0.0128	−0.00839	0.375 ***	1
(g) GDP Growth	2327	0.0222	0.0250	−0.0281	0.0636	−0.0230 *	0.0195 *	−0.00678	0.00142	0.0587 ***	−0.231 ***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All firms with three or more size observations, 1978–1987.

Table 3. Size variable: Sales, gathered from Compustat database.

Variables	N	Mean	SD	Min	Max	Correlations						
						(a)	(b)	(c)	(d)	(e)	(f)	(g)
(a) Sales Growth	335	296.9	469.7	−685.8	3047	1						
(b) Sales	335	1389	1754	0	8603	0.732 ***	1					
(c) Age	335	3.920	0.822	1.386	4.949	0.117 ***	0.144 ***	1				
(d) Diversification	335	3.728	2.770	1	12	0.390 ***	0.528 ***	0.135 ***	1			
(e) Norm. Herfindahl	335	0.0185	0.00118	0.0164	0.0207	0.122 ***	0.354 ***	−0.0666 ***	−0.0139	1		
(f) M. Speed Growth	335	0.0822	0.0704	0	0.150	0.0343	0.139 ***	−0.0128	−0.00839	0.375 ***	1	
(g) GDP Growth	335	0.0213	0.0255	−0.0281	0.0636	0.0189	0.0514 *	−0.00678	0.00142	0.0587 ***	−0.231 ***	1
(h) Leverage	335	1.021	0.511	0.148	3.795	0.00107	0.00570	0.00433	−0.00713	−0.0890 ***	−0.0337	−0.0111

*** $p < 0.01$, * $p < 0.1$. All firms with three or more size observations, 1978–1987.

Table 4. Size variable: Number of Employees, gathered from Compustat databasebase.

Variables	N	Mean	SD	Min	Max	Correlations						
						(a)	(b)	(c)	(d)	(e)	(f)	(g)
(a) Employees Growth	314	−0.245	0.158	−0.756	0.683	1						
(b) Number of Employees	314	−4.642	0.299	−5.325	−3.768	−0.217 ***	1					
(c) Age	314	3.905	0.813	1.386	4.949	−0.0450	0.115 ***	1				
(d) Diversification	314	3.787	2.832	1	12	−0.0390	−0.104 ***	0.135 ***	1			
(e) Norm. Herfindahl	314	0.0186	0.00117	0.0164	0.0207	0.463 ***	−0.751 ***	−0.0666 ***	−0.0139	1		
(f) M. Speed Growth	314	0.0813	0.0705	0	0.150	0.238 ***	−0.438 ***	−0.0128	−0.00839	0.375 ***	1	
(g) GDP Growth	314	0.0213	0.0256	−0.0281	0.0636	0.0592 *	−0.101 ***	−0.00678	0.00142	0.0587 ***	−0.231 ***	1
(h) Leverage	314	0.997	0.480	0.148	2.637	0.0385	0.0351	0.00433	−0.00713	−0.0890 ***	−0.0337	−0.0111

*** $p < 0.01$, * $p < 0.1$. All firms with three or more size observations, 1978–1987.

3.3. *Research Methodology*

To expose the sustainability of firm performance, we analyze the temporal behavior of the dependent variable—firm growth. If the growth rate increases over time, we classify firm performance as sustainable. However, if firm growth decreases, then the performance is deemed unsustainable. To assess the sustainability of firm performance in an incremental innovation phase, we first fit a panel data linear model with production capacity growth (PCG) as the dependent variable and the following independent variables lagged three periods: production capacity (PC), age (AGE), normalized Herfindahl index (NHI), machine speed growth (MSG), diversification (DIV), GDP Growth (GDP), and the interaction term between production capacity and age. More specifically, we develop the following multifactorial regression model (Model 1):

$$PCG_{i,t} = \beta_0 + \beta_1 PC_{i,t-3} + \beta_2 AGE_{i,t-3} + \beta_3 NHI_{i,t-3} + \beta_4 MSG_{i,t-3} + \beta_5 DIV_{i,t-3} + \beta_6 GDP_{i,t-3} + \beta_7 PC_{i,t-3} AGE_{i,t-3} + \varepsilon_{i,t}$$

where $\beta_0, \beta_1, \ldots, \beta_7$ are the regression coefficients, and $\varepsilon_{i,t}$ denotes the measurement error term. This first panel data comprises data from the most extensive dataset, i.e., the FPL and Scandinavian P&P database, containing 567 large and small firms. We divide the sample into two periods, each of five years before and after an innovation, so that we can study the different behaviors of firm growth depending on size separately for each period.

One of the challenges of studying the sustainability of firm performance is the potential presence of several econometric problems that can bias the results, particularly heteroscedasticity and serial correlation. In our context, heteroscedasticity might arise from inequality in growth variances across firms of different sizes. Serial correlation might appear due to the overlapping multi-period growth, which may render least squares estimators inconsistent. We test for the presence of these potential problems with the Breusch–Pagan test for heteroscedasticity and a Wooldridge test for autocorrelation [139]. Since we observe evidence for both heteroscedasticity and autocorrelation of order one in all the panel data models, we follow Hansen [140] to fit the models using generalized least squares (GLS), accounting for the presence of AR (1) autocorrelation within panels and heteroscedasticity across firms [141].

Two more panel data linear models are analyzed. One of them uses sales growth (SLG) as the dependent variable, and the other, number of employees growth (EMG). These two last panel data employ the same independent variables as the first, but we substitute the size variable production capacity by sales (SL) in Model 2 and by Number of Employees (EM) in Model 3. The resulting balanced panel includes only 53 public, large firms. Because with this sample, there is no option to assess the differentiated effect of incremental innovation in small firms and the number of observations is small, we use the preferred method of adding the dummy variable After Innovation (AIN) instead of dividing the sample into two periods. We added one more variable from the Compustat database: leverage (LEV), lagged three periods, and the interaction terms between sales, number of employees, age, and after innovation. The resulting models are presented below:

Model 2:

$$\begin{aligned} SLG_{i,t} = {} & \beta_0 + \beta_1 SL_{i,t-3} + \beta_2 AGE_{i,t-3} + \beta_3 NHI_{i,t-3} + \beta_4 MSG_{i,t-3} + \beta_5 DIV_{i,t-3} + \beta_6 GDP_{i,t-3} + \beta_7 AIN_{i,t} + \beta_8 LEV_{i,t-3} \\ & + \beta_9 SL_{i,t-3} AGE_{i,t-3} + \beta_{10} AIN_{i,t} AGE_{i,t-3} + \beta_{11} SL_{i,t-3} AGE_{i,t-3} AIN_{i,t} + \varepsilon_{i,t} \end{aligned}$$

Model 3:

$$\begin{aligned} EMG_{i,t} = {} & \beta_0 + \beta_1 EM_{i,t-3} + \beta_2 AGE_{i,t-3} + \beta_3 NHI_{i,t-3} + \beta_4 MSG_{i,t-3} + \beta_5 DIV_{i,t-3} + \beta_6 GDP_{i,t-3} + \beta_7 AIN_{i,t} + \beta_8 LEV_{i,t-3} \\ & + \beta_9 EM_{i,t-3} AGE_{i,t-3} + \beta_{10} AIN_{i,t} AGE_{i,t-3} + \beta_{11} EM_{i,t-3} AGE_{i,t-3} AIN_{i,t} + \varepsilon_{i,t} \end{aligned}$$

where $\beta_0, \beta_1, \ldots, \beta_{11}$ are the regression coefficients, and $\varepsilon_{i,t}$ denotes the measurement error term.

4. Empirical Results

Tables 5 and 6 report the results of the panel data model used to analyze the sustainability of firm performance using production capacity growth as the firm performance measure (Model 1). We compare two periods: the 1978–1982 period, five years before the innovation observed in 1982 (Table 5), and the 1983–1987 period, five years after the innovation (Table 6). They show the GLS parameter estimation of the model with three-year growth as the dependent variable and different sets of covariates. Therefore, the sign of an estimated coefficient indicates the direction of the variable effect on firm growth, with a positive coefficient being related to more significant growth in the following three-year period (results are robust to different length growth calculations, producing coefficients similar in sign and significance). Since an R-squared statistic computed from GLS does not correctly represent the percentage of the total variation in the dependent variable due to the model [142], we use the Wald chi-squared test as an approximation for the goodness of fit.

Table 5. Pre-Incremental Innovation Period (1978–1982). Dependent Variable: Production Capacity Growth. Size as Production Capacity.

Variables	(1)	(2)	(3)
	Production Capacity Growth		
L3.Norm. Herfindahl	2.679 ***	2.316 ***	4.632 ***
	(0.467)	(0.532)	(0.708)
L3.GDP Growth	0.0246 **	0.0220 **	0.0107
	(0.0101)	(0.0112)	(0.0122)
L3.M. Speed Growth	0.0541 ***	0.0473 ***	0.0922 ***
	(0.00684)	(0.00793)	(0.0125)
L3.Diversification	0.00490 ***	0.000299	−0.00523 ***
	(0.00129)	(0.00194)	(0.00164)
L3.Age			0.0220 ***
			(0.00434)
L3.Production Capacity × L3.Age			−0.00894 ***
			(0.00125)
L3.Production Capacity		0.00795 ***	0.0486 ***
		(0.00192)	(0.00497)
Constant	−0.00411	−0.0259 ***	−0.160 ***
	(0.00765)	(0.00941)	(0.0215)
Observations	1212	1212	1075
Number of Firms	261	261	231
Degrees of Freedom Person Chi2	685	684	605
Wald Chi2	114.2	117.1	347.5

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, GLS with Panel-specific AR(1) correlation and heteroskedatic. All firms with 3 or more observations.

Table 6. Post-Incremental Innovation Period (1983–1987). Dependent Variable: Production Capacity Growth. Size as Production Capacity.

Variables	(1)	(2)	(3)
	Production Capacity Growth		
L3.Norm. Herfindahl	−2.418	−2.431	−3.329 **
	(1.774)	(1.737)	(1.614)
L3.GDP Growth	0.233 ***	0.238 ***	0.225 ***
	(0.0294)	(0.0297)	(0.0271)
L3.M. Speed Growth	−0.145 ***	−0.149 ***	−0.141 ***
	(0.0219)	(0.0218)	(0.0206)
L3.Diversification	0.000760	0.00157	0.00304 ***
	(0.00113)	(0.00129)	(0.000919)
L3.Age			−0.0500 ***
			(0.00727)
L3.Production Capacity × L3.Age			0.00539 ***
			(0.00138)
L3.Production Capacity		−0.00195	−0.0223 ***
		(0.00233)	(0.00612)
Constant	0.0973 ***	0.105 ***	0.303 ***
	(0.0340)	(0.0344)	(0.0499)
Observations	1142	1142	1054
Number of Firms	247	247	227
Degrees of Freedom Person Chi2	643	642	592
Wald Chi2	88.08	91.42	588.1

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, GLS with Panel-specific AR(1) correlation and heteroskedatic. All firms with 3 or more observations.

Results in Table 5 show that the estimated coefficient for production capacity before the incremental innovation is positive and significant at the 1% level. Additionally, the best-fitting model in Table 6 shows that for the time after the incremental innovation, the coefficient for production capacity is still significant at the 1% level, but it changes the sign, becoming negative. Thus, results strongly support significant incremental innovation affecting performance sustainability, giving a temporary advantage to small-sized companies relative to larger firms, confirming hypotheses 1 (H1) and 2 (H2).

Tables 7 and 8 represent the results obtained from the panel data containing the Compustat variables sales (Model 2) and number of employees (Model 3) as size measurements. Because the Compustat database considers only publicly traded companies, Tables 7 and 8 show the behavior of large firms exclusively. Results with the dependent variable Sales Growth are aligned with those obtained considering size as Production Capacity Growth, showing that large firms increase performance as they increase size (see Table 7). However, when we observe firm performance as the growth in the number of employees, large firms decrease performance as they increase size (see Table 8). A possible explanation for these mixed results is that measuring performance based on the number of employees takes into account additional effects, such as automatization, which could generate a misleading interpretation. Nevertheless, no matter which variable we use to measure firm growth, large firms show higher performance before than after innovation.

Table 7. Full Period 1978–1987. Large Firms only. Dependent Variable: Sales Growth. Size as Sales.

Variables	(1)	(2)	(3)	(4)
	Sales Growth			
L3.Norm. Herfindahl	16,456 ***	−4694	−6686	−6673
	(6378)	(8264)	(9119)	(9007)
L3.GDP Growth	336.9 ***	200.6 **	192.9	195.1
	(124.6)	(95.42)	(148.6)	(144.8)
L3.M. Speed Growth	−513.0 ***	−619.4 ***	−673.7 ***	−678.5 ***
	(86.42)	(108.6)	(119.5)	(118.2)
L3.Diversification	77.57 ***	16.62 **	13.99 *	14.55 *
	(7.540)	(7.444)	(8.348)	(8.257)
L3.Leverage	−0.0348	−0.0459	11.10	13.43
	(0.108)	(0.114)	(17.27)	(16.74)
After Innovation		10.81	9.248	5.535
		(22.53)	(25.38)	(25.03)
L3.Age			−0.0229	−4.949
			(18.68)	(17.31)
L3.Sales × L3.Age			−0.0401	−0.00932
			(0.0407)	(0.0210)
L3.Sales		0.265 ***	0.429 ***	0.302 ***
		(0.0296)	(0.166)	(0.0811)
After Innovation × L3.Sales		−0.0762 ***	−0.193	−0.0701 **
		(0.0268)	(0.144)	(0.0277)
After Innovation × L3.Sales × L3.Age			0.0297	
			(0.0341)	
Constant	−301.1 ***	94.60	131.7	150.3
	(116.1)	(144.0)	(172.9)	(168.6)
Observations	339	339	324	324
Number of Firms	41	41	39	39
Degrees of Freedom Person Chi2	251	248	234	235
Wald Chi2	213.4	428.8	283.8	289.9

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, GLS with Panel-specific AR(1) correlation and heteroskedatic. All firms with 3 or more observations.

Table 8. Full Period 1978–1987. Large Firms only. Dependent Variable: Employees Growth. Size as Number of Employees.

Variables	(1)	(2)	(3)	(4)
	Employees Growth			
L3.Norm. Herfindahl	28.30 ***	−49.98 ***	−43.77 ***	−39.70 ***
	(4.713)	(7.975)	(7.680)	(7.387)
L3.GDP Growth	−0.244 *	−0.533 ***	−0.502 ***	−0.484 ***
	(0.137)	(0.150)	(0.157)	(0.155)
L3.M. Speed Growth	0.988 ***	0.109	0.153	0.191 **
	(0.0679)	(0.0968)	(0.0954)	(0.0922)
L3.Diversification	−0.00292 **	−0.00827 ***	−0.00906 ***	−0.00812 ***
	(0.00134)	(0.00309)	(0.00297)	(0.00285)
L3.Leverage	−0.00483	−0.00839	−0.0962 ***	−0.0986 ***
	(0.00764)	(0.00603)	(0.0130)	(0.0126)
After Innovation		−0.190	−0.191	−0.166
		(0.221)	(0.215)	(0.215)
L3.Age			0.223 *	0.0353
			(0.116)	(0.0874)
L3.Number of Employees x L3.Age			0.0548 *	0.00706
			(0.0280)	(0.0199)
L3.Number of Employees		−0.342 ***	−0.525 ***	−0.330 ***
		(0.0273)	(0.117)	(0.0856)
After Innovation × L3.Number of Employees		−0.0498	−0.0142	−0.0458
		(0.0485)	(0.0498)	(0.0474)

Table 8. *Cont.*

Variables	(1)	(2)	(3)	(4)
	Employees Growth			
After Innovation × L3.Number of Employees × L3.Age			−0.00985 **	
			(0.00393)	
Constant	−0.772 ***	−0.851 ***	−1.602 ***	−0.906 **
	(0.0831)	(0.152)	(0.481)	(0.387)
Observations	316	316	304	304
Number of Firms	40	40	38	38
Degrees of Freedom Person Chi2	230	227	216	217
Wald Chi2	240.4	408.3	411.9	449

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, GLS with Panel-specific AR(1) correlation and heteroskedatic. All firms with 3 or more observations.

The empirical results are graphically displayed in Figure 2. Comparing firm performance before and after the significant process innovation, small firms show sustainable performance after the innovation event. In contrast, large firms exhibit sustainable performance before the incremental innovation. The effect is significantly stronger for small than large firms.

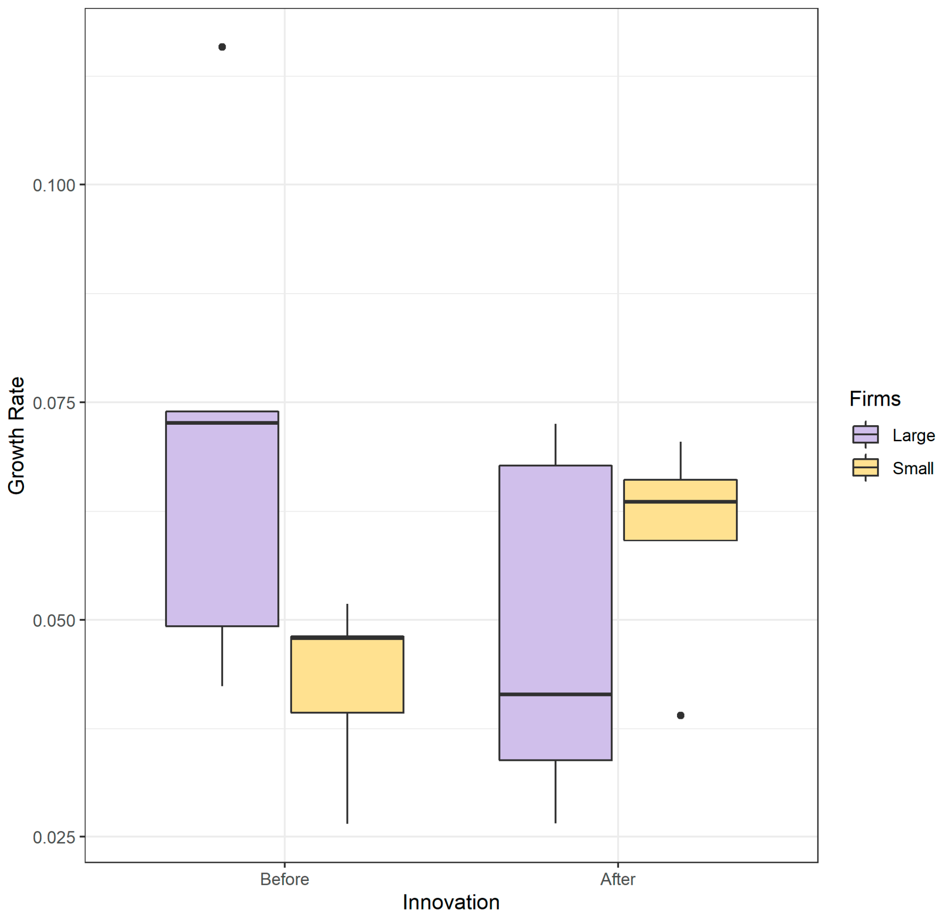

Figure 2. Growth Rate (Production Capacity Growth), Large and Small Firms, 1978–1987 (Box plot). Size Classification Criterium: public firms are considered large firms. The smallest public firm in terms of number of employees and production capacity is Badger Paper, with a manufacturing capacity of 72,700 annual metric tons of paper. Thus, all firms with a smaller production capacity are considered small firms; the rest are large firms.

5. Discussion and Conclusions

Studies in the firm performance literature show inconsistent results explaining the relationship between size and growth. In just the P&P industry, we find investigations that affirm that larger pulp and paper mills perform better than their smaller counterparts because they take advantage of their scale to achieve higher productivity [143]. These studies argue that smaller plants tend to perform better than large ones [144,145], and finally, there are scholars that find no growth–size relationship, i.e., paper mills that grow according to Gibrat's Law [146,147].

This paper contributes to clarify the mixed findings and to fill the gap in understanding the relationship between firm size and firm performance by introducing incremental innovation as a critical determinant of the forces affecting the sustainability of firm performance. Our study demonstrates that firm growth is not a "random walk" process and is not linear over time. Thus, even when Gibrat's Law is not assumed, it is incorrect to suppose that a unique performance–size relationship applies to the whole industry at any time, as many studies claim. Incremental innovation generates a discontinuity beyond its influence on process improvement, affecting firm sustainability at an industry level, generating a competitive opportunity for small firms and a performance decline for large firms.

Incremental change is the most common kind of innovation, and size is a critical organizational dimension when analyzing growth. However, there are few studies on how incremental innovation affects performance in an industry, even though a large body of literature focuses on radical, disruptive innovation. In this study, we theoretically argue that before a significant incremental innovation takes place, larger firms' performance is higher than that of smaller firms, supported by firms' resources and the isolating mechanisms of the industry. Nevertheless, with the advent of significant incremental innovation, smaller firms adapt faster to changes because of their strategic flexibility, presenting higher performance than larger firms. Empirical findings provide support for our theoretical claim. Factors explaining this argument lie in the sunk costs, complementary assets, and irreversibility of capital-intensive investments required in natural resource industries. Once an investment is made, new incremental innovations will comparatively reduce the efficiency of the processes in place, thus affecting performance. Our research adds to the literature on incremental innovation by confirming that incremental change is a potential game-changer that can impact competitive dynamics and industry structure [148,149]. The novelty of our study lies in the consideration of incremental innovation as an environmental factor, not a consequence, and in the introduction of a specific setting: natural resource industries. In these, contrary to previous research, smaller firms bringing about incremental innovations raise their chances of success [48].

Our results also introduce a new question: since large firms will benefit from the industry's competitive isolating mechanisms in the long term, how long does the temporary advantage small firms enjoy after an incremental change last? Data from the P&P industry suggests that large firms can catch up with small firms in seven years. However, we suspect that the length of the temporary advantage depends on the structural properties of the industry, such as the level of capital required for new investments, or the time needed to update specific internal capabilities and routines. Therefore, additional research is needed within P&P and in multiple industries to properly answer that question.

To achieve our results, we first had to overcome an important theoretical challenge since size generates alternative mechanisms of competitive dynamics. Size directly affects unit costs, providing a competitive advantage for larger competitors focusing on a single product. In natural resource industries, competitors are price takers: cost advantages are fundamental for performance. For instance, in periods of price volatility, which generates systematic cycles of excess capacity, size reduces unit cost and provides a competitive advantage, while excess capacity acts in the opposite direction. Periods of low prices particularly penalize those companies that have made the most significant investments. Therefore, size acts as a double-edged sword for larger competitors, producing cost advantages in good periods but cost disadvantages in periods of low prices.

Limitations and Implications

Although this study contributes to the understanding of firm competitive dynamics at the industry level and their effect on a firm's performance, we point out several limitations. First, we make generalizable claims valid for natural resources industries like oil or mining. However, these findings may also apply to service industries or sectors where competition is high, political intervention or regulation is not essential, investments are capital-intensive, or products are commoditized. Second, our research focuses on incremental technological innovation, affecting processes. Other non-technological incremental innovations, such as organizational or marketing innovations, were not considered. Thus, our study opens avenues for further research exploring the sustainability of firm performance in the presence of different types of incremental innovation in other industries.

The managerial consequences of our study will be helpful in guiding the strategies of firms in capital-intensive industries when considering optimal size. Our results question the sustainability of a niche strategy and the convenience of being large. For small companies, the imperative is to grow. However, for large companies, this imperative should be a careful balance to avoid over-investments in scale and unnecessarily broad product portfolios.

Finally, for practitioners, we draw two final implications from this research. First, because incremental change does frequently happen, even in mature industries, managers should consider developing competencies that reduce the adaptation period, such as R&D capabilities or permanent support contracts with suppliers, especially in industries where the speed of technological change is high. In a world of fast technological evolution, the ability to direct incremental innovation affects profitability and the firm's sustainability. Second, when evaluating a capacity increase, it is key to consider the relative productivity fall, compared to competitors, as a result of commitment to a particular technology. Therefore, strategic decisions should look for an equilibrium between obtaining economies of scale and the potential for consequent productivity loss over time.

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