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TECHNOLOGICAL INNOVATION TOWARDS SUSTAINABILITY: learning from both success and failure

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Resumo
O objetivo deste estudo é compreender como determinantes específicos influenciam o desempenho da eco-inovação no setor corporativo. O método utilizado foi o estudo de caso múltiplo. O artigo analisa quatro casos de empresas multinacionais em diferentes setores: bens de consumo, etanol, química e transporte. Os resultados evidenciam como diferentes instrumentos de política pública e ambientes institucionais contribuem com o desempenho da eco-inovação. Demanda do mercado e regulação foram os determinantes mais relevantes que influenciaram positivamente o desenvolvimento e desempenho da eco-inovação. Por outro lado, a falta de incentivos governamentais para reduzir o custo privado da eco-inovação, e a ausência de subsídios para incentivar o aumento da demanda foram determinantes para o baixo desempenho. Uma das principais contribuições do estudo é baseada na compreensão mais aprofundada dos determinantes específicos no desempenho de eco-inovações em setores específicos. O artigo discute a teoria à luz de casos empresariais reais, e almeja contribuir com a formulação e implementação de políticas públicas orientadas para o fomento da eco-inovação no setor empresarial, com vistas ao desenvolvimento sustentável e viabilidade de iniciativas que contribuam com a mitigação dos impactos ambientais, especialmente aqueles relacionados à mudança climática.

Abstract
The objective of this study is to understand how certain determinants influence the performance of eco-innovation in different companies. It was used the multiple case study method. The article analyzes cases of multinationals companies in different sectors in Brazil: consumer goods, ethanol/energy, chemical and transportation. The comparative analysis presents how different public policy instruments and institutional environments are driving the performance of eco-innovation. Market demand and regulatory push were the most relevant determinants that influence positively the development and the performance of eco-innovation. On the other hand, the lack of government incentives to reduce the private cost of eco-innovation, and the absence of subsidies to encourage the increase of market demand were determinants for the failure of the initiatives. One of the major contributions of the study is based on a deeper understanding of specific determinants on the performance of eco-innovations. The article provides some insights that may contribute to the formulation and implementation of public policies focus on eco-innovation in the corporate sector, aiming at the sustainable development and the feasibility of initiatives that contribute with the mitigation and adaptation to environmental impacts, especially those related to climate change.

Palavras-chave: eco-innovation; green innovation; sustainable strategy

1. Introduction

The contemporary world uses fewer materials to produce the same unit of wealth. However, the pressure on resources continues to grow in absolute terms due to the magnitude of the growth in production, specially related to excess of consumption and the use of natural resources. Modern societies have not yet succeeded in generalizing innovation systems aimed at sustainability able to balance the size of the economic system and the limits of ecosystems. It is necessary to establish a new global governance, which considers the limits of ecosystems and the reduction of inequalities as central factors for public and private economic decisions (ABRAMOVAY, 2012).

Brazil is a country with a vocation for sustainability due to its natural resources and biodiversity, and has great potential to contribute to mitigate the consequences of the climate change. Unlike countries with mature economy, Brazil has an industrial and technological infrastructure that is still under development, allowing the adoption of new technologies to meet the requirements of sustainability, without demanding many infrastructure retrofits (KRUGLIANSKAS and PINSKY, 2014).

This context demands the formulation of environmental public policies based on systematic actions that consider complex contemporary issues of sustainability and the diversity of players involved in this process. The traditional model of environmental regulation, based on pollution control, has limits, including shortcomings in the solution of some problems, such as the saturation of the air quality in urban centers, and the failure to consider certain types of problems in its scope, such as the climate change (RIBEIRO and KRUGLIANSKAS, 2011).

The global challenges to be faced with the climate change publicly emerge with more emphasis in view of the results of the UN Climate Change Conference (COP 20) held in December 2014 in Lima, Peru. The guidelines discussed for the new global climate agreement, replacing the Kyoto Protocol, involves 195 countries and focused on four aspects: 1) industrialized countries recognize their greater responsibility to reduce CO_2 emissions, and developing countries should also establish reduction targets based on the principle of common but differentiated responsibilities; 2) until March 2015 all countries should submit their emission reduction targets with the horizon set in 2030, though the base year has not been defined; 3) the countries must submit adaptation targets; 4) developed countries should offer compensation to poor countries that suffer the impacts of climate extremes (UNFCCC, 2014).

The emission reduction and adaptation targets of the countries should guide the transformation of societies, including profound changes in the energy sources, in production systems and in the consumption of the world population. This context will require sustainability-oriented technological innovations, availability of venture capital and should rely on the leadership of companies, supported by public policies consistent with the challenges posed by climate change and the development of a new low-carbon economy.

The understanding of the dynamics of sustainability-oriented innovation is incipient in the field of business administration. In general, the knowledge base on eco-innovation is little studied, and one of the reasons is that sustainable innovation does not belong to any official sector (KEMP and PEARSON, 2007). The Brazilian academic research on the topic is new, but has been gradually expanded with studies conducted in several sectors, including the energy sector (CARVALHO and BARBIERI, 2010), industrial sector (MEDEIROS et al, 2012; GOMES et al, 2009), agribusiness (OLIVEIRA and IPIRANGA, 2011), chemical (GIOVANNINI and KRUGLIANSKAS, 2008; MENEZES et al, 2013), in addition to conceptual articles (BARBIERI et al, 2010; GONÇALVES-DIAS et al, 2012). Most articles published by Brazilian scholars are case studies or theoretical in nature, making it impossible to generalize the results (YIN, 2005).

Considering that a new low-carbon economy is focused on the minimization of social and environmental impacts, which pose a threat and, at the same time, an opportunity for the companies, this research seeks a deeper understanding on the dynamic of eco-innovation in the corporate sector, and how this knowledge can contribute to the formulation of public policies. Therefore, the main purpose of this study is to understand how certain determinants influence the performance of eco-innovation in different companies.

2. Theoretical Background

2.1 Innovation and Sustainability

Innovation is one of the main factors that influence the economic growth of countries, being essential for the generation of competitive advantage in highly turbulent environments. The ability to innovate is directly related to the competitive ability of an individual, company, region or country (NEELY and HILL, 1998; IBGE, 2013).

The diffusion of new technologies is essential for the sustained growth of results and increased productivity, and is defined as the way an innovation is disseminated from its first application to another country, region, industry, market or company. Innovation processes and their economic impacts are still deficient (OECD, 2005), considering, for example, the difficulties in the diffusion and the low rate of adoption of key technologies in critical sectors with considerable potential to contribute to the development of sustainable solutions, such as the chemical, sugar and energy, transportation and consumer goods sectors.

Among the main external barriers to innovate are the lack of infrastructure, deficiency in training and education, lack of adequate legislation and qualified professionals. Internal barriers include organizational arrangements and rigid procedures, formal and hierarchical communication structures, conservatism, conformity and lack of vision, resistance to change and to take risks (NEELY and HILL, 1998).

The technological product and process (TPP) innovation is defined in the Oslo Manual by the Organization for Economic Cooperation and Development (OECD) as:

> [...] implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organizational, financial and commercial activities (OECD, 2005, p. 31).

Technological innovation towards sustainability stands out as an alternative to contribute to the construction of a new capitalism approach that considers the unity between society and nature, economics and ethics (ABRAMOVAY, 2012), with its many benefits aimed to the corporate sector, including differentiation, development of new products, processes and services, access to new markets, efficiency in the value chain, compliance, cost and risk reduction (PORTER and VAN DER LINDE, 1995; HART and MILSTEIN, 2004; SCHOT and GEELS, 2008; NIDUMOLU, PRAHALAD and RANGASWAMI, 2009; FRONDEL et al, 2010).

The concept of sustainability-oriented innovation is comprehensive and receives different names in the literature, such as sustainable, green, eco or environmental innovation. This paper considers the concept of eco-innovation that was developed based on the definition of innovation of OECD:

> [...] eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives (KEMP and PEARSON, 2007, p. 7).

Environmental improvement is the central aspect of this definition, from the perspective of result, and not as a goal established prior to its development. The purpose of an eco-innovation can be, for example, the reduction of costs through the efficient use of natural resources (KEMP and PEARSON, 2007; HORBACH, RAMMER and RENNINGS, 2012).

2.2 Determinants and Obstacles of Eco-innovation

Among the main determinant factors of a corporate innovation are market share and profitability. Therefore, the analysis of the conditions of specific sectors for the development of an eco-innovation is relevant, since companies only make investments in initiatives involving innovation with perceived value and potential return (HORBACH, 2005).

Eco-innovation covers three types of changes aimed at sustainable development: technological, social and institutional innovation (RENNINGS, 2000). This study focuses on technological eco-innovation. Although the technological change is not a sufficient condition for the transition to sustainability, it is one of the main factors that contribute to the reduction of environmental impacts in production processes. Sustainability-oriented technological changes are driving by social, economic and institutional factors, and by the specific characteristics of innovation, such as the degree of complexity of its implementation, compatibility with the existing production system and the availability of capital (DEL RIO GONZALEZ, 2009).

Several studies have analyzed the determinants of eco-innovation, including its drivers and barriers (RENNINGS, 2000; HORBACH, 2005; KEMP and PEARSON, 2007; HORBACH, RAMMER and RENNINGS, 2012). According to these studies, the main determinants of eco-innovation can be classified into four broad groups: company specific factors, technology, market demand and regulatory push. Table 1 presents a set of eco-innovation indicators that can be considered independent variables in studies of this nature.

Table 1: Determinants of Eco-innovation

Technology	Product quality; material efficiency; energy efficiency; technology path dependency
Market Demand	State, consumer, company and institution; social awareness of the need for clean production; sustainable consumption; fitting time window; cost reduction; image; market share; competition (number of competitor, concentration of the market, monopoly); new markets; influence of stakeholders
Regulatory Push	Environmental policy (incentive based instruments or regulatory approaches; institutional structure (innovation networks; political opportunities for environmentally oriented groups); international agreement or convention; patent legislation; standards; expected regulation
Company Specific Factors	Inputs: financial resources (including availability of risk capital) and R&D expenditures supporting eco-innovation; technological capability; existence of environment management system, practices and tolls; high qualified employees with skills to develop eco-innovation; environment patents

Source: Adapted by the authors from Rennings (2000), Horbach (2005), Kemp and Pearson (2007), Horbach, Rammer and Rennings (2012).

The government influence is a major determinant of corporate eco-innovation. According to the Porter Hypothesis, there is a positive relationship between the level of requirements of an environmental regulation and the competitiveness of companies that benefit from the reduction of cost and risk through innovation and the compliance with the regulation concurrently. The expected results are the reduction of environmental impact, the development of products with better quality, and the increased international competitiveness of enterprises (PORTER and VAN DER LINDE, 1995). On the other hand, the regulatory force may be associated with several other factors that motivate eco-innovation, such as the technological capacity (OLTRA and JEAN, 2009) and the environmental targets focused on cost reduction (FRONDEL, HORBACH and RENNINGS, 2008).

The institutional context, the environmental regulation, the rigidity in the regulatory control, as well as the diversity of economic incentive instruments should be analyzed in eco-innovation studies (KEMP and PEARSON, 2007; HORBACH, 2008). Regulation combined with subsidies are determinants due to the fact that many eco-innovation initiatives involve risks and their benefits are difficult to internalize, making it difficult to justify the investment in the corporate sector (VICTOR, 2011).

Innovation policies and environmental policies must be coordinated (RENNINGS, 2000). Innovation policies play an important role in the development of eco-innovation due to the existence of externalities that lead to market failures, especially in pioneering projects, because they are expected to be successful and disseminated on the market (HORBACH, 2005). As for environmental policies, these are essential to establish the limits of use of ecosystems compatibly with the current economic development system (ABRAMOVAY, 2012).

Governments may encourage eco-innovation through measures that reduce the private cost in the development of projects (technology-push) or that increase the private payoff with the success of the innovation (demand-pull). Government sponsored R&D, tax credits for companies to invest in R&D, enhancing the capacity for knowledge exchange, support for education and training, and funding demonstration projects are examples on how technology-push public policies can reduce the cost to companies of eco-innovation initiatives. On the other hand, intellectual property protection, tax credits and rebates for consumers of new technologies, government procurement, technology mandates, regulatory standards, and taxes on competing technologies are some approaches based on demand-pull public policies (NEMET, 2009).

3. Methodological Aspects

The main purpose of this study is to understand how certain conditioning factors influence the performance of eco-innovation. The following research question guided the data gathering and the analysis of results: Is there a relationship between determinants and the performance of eco-innovation?

It is a descriptive and qualitative research using the multiple-case study as the method chosen. The justification of the method is centered on the contemporaneity of the subject, allowing an in-depth analysis in an area where there are few theories or a poor set of knowledge (COLLIS and HUSSEY, 2005; YIN, 2005). The choice of cases, by convenience, considered the following criteria: 1) recognized innovative and large companies; 2) different sectors of operation, seeking contrasts in the comparison; 3) relevance of the sector in light of the environmental impacts of the product/process. Table 2 shows the four cases chosen. There are two Brazilian multinational companies and two Brazilian subsidiaries of Swedish and American origin.

Table 2: Case Studies

Company	Sector	Core Business	2013 Revenue (mi)
Grupo Sao Martinho	Sugar and Ethanol	Sugar, ethanol, energy and byproducts. One of the largest Brazilian producers of sugar.	R$ 2.047 (USD 779)
Kimberly Clark Brazil	Consumer Goods	Leader in consumer goods in Brazil. Personal care, consumer tissues and professional (health care and commercial business	R$ 3.500 (USD 1,332)
Oxiteno	Chemistry	Brazilian chemical company that operates worldwide, leading manufacturer of surfactants and specialty chemicals.	R$ 3.278 (USD 1,248)
Scania Brazil	Transportation	Trucks, buses and coaches, engines and services, including banking in Brazil.	NA

Source: Elaborated by the authors, 2014.

The units of analysis of the research considered the main eco-innovation of each company, which has been implemented for more than two years in Brazil. The focus of analysis centered on the identification of the determinants of the eco-innovation and their relationship with the performance of the product/process. Table 3 shows the eco-innovations analyzed.

Table 3: Research Unit of Analysis – Eco-innovation

Company	Eco-innovation Project	Category
Grupo Sao Martinho	Sugarcane harvest mechanization	Process
Kimberly Clark	Neve Naturali toilet paper	Product
Oxiteno	High performance solvent system	Product
Scania	Ethanol bus	Product

Source: elaborated by the authors, 2014.

The data collection technique included personal and in-depth interviews with executives from companies in the areas of innovation, sustainability, research and development. The interviews were conducted in the period between March 2013 and December 2014 at the offices of the companies in Maua (Oxiteno), Mogi das Cruzes (Kimberly-Clark), Sao Bernardo do Campo (Scania) and Sao Paulo (Grupo Sao Martinho). The interviews were recorded and transcribed. The document analysis was conducted through the reading of sustainability reports and information available on the companies' websites, laws and decrees related to each sector and to the eco-innovation analyzed. The script of the interviews was developed based on four broad factors: technological change, market demand, regulatory push and company specific factors (RENNING, 2000; HORBACH, 2005); KEMP and PEARSON, 2007), HORBACH, RAMMER and RENNINGS, 2012). Each one of these factors brings together a set of indicators (independent variables), previously described in Table 1, which guided the collection of the primary data.

Although the focus of the analysis of an eco-innovation is primarily centered on environmental aspects, Horbach (2005) argues that the process or innovation system should be analyzed as a whole, including its determinants, the description of the innovation (product, service, process, organizational, end-of-pipe) as well as the environmental, economic and social impacts. The comparative analysis of primary and secondary data considered the four determinant factors of eco-innovation to guide the discussion of results. We developed an array of categories, where the evidences were classified with the support of a Microsoft Excel spreadsheet, and then analyzed.

4. Results

The cases are described individually, followed by a comparative analysis of the determinants of eco-innovation in light of the peculiar characteristics of each sector and public policies.

4.1 Grupo Sao Martinho (GSM) – Sugarcane Harvest Mechanization

The mechanization of sugarcane fields is the most relevant eco-innovation at GSM. The initial drivers of this initiative were the anticipation of the risks by virtue of a law that would restrict burnings due to the high level of emissions, and the productivity gain perspective. In the 70s, GSM started investing innovatively in Brazil in planting mechanization processes. Since then, technological innovation and the mechanization of sugarcane crops have become priorities in the business strategy of the company, focusing on increased productivity and cost reduction. In the 90s, the group acquired an Australian manufacturer of harvesting machinery, aiming to increase its technological capacity to implement large-scale mechanization. A few years later, the company was sold to Fiat Case IH, a producer of precision farming machinery and equipment, establishing a partnership that is still ongoing, and is maintained by technical and intellectual cooperation agreements for the development of new technologies for sugarcane crops.

The legislation that provides for the end of burnings in crops started being discussed only in 2007 in Brazil. The State of Sao Paulo Agro-Environmental Protocol, signed in 2008 by the producers associated with the Sugarcane Industry Association (UNICA) is part of the Federal Government's Green Ethanol Project, and aims at the sustainable production of ethanol by controlling pollution with the determination of eliminating burnings by 2017 (SME, 2014). Currently, about 90% of the sugarcane harvested by GSM is mechanized, the highest rate of the sugarcane industry in Brazil.

Mechanization is the most challenging eco-innovation initiative for GSM. If on the one hand the company reduced its environmental impact (emissions), reduced the risks of injuries to employees, increased its productivity, enabled a better soil conservation, reduced costs and gained competitiveness (PORTER and VAN DER LINDE, 1995), on the other hand, the mechanization of agriculture changed the employment relationship with the mass dismissal of employees. The equipment used in mechanization is guided by modern technologies via GPS and have full availability for planting and harvesting (24/7), involving up to three working shifts.

According to UNICA, a sugarcane harvester machine replaces the work of eighty people, usually low skilled, but requires twelve professionals with skills in automation and mechanization. Therefore, GSM had to invest in the qualification of its employees, aiming at their reintegration in activities that started demanding technical qualification.

The main determinants of this eco-innovation are related to market demand and environmental regulation. The cost reduction through the efficient use of raw material, pressured by the low margins that the sector operates in the sale of sugar and ethanol, requires high operational efficiency, technological and investment capacity. In addition, the search for new international markets also determined eco-innovation, as the commercial viability to some export markets is subject to the evidence of sustainable practices of the company, based on the its environmental management system (ISO 14001), such as the Greenergy from UK. The environmental regulation was crucial for the mechanization to gain scale (RENNINGS, 2000; HORBACH, 2005; KEMP and PEARSON, 2007; HORBACH, RAMMER and RENNINGS, 2012).

4.2 Kimberly Clark (K-C) – Neve Naturali Toilet Paper

Neve Naturali toilet paper, launched in 2009, was the only product developed by K-C in Brazil that considered sustainability aspects throughout its life cycle. The product did not present economic feasibility and was discontinued in mid-2014. The product design emerged from the company's perception of the growing demand of its final consumers for more environment-friendly products, and encouraged by the partnership with Walmart. Through the "End-to-end Sustainability" initiative, the retailer gathered some of its major suppliers in this project, which enabled the development of sustainable products through workshops and training in the use of life cycle assessment tool (LCA). Through the LCA, it was possible to identify several opportunities for improvement in the production process, change in the packaging and optimization in the transportation, which led to improved environmental indicators, such as the reduction of emissions, the use of materials and waste management.

Neve Naturali was composed of 100% recycled fibers. The eco-design was used in the development of the new packaging through the use of the green plastic from Braskem, polyethylene produced from sugarcane ethanol instead of petroleum. In addition, the company implemented a new compression process of rolls that resulted in a 13% reduction of the plastic used in the 8-roll packaging, and a reduction of up to 18% of the occupation of pallets used in the transportation from the factory to retail.

The main determinants of this eco-innovation were factors related to market demand, including the influence of clients (Walmart and final consumer) with respect to the increased social awareness to consume goods produced from cleaner processes, concern with the company's image and marketing positioning towards sustainability, and cost reduction. There was no influence from the government in the development of this product (RENNINGS, 2000; HORBACH, 2005; KEMP and PEARSON, 2007; HORBACH, RAMMER and RENNINGS, 2012).

The causes of the failure of this product are related to the actual market demand below the company's estimates, and the absence of government incentives in tax reduction for sustainability-oriented products. Internal factors at K-C also impacted the production cost, such as the fact that the suppliers of recycled quality paper scrap are located in the states of Rio de Janeiro and Sao Paulo, while the factory of Neve Naturali is located in the state of Santa Catarina. In addition, the paper deinking process consumes a large amount of water in comparison with the process of virgin fibers (pulp), requiring investments in an efficient recycling process for scraps and sludge treatment (residue from the pulp production process).

Thus, the cost of the paper produced from recycled scrap is higher than that of conventional paper, and the green plastic is also more expensive. Although these costs were not transferred to the final consumer, the product had a very low acceptance mainly due to the fact that Neve Naturali had a different color than conventional paper (not being as white). Consumers would not perceive the value added to the product, the company was unable to position itself and clearly communicate the environmental and social benefits in the value proposal of Neve Naturali, thus leading to the commercial unfeasibility of a product that has not reached production scale. After nearly five years in the market, the product was discontinued. It was not possible to keep the product with low margin and little turnover in the product portfolio of K-C.

However, some improvements developed for Neve Naturali were transferred to other products in the same category, such as the use of green plastic packaging and compaction rollers. The market quickly copied the new compression process, and today all the competing brands of toilet paper in Brazil also use this technology.

4.3 Oxiteno – High Performance Solvent System

The most successful Oxiteno's eco-innovation was the development of a line of products and solutions with sustainable surfactants and solvents. Oxiteno designed the innovation project, and its development occurred through partnerships with universities, research institutes and companies in the production chain. It is a high performance solvent system for printing inks, with higher level of renewable carbon, produced from sugarcane. The global uniqueness of the solution affected the traditional chemical routes of the production of solvents used in flexographic printing inks in Brazil (CNI, 2013; PINSKY, et al., 2014).

The strategy was motivated by global trends in the search for chemicals that are more sustainable, safe, with lower level of toxicity and emissions, in line with the principles of green chemistry. The increase of voluntary restrictions and regulatory aspects guide the chemical industry as a whole through the search for technological changes centered on the use of raw materials of renewable or synthetic origin, which in Brazil, are favored by the richness of the biodiversity.

The project involved a high technological and investment risk for Oxiteno, since the innovation was disruptive and there was no guarantee of market acceptance. The central premise was that the performance of the solution should be equal to or higher than the products formulated with petrochemical inputs, considering the following attributes: cost, print quality, toxicity and environmental impact. The challenge of Oxiteno was to influence the various actors of the chain that the gains in the adoption of the eco-innovation would offset the risks of replacing a mature technology, used for years in the Brazilian chemical industry. Tests were performed in the laboratories of clients (ink manufacturers), and with companies in the final link of the chain (industrializers of food, beverages and retailers), who approved the solution and influenced the adoption of the technology in the previous links of the chain.

The primary lesson from this case is the way the process was conducted by Oxiteno. The pioneering spirit of the company in proposing and collectively developing a new, more sustainable solution, which was adopted by an entire production chain in Brazil, resulted in increased revenue and market share, as the product generated a patent and brought opportunities and access to new international markets. The benefits for the chain and society are based on a product with lower environmental impact (reduction of emissions and human toxicity), with higher yield by 20% in relation to the traditional solvent system, reducing the cost of the input.

In this case, the determinants were the technological factors, by seeking to improve the technical quality of the product, made possible by the technological change and source of the input. The market demand for more sustainable chemical products also determined the eco- innovation, as well as the government influence, with the anticipation of a future regulation that could restrict the product. With regard to the specific factors of the company, the availability of venture capital and the technological capacity were essential (RENNINGS, 2000; HORBACH, 2005; KEMP and PEARSON, 2007; HORBACH, RAMMER and RENNINGS, 2012).

4.4 Scania – Ethanol Bus

One of the main eco-innovation projects of Scania is the ethanol bus. The company has engines with technology adapted to various types of renewable fuels. However, the only fuels that currently have commercial viability are ethanol, biodiesel and biogas, although these are still more expensive compared to other alternatives based on non-renewable fuel.

Scania engines powered by ethanol (a blend of 95% ethanol and 5% additive to promote the ignition) have reduced the emissions of greenhouse gases by 80%, 90% of the emission of particulate material, 62% of carbon oxides and do not emit sulfur in the air. In the 80s, Scania developed this technology at its R&D center in Sweden, and the production scale began only in 1989. Currently, there are approximately 500 Scania ethanol buses in operation in the city of Stockholm, and 60% of the ethanol used in the buses comes from Brazil, with import tax subsidized by the Swedish government. In Brazil, although the market does not demand this product in scale yet, Scania maintains its leadership and is still the only company to commercialize the ethanol technology for buses.

In 1997, Scania brought two ethanol buses for demonstration in Brazil. However, the sale of the first bus was accomplished in the country in 2007, acquired by the Municipality of Sao Paulo. Two years later, the Municipality acquired a second bus. In 2011, the company improved its technology for engines powered by ethanol aiming to meet the new emission control regulation (Proconve P7), similar to the standard Euro 5, and sold 50 ethanol bus chassis to Viacao Metropolitana. This partnership was only made possible through a protocol entered into with the Sugarcane Industry Association (UNICA), which is committed to subsidize ethanol with additives at a level equivalent to 70% of the price of diesel up to 2013. Nowadays, local government sustains the same level of ethanol subsidy.

The main determinant of this eco-innovation developed in Europe and adapted to the Brazilian emission standard, was a set of actions of Swedish public policies aimed at promoting sustainable transportation, including legislation (emission standard), and substantial subsidies for fuel originated from a clean energy source and for the purchase of the vehicle. The technological change factor, considering the search for improvement in the quality of vehicles, greater energy efficiency with the use of a more sustainable fuel, associated with specific factors of the company, such as technological, innovation and investment capacity of Scania in Sweden determined this eco-innovation (RENNINGS, 2000; HORBACH, 2005; KEMP AND PEARSON, 2007; HORBACH, RAMMER AND RENNINGS, 2012).

In Brazil, a market demand for this technology is expected in the coming years due to more restrictive environmental regulations in force. Among the main regulatory frameworks and programs that have recently established standards for vehicle emissions are the Air Pollution Control Program for Motor Vehicles (Proconve) and the Climate Change Policy in São Paulo, both designed to meet the resolutions of the National Environmental Council (CONAMA). Proconve establishes emission limits and technological standard for motor vehicles, including trucks and buses, based on European standards Euro5 (IBAMA, 2014). As for the Policy, it determines that from 2009 there should be a progressive reduction in the use of fossil fuels by at least 10% every year for buses in the public transportation system, and the use, by 2018, of renewable energy resources in all buses of the system (PMSP, 2014a). The public transportation system of the city of Sao Paulo operates with a fleet of 14,822 buses in municipal lines (PMSP, 2014b).

There are several barriers to the adoption of this new technology, which primarily includes the lack of economic incentive to the adoption of technologies based on renewable fuels and the subsidy to petroleum byproducts established by the Brazilian Federal Government in recent years. The high costs (technology and operation) are impediments to the market, in addition to the lack of specific credit facilities with subsidized rates. The price of ethanol engine is approximately 10% to 15% higher than the similar powered by diesel. On the other hand, ethanol has a consumption of approximately 30% higher than diesel – if this proportion is not represented as a lower price of ethanol, it is no longer a viable option from the perspective of the operating cost. In this sense, the option is attractive only to environmentally responsible transport operators who decide to assume the higher cost of the vehicle and fuel by strategic orientation, associated with its marketing positioning. Unfortunately, this is not the reality in Brazil.

The first bio-methane bus is undergoing tests in Brazil since December 2014. Manufactured in Sweden, the vehicle complies with Euro 6 standard and is considered one of the most modern public transport vehicles in the world, with engine dedicated to the use of natural gas and bio-methane. This engine emits 70% less pollutant than a similar diesel engine. The initiative is the result of a partnership between Scania, Itaipu Binacional, the International Center for Renewable Energies - Biogas, the Itaipu Technological Park Foundation and Granja Haacke (poultry farm), responsible for supplying bio-methane. Produced from laying poultry waste, the gas is filtered and bottled. The Brazilian National Petroleum Agency (ANP) has an open public hearing to regulate the use of the fuel. This is an alternative that will contribute to a more sustainable transportation, but its adoption in scale will certainly permeate the same challenges posed in the adoption of ethanol buses.

5. Discussion

The main purpose of this study was to understand how specific determinants influence the performance of eco-innovation in the corporate sector. Through a comparative analysis of different eco-innovations and sectors, it was possible to identify that the factors market demand and regulatory push (RENNINGS, 2000; HORBACH, 2005; KEMP AND PEARSON, 2007; HORBACH, RAMMER AND RENNINGS, 2012) were the most prominent and positively influenced the development of eco-innovation. On the other hand, by analyzing the performance of the initiatives in view of their determinants, the lack of government incentives to reduce the private cost of eco-innovation products, and the absence of subsidies to encourage the increase of market demand were determinants for the failure of the initiatives (NEMET, 2009). In this sense, the absence of appropriate legislation was identified as the main external factor that led to the low performance of the analyzed eco-innovations (NEELY and HILL, 1998). Table 4 lists the determinants of the eco-innovations.

Table 4: Determinant in the Eco-innovation

Factors	Independent Variables	GSM	K-C	Oxiteno	Scania
Technology	Product quality	-	-	Yes	Yes
	Material efficiency	Yes	-	-	-
	Energy efficiency	-	-	-	Yes
	Technology path dependency	-	-	-	-
	Social awareness of the need for clean production	-	Yes	Yes	-
Regulatory Push	Environmental regulation, standards	Yes	-	-	-
	Incentive based instruments	-	-	-	Yes
	Patent legislation	-	-	Yes	-
	International agreement or convention	-	-	-	-
	Expected regulation	Yes	-	Yes	-
Market Demand	Cost reduction	Yes	Yes	-	-
	Image	-	Yes	-	-
	New market (national or international)	Yes	-	Yes	-
	Influence of stakeholders	Yes	Yes	Yes	Yes
Company Specific	Organizational culture toward sustainability (mission and core values)	Yes	-	-	-
	Availability of risk capital for eco-innovation	-	-	Yes	-
	R&D expenditures supporting eco-innovation	Yes	Yes	Yes	Yes
	Technological capability	Yes	Yes	Yes	Yes
	Existence of environment management system	-	-	-	-

Source: Elaborated by the authors from Rennings (2000), Horbach (2005), Kemp and Pearson (2007), Horbach, Rammer and Rennings (2012).

The variables that determine the design and development of the projects are peculiar to each sector and type of eco-innovation (HORBACH, 2005). The study shows evidences that specific factors of each company, such as the availability of R&D investment focused on eco- innovation, as well as the technological capacity, emerge as a basic requirement for achieving a project with these characteristics. The maturity of the environmental management, identified in this study through the existence of an environmental management system, emerges more as a facilitator of eco-innovation than a driver. Three of the companies analyzed do not have the commitment to sustainability stated in their mission and core values. However, this factor did not have any negative implication in the development of eco-innovation, since the initiatives have a business rationale and were in line with the sustainability strategies declared by the companies. All initiatives analyzed presented compatibility with the existing production system in the companies (DEL RIO GONZALEZ, 2009), and no substantial technological investment was demanded in the process.

Out of the four eco-innovations analyzed, two presented high performance, one product demonstrates low performance, and the other failed and was discontinued, as described in Table 5. The intensity of the determinants on the development of eco-innovations was specific to each sector. The factors identified as barriers to the performance of the eco-innovation, considering the economic and commercial viability of the products, were the same in two cases: K-C and Scania. The low market demand, the absence of subsidies for sustainability- oriented innovation projects, as well as the lack of demand-pull public policies, such as tax credits and rebates for consumers of sustainable technologies (NEMET, 2009), were the main determinants in the discontinuity of Neve Naturali and justify the low market adoption of Scania ethanol buses.

Table 5: Performance, Drivers and Barriers.

Project/Sector	Performance	Main drivers	Main Barriers
Sugarcane harvest mechanization / Ethanol and Energy	Successful	Material efficiency, cost reduction, environmental regulation and expected regulation	
Neve Naturali Toilet Paper / Consumer Goods	Failed		Low market demand, lack of government subsidies to sustain the product competitive (high price of the input and production process) and nonexistence of demand-pull public policies
High performance solvent system / Chemistry	Successful	Market share, new market (international), social awareness of the need for clean production, availability of risk capital	
Biofuel Bus / Transportation	Low performance		Low market demand, lack of government subsidies to make the product competitive (high price of the biofuel) and nonexistence of demand-pull public policies

Source: Elaborated by the authors, 2014.

The successful and high performance eco-innovations show evidences of the Porter Hypothesis (PORTER and VAN DER LINDE, 1995). The implementation of the sugarcane harvest mechanization process (GSM) and the development of new solvent system (Oxiteno) increased the competitiveness of the enterprises by reducing cost and providing access to international markets, concomitantly with the reduction of environmental impact. One of the most relevant determinants of these eco-innovations was the expected regulation, whereas the government tightly regulates ethanol/energy and chemical sectors.

The cases, chosen by convenience, coincidentally present ethanol as one of the components in the eco-innovations. From the implementation of the sugarcane harvest mechanization process of GSM for the production of ethanol, to the use of this component in the composition of green plastic used in the toilet paper Never Naturali of K-C, the new solvent system of Oxiteno and the Scania ethanol bus. Ethanol is definitely a renewable source with relevant potential to contribute with the reduction of CO_2 emissions in replacement to petroleum byproducts. In this sense, Brazil has shown competitive advantages due to the availability of this input. The country is the world largest producer of sugarcane, the second largest producer and exporter of ethanol, with 20% of market share (UNICA, 2013).

6. Concluding Remarks

Managerial Implications

One of the major contributions of this study is based on a deeper understanding of specific determinants on the performance of eco-innovations. The article provides some insights that may contribute to the formulation and implementation of public policies focus on eco-innovation in the corporate sector, aiming at the sustainable development and the feasibility of initiatives that contribute with the mitigation and adaptation to environmental impacts, especially those related to climate change. The study identified the main determinants of eco-innovations in different sectors by using the set of indicators proposed in other studies (RENNINGS, 2000; HORBACH, 2005; KEMP AND PEARSON, 2007; HORBACH, RAMMER AND RENNINGS, 2012). The cases showed evidences that the main barrier that impact the performance of eco-innovations is related to the lack of a efficient public policies that foster innovation initiatives through incentive mechanisms (economic viability). It was also found overlaps and lack of coordination between policies (RENNINGS, 2000) that compromised the eco-innovation performance in specific sectors. This context brings challenges and opportunities at the same time to the private sector by addressing their business strategies focused on solutions that contribute to a low carbon economy. There is technology available and innovation capacity geared towards sustainability in the private sector. However, the market demand, identified in this study as one of the most important determinants, also relies on government intervention at the local, state and global levels to promote the economic viability of the eco-innovation. It is not just a matter of improving the aspects of eco-efficiency in the production processes, but to collectively rethink the government and business strategies, and the consumption patterns of contemporary societies. It is desirable to promote a win-win situation for governments, businesses and individuals. Public policies oriented to eco-innovation should better coordinate a government system that combines innovation and environment (ABRAMOVAY, 2012), including long-term goals, technological and institutional changes in a systematic way, and develop a set of political measures consistent with a transition to the sustainable development.

Academic Implications

A comparison between the cases cannot be generalized due to the limited size of the sample, and the variety of types of eco-innovations. The peculiarities of each sector must be analyzed individually also, as certain industries are highly regulated due to the environmental impact throughout their supply chain, such as the chemical industry. For future studies, it is recommended to increase the number of cases, particularly business in the same sectors analyzed in this study, aiming comparison, validation of the finds and further analysis.

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