Conditioning factors on the performance of eco-innovation projects and the influence of public policies

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Abstract
The qualitative research analyzes cases of multinationals companies in different sectors in Brazil: consumer goods, sugarcane, chemical and transportation. The main contribution is focused on how different public policy instruments and institutional environments are driving corporate innovation focus on the development of a low carbon economy.

Keywords: Sustainable innovation, Green innovation, Environmental innovation.

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 governance that considers the limits of ecosystems and the reduction of inequalities as central factors of 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 the 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 focus especially on countries

mitigation by establishing reduction and adaptation targets (UNFCCC 2014). This 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 main purpose of this study is to understand how certain determinants influence the performance of eco-innovation.

Theoretical Background

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. The diffusion of new technologies is essential to sustained growth of results and productivity. 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. 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).

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 many benefits aimed to the corporate sector, including differentiation, development of new products 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 et al. 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).

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 specific characteristics, such as the degree of complexity to implemet, 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 et al. 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 considered in this study.

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

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. The expected results are the reduction of environmental impact, the development of products with better quality, and the increase of international competitiveness (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 environmental targets focused on cost reduction (Frondel et al. 2008).

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).

Methodological Aspects

The main purpose of this study is to understand how certain conditioning factors influence the performance of eco-innovation. The following 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 qualitative research using the multiple-case study as the method chosen. The choice of cases, by convenience, considered the following criteria: 1) recognized innovative and large companies; 2) different sectors, seeking contrasts; 3) relevance of the sector in light of the environmental impacts of the product/process. Table 2 shows the four cases: two Brazilian multinational companies and two Brazilian subsidiaries (Swedish and American origin).

Table 2: Cases Studied

Company	Sector	Unit of Analysis	2013 Revenue (mi)
GSM	Sugar and Ethanol	Sugarcane Harvest Mechanization	USD 779
K-C Brazil	Consumer Goods	Neve Naturalli Toilet Paper	USD 1,332
Oxiteno	Chemistry	High Performance Solvent System	USD 1,248
Scania Brazil	Transportation	Ethanol Bus	NA

The unit of analysis 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. The data collection technique included personal and in-depth interviews with executives in the areas of innovation, sustainability, research and development, conducted in the period between March 2013 and December 2014. The document analysis was conducted: 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 as per described in Table 1.

Results

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. The legislation that imposes 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. A sugarcane harvester 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 technical activities. 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 et al. 2012).

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. Unfortunately, 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. The product was composed of 100% recycled fibers. The eco-design was used in the development of the new packaging through the use of a green plastic (polyethylene produced from sugarcane ethanol). 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 et al. 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. Company internal factors also impacted the production cost. 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.

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. 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 value 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. 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. The availability of venture capital and the technological capacity were essential (Rennings 2000, Horbach 2005, Kemp and Pearson 2007, Horbach et al. 2012).

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 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 emission standard, and substantial subsidies for clean energy 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 et al. 2012). 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.

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 et al. 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 presence of the determinants of the eco-innovations.

Table 4: Presence of the Determinant in the Eco-innovations Analyzed

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	-	-	-	-

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 (GSM and Oxiteno), one product demonstrates low performance (Scania), and the other failed and was discontinued (K-C). 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.

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 CO2 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).

Concluding Remarks

Considering managerial applications, 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 et al. 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.

For 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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