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Challenges to Diffuse Eco-innovation in the Brazilian Transportation Sector

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Title: Challenges to Diffuse Eco-innovation in the Brazilian Transportation Sector

Abstract
The main purpose of this study is to analyze the process of development and diffusion of eco-innovation projects and understand the influence of public policies in the transportation sector in Brazil. The method used was the case study. The main determinants of the company's eco-innovation projects are related to market demand, public policies, technological changes and the company-specific factors such as technological, innovation and investment capacity. The government influence was identified as one of the main drivers of eco-innovation and, at the same time, the main barrier in the adoption of eco-innovation at Scania due to the current Brazilian subsidy policy to oil byproducts, which makes the renewable fuels more expensive, and the lack of subsidized credit facilities for sustainable products in this sector. These factors lead to the lack of market demand.

Keywords: sustainable transportation; sustainable innovation; green innovation; strategy; public policies.

1. Introduction

The world population is increasingly urban and has grown from 746 million in 1950 to 3.9 billion in 2014. It is expected that the urban population exceed six billion by 2045. There are several challenges in meeting the needs of the growing urban population, including education, health, housing, infrastructure, transportation, energy and pollution control (UN, 2014). To meet those needs, the number of vehicles is expected to increase. The demand for new technologies focused on resource-efficient mobility will increase, especially from governments that are challenged by traffic jam and pollution in urban centers.

In addition, the global challenge to be faced with the climate change publicly emerges with more emphasis in view of the results of the UN Climate Change Conference (COP 20) held in December 2014 in Lima, Peru. Among the main elements of the next global climate change agreement that will replace the Kyoto Protocol, agreed between the 195 countries of COP are: 1) industrialized countries recognize their greater responsibility to reduce CO_2 emissions, and developing countries recognize their emissions and undertake to establish reduction targets (common but differentiated responsibilities); 2) all countries should submit their emission reduction targets until 2030 up to March 2015; 3) the countries must submit adaptation targets; 4) developed countries should offer compensation to poor countries that suffering the impacts of climate extremes (losses and damages) (UNFCCC, 2014).

The expectation is that countries emission reduction and adaptation targets of the countries should guide the transformation of societies, including deep changes in the energy sources, in production systems and in the consumption of the world population. This context will demand sustainability-oriented technological innovations, and should rely on the leadership and investment from the private sector, supported by consistent public policies that consider a more demanding environmental regulatory framework, concomitantly with the use of economic incentive instruments.

Sustainable transportation strategies play a key role in the promotion of a low carbon economy. The development and dissemination of new technologies focused on sustainability, combining high-performance solutions in transportation with low environmental impact are a challenge and at the same time an opportunity for the companies. The use of biofuels, such as ethanol, brings benefits related to the reduction of emissions, especially to urban centers where there is a lower dispersion of pollutants.

In Brazil, public policies are gradually implemented through decrees and programs that promote eco-innovation in the transportation sector. One of the main initiatives in this area is the Incentive Program to Technological Innovation and Densification of the Production Chain of Motor Vehicles (Inovar-Auto Program), approved by Decree No. 7.819/2012, which aims to increase the competitiveness of companies in the automotive sector by encouraging the manufacture of more economical and safe vehicles, investment in the supply chain and in engineering, basic industrial technology, research and development (R&D) and the training of suppliers. The program is part of the industrial, technological and foreign trade policy *Plano Brasil Maior* (BRAZIL, 2014).

Companies can benefit from the reduction of the Tax on Industrialized Products (IPI) by increasing the investment in innovation and R&D. To qualify to the new regime, the companies must establish goals focused on the development of more modern production technologies, more efficient engines (reducing emissions and fuel consumption), lighter parts and raising the quality standards (BRAZIL, 2014).

Among the main regulatory frameworks and programs that have recently set standards for vehicle emissions are the Air Pollution Control Program for Motor Vehicles (Proconve) and the Climate Change Policy in Sao Paulo, both designed to meet the resolutions of the Brazilian National Environmental Council (CONAMA). Proconve establishes emission limits and technological standard for motor vehicles, including trucks and buses, based on the European standard 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, 2014).

The importance of the search for a better understanding of the eco-innovation process is justified by the need for a drastic reduction in the current level of pollutant emissions, and the demand for regulatory strategies that encourage the development of new clean technologies. In addition to the reduction of emissions, there is an expectation that innovation reduces the costs generated by the requirements of environmental regulations. New technologies for vehicles and renewable energy systems may take a decade or more between the period of the invention, adaptation and diffusion. It is realistic to consider a period of at least half a century for the consolidation of major changes in socioeconomic subsystems, including the change of technological standards in the energy and transportation systems (RENNINGS, 2000).

This context, in light of the incipient Brazilian environmental regulatory framework, demonstrates the importance of analyzing the transition process and the learning of the transportation sector in the development of eco-innovation. Therefore, the main purpose of this study is to analyze the process of development and diffusion of eco-innovation and understand the influence of public policies in the transportation sector in Brazil. The method used was the case study of the Brazilian subsidiary of Scania.

2. Theoretical Background

2.1 Sustainability-Oriented Innovation

Sustainability is currently considered one of the main drivers of innovation, and is strategically related to the competitive advantages of the companies. Business models focused on sustainable development bring reduction in the use of resources and costs, opportunities in new markets, and development of higher quality products. Companies that anticipate and adequate to comply with regulations present the advantage of having more time for their developments focused on new materials, technologies and processes, which is the first stage of a company seeking a strategy focused on sustainability – as compliance is seen as an opportunity to innovate. As the company incorporates new values, it enhances its strategy and develops new processes geared towards sustainability, other maturity stages are reached with the search for efficiency in the value chain, the development of new products and services that consider sustainability aspects and the creation of new business with high value- added (NIDUMOLU, PRAHALAD and RANGASWAMI, 2009).

The concept of sustainability-oriented innovation is comprehensive and receives different names in the literature, such as sustainable, green, eco or environmental innovation. All these concepts consider the environmental risk reduction as a central factor in the innovation process. In this study, we adopted the concept of eco- innovation proposed by Kemp and Pearson (2007), and based on OECD's definition of innovation:

> "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).

In this concept, every environment improved product or service is considered an eco-innovation, as well as new processes more efficient in the use of resources. The main objective of an eco-innovation may be based on an economic justification, such as increase market share or cost reduction, and not necessarily need to have an environmental target, even though this is one of the outcomes (KEMP and PEARSON, 2007; HORBACH, RAMMER and RENNINGS, 2012).

2.2 Determinants of Eco-innovation

Eco-innovation covers three types of changes aimed at sustainable development: technological, social and institutional innovation. From this perspective, the externality of the problem, the push/pull regulatory effect and the growing importance of innovation in the social and institutional context are peculiar factors present in eco- innovations (RENNINGS, 2000). The main determinants (drivers and barriers) of eco-innovation can be consolidated into four broad groups: company specific factors, technology, market demand and regulatory push. Table 1 presents a comprehensive set of eco-innovation indicators, which was consolidated based on the studies of Rennings (2000), Horbach (2005), Kemp and Pearson (2007), Horbach, Rammer and Rennings (2012).

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: Adaptado pelos autores a partir de Rennings (2000), Horbach (2005), Kemp and Pearson (2007), Horbach, Rammer and Rennings (2012).

The government influence is found in the literature as one of the main determinants of eco-innovation, and can occur through economic mechanisms (tax incentive, environmental permits, subsidies) or command and control mechanisms (environmental regulation, emission standard, product restriction). These instruments seek to add the value of the environmental good in the production process aiming to reduce the use of natural resources and environmental degradation. The penalties through the collection of taxes and fees, based on the polluter pays principle are one of the main instruments. On the other hand, the environmental subsidy is the reverse of taxation (SEIFFERT, 2007; LI, 2013).

According to the Porter Hypothesis (PH) strict environmental regulations can induce efficiency and encourage innovations that help improve the firms competitiveness. Through the innovation process based on compliance, the company benefits from the cost and risk reduction, develops products with better quality, increases international competitiveness and reduces its environmental impact (PORTER and VAN DER LINDE, 1995). PH is based on the change in the pollution control model to increase the productivity of resources, oriented by regulation (HORBACH, 2008).

However, eco-innovation should not be considered only as a systematic response to regulatory pressure, because many other factors may influence, such as intellectual capital, technological opportunities (OLTRA and JEAN, 2009) and environmental targets aiming cost reduction (FRONDEL, HORBACH and RENNINGS, 2008).

The reduction of the level of emissions focused on the development of a low-carbon economy requires new technologies. However, few companies are able to justify the investment in new technologies focused on eco-innovation, since the benefits are often uncertain, involve risks and are difficult to internalize (HORBACH, 2005; VICTOR, 2011). In this sense, innovation policies and environmental policies should be coordinated (RENNINGS, 2000).

The technological change, despite not being a sufficient condition for the transition to sustainability, is one of the main factors that influence the reduction of environmental impacts of manufacturing processes, by increasing the efficiency in the use of resources, reducing emissions, using less polluting inputs, and adopting cleaner production processes. Companies that decide to invest in environmental technological changes are influenced by various socio-economic and institutional factors, namely: 1) internal factors – specific to the company that facilitates the involvement in environmental technological change; 2) external factors – market pressure, information flow and stakeholders (associations, suppliers, investors, insurance firms, final consumers/industrial clients, competitors, environmental NGOs, media, research centers and financial institutions); 3) characteristics of technological innovation, such as the degree of complexity of its implementation, compatibility with the existing production system and availability of capital (DEL RIO GONZALEZ, 2009).

Despite the growing development and diffusion of new technologies able to increasingly reduce the use of materials, energy and emissions resulting from the supply of products and services, it is necessary to consider the widespread expansion of consumption in which economic development is based. Modern societies have not yet succeeded in generalizing innovation systems aimed at sustainability able to combine the size of the economic system with the limits of the ecosystems (ABRAMOVAY, 2012).

2.3 Diffusion of Innovations Theory

Several innovations require a long period of time to be adopted; others are rapidly disseminated and adopted. On the one hand, the diffusion of eco-innovation has increased over the years, but its adoption depends on various socioeconomic, cultural and institutional factors. Diffusion is a process in which innovation is communicated through certain channels over a period to individuals of a social system, and can be considered a type of social change. When new ideas are invented, disseminated and adopted, they lead to certain consequences where social change occurs (ROGERS, 1983).

The adoption of an innovation is a process that involves individuals and groups who decide to adopt it as the best option available. Once individuals or groups have adopted an innovation, it may or may not be diffused. The adoption of an innovation is based on three types of decision for its use: optional, collective or authority decisions (ROGERS, 1983).

According to the Diffusion of Innovations Theory, not all innovations should be considered equivalent units of analysis. The characteristics of an innovation, according to the perception of individuals, help to explain the different levels of adoption. Rogers (1983) proposes five different perceived attributes of innovation: 1) relative advantage: degree to which an innovation is perceived as being better than its precursor; 2) compatibility: degree to which an innovation is perceived as being consistent with the existing values, needs and past experiences of potential adopters; 3) complexity: degree to which an innovation is difficult to be understood and used; 4) trialability: degree to which an innovation can be experimented; 5) observability: degree to which the results of an innovation are observable by others.

Although this theory was developed to measure the perception of individuals rather than companies in the adoption of a technology, for this study the set of perceived attributes of innovation was used to guide the discussion of the results of the case study, and to facilitate the understanding of the diffusion and adoption of eco-innovation.

3. Methodological Aspects

The main purpose of this study is to analyze the process of development and diffusion of eco-innovation projects and understand the influence of public policies in the transportation sector in Brazil. This is a descriptive and qualitative research. The method used was the case study and is justified by the contemporaneity of the subject, allowing an in-depth analysis in an area where there are few academic studies or a poor set of knowledge (COLLIS and HUSSEY, 2005; YIN, 2005). Case studies based on interviews or other data sources capture the details of environmental technologies, internal and external factors of a company, social and economic relations that are relevant to explain the details of the environmental technological change that are not possible to be raised in quantitative studies (DEL RIO GONZALEZ, 2009).

The data collection technique included personal and in-depth interview with company executives held in December 2014. The interviews were recorded and transcribed. The data collection instrument was a semi-structured questionnaire developed based on eco-innovation indicators adapted from Rennings (2000), Horbach (2005), Kemp and Pearson (2007), and Horbach, Rammer and Rennings (2012), as described in Table 1. The analysis of results considered the primary data collected in the interviews and secondary data, including sustainability reports and information on Scania's website (Brazil and Global), articles from magazines with statements from the company's executives, as well as laws and decrees mentioned in this study.

4. Results

4.1 Scania do Brasil

Scania is one of the world leaders in the manufacture of trucks and buses for heavy transportation, industrial and marine engines. In Brazil, there is no production of buses, only the manufacture of chassis. Its portfolio includes maintenance services, parts and accessories, and financial services. Scania started the Brazilian operation in 1957, and is positioned as one of the main subsidiaries of the Swedish company. Its business strategy is focused on niche markets through the manufacture of heavy-duty vehicles with high availability, which requires little maintenance, use cleaner technologies with fuel efficiency. The company has four thousand employees – approximately 10% of Scania's employees worldwide.

The main objective of the organization's strategy is to provide operational savings to its clients by offering optimized products, and is guided by the following core values: customer first, respect for the individual and quality. Sustainability aspects are not declared in its corporate strategy and core values.

Scania's clients are predominantly transportation companies and the commercialization of its products is through a structured network of dealers in more than 100 retailers throughout Brazil. In 2013, the factory located in the city of Sao Bernardo do Campo (State of Sao Paulo) produced 28,495 vehicles (trucks and buses) and 2,471 engines (industrial and marine). It has 32.2% of the domestic market share for heavy-duty trucks and 16.6% in the bus market in Brazil. The company does not report its local revenue.

4.2 Corporate Sustainability

Scania has an ambitious goal of reducing by 50% the emissions of CO_2 equivalent per kilometer of its trucks by 2020, based on the year 2008. In addition to investments in engines and the design of the vehicles, it is also possible to reduce emissions with an improved efficiency in the use of vehicles, such as through efficient training and couching to drivers, being able to reduce the consumption of fuel by 10% and hence reach a significant reduction in emissions. The company invests in partnerships with the academic sector, such as the recent agreement signed with Polytechnic School of the University of Sao Paulo to build a laboratory in a technology park. The partnership initially aims to support research on the behavior of airflows into the engine combustion chamber, aiming to generate scientific knowledge to contribute to the development of new pollutant emission control technologies.

Scania Brazil was the first company in the manufacturing transportation sector in Latin America to receive ISO 14001 certification. Its environmental policy has goals and action plans in each industrial operation, which are based on corporate goals, local conditions, and on the relevance of the environmental aspects and impacts. Primary goals established in 2013: a) train the leadership on safety, health and environment responsibilities; b) implement the Environmental Management System in the new Logistics Center located in the city of Vinhedo (Sao Paulo); c) promote an event to raise awareness with managers on Scania's sustainable production practices.

Regarding the use of raw materials, chemicals, energy and water consumption, the company aims to reduce consumption and seeks alternatives with lower environmental impact. There are several initiatives that focus on the continuous improvement of the environmental indicators. Some initiatives have already indicated positive results. However, the company doesn't present any goal or initiative with focus sustainability to cascade to the various operating units of the company, such as the engine, transmission, transmission, cabins, chassis and maintenance plants. The actions are planned and implemented individually in each operation unit.

The environmental indicators presented in the 2013 sustainability report indicate an increase in absolute numbers in the consumption of water and energy, generation of solid waste and industrial effluent. However, by analyzing the historical data, is possible to identify a significant improvement when these indicators are correlated with the increase of production units. The only indicator that indicated growth were the emissions of Volatile Organic Compounds (VOCs), considered a dangerous pollutants.

The company considerers in all projects the reuse and recycling of at least 90% of all its components. There is a focus on the search for less polluting substances, aiming to reduce gas emissions and noise. Every detail is designed to reach the maximum performance, lower environmental impact and higher operating savings. This translates into the search for a better vehicle performance, reduced fuel consumption and low emissions.

4.3 Technological Strategy and Product Development

The purpose of the company's R&D is to develop solutions that enhance the productivity and profitability of the clients' operations, and the efforts are guided by the search for reducing the lead-time in the project development up to the market. Process and production flows are defined and balanced according to the market demand, and leads to waste reduction and quality improvement. The basis of product development is focused on the combination of the following factors: low fuel consumption, high availability, low service cost with high quality and good performance.

The company adopts a centralized geocentric R&D organization (GASSMAN and ZEDTWITZ, 1999), with the main R&D located in Sweden and some other centers located in subsidiaries, as in the case of Brazil. The development and transfer of technology have high efficiency due to the scale and specialization, aiming at low R&D costs and reduction of the total development time. In the center of excellence in Sweden, there are 3,400 employees, mostly highly skilled engineers. The R&D in Brazil has approximately 100 employees. In 2013, the company invested 6% of its net revenue in R&D.

Investments in R&D and new recruitment of engineers and researchers in Brazil have considerably increased since 2013 with the lunch of the Inovar-Auto Program. This public policy centered on economic incentive through the reduction of taxes (IPI) to companies that invests on innovation was the determinant that led the company to review its local R&D strategy and increase the investment.

However, although some developments started being conducted in Brazil since 2013, the focus is centered on innovation projects that are not priority for Scania in terms of global strategy. Local innovations are focused on products that meet only specific demands of developing countries, such as the case of Brazil. The industrial park in Brazil follows the same global technological standard of Scania, with modern and technologically updated assembly lines, at the same levels of factories in Europe.

4.4 Environmental Regulation as a Conditioning Factor of Eco-innovation

The compliance with the regulation of each location is one of the main determinants of Scania's eco-innovations. In Brazil, Proconve has been establishing emission limits for heavy-duty vehicles since 2004. The program, similar to the Euro 5, established new standards to control emissions since 2012, and required modifications in the engines, new post-treatment systems of exhaust gases and diesel with reduction of sulfur emission.

This program, which is part of the Brazilian Emission Control Public Policy, was the determinant for several eco-innovations aiming compliance. The developments were focused on new technologies to attend the legislation requirements, without compromising the fuel efficiency, and demanded the manufacture of new vehicles with transmissions, engines, drive axles and more efficient cooling systems and maps of electronic regulation systems of engines properly calibrated for the new technology (ANFAVEA, 2014).

It should be noted that in Brazil an inferior technology to control vehicle emissions is used in relation to the products sold in Europe, because the European law has a more restrictive emission standard with the establishment of the Euro 6 in December 2013.

4.5 Market Demand

Scania's clients increasingly seek efficient solutions in fuel consumption, focusing on cost reduction. In this sense, the demand guides the technological innovations focused on energy efficiency. Another important aspect that drives innovation projects is the growing global demand for more sustainable transport solutions in various industrial segments and sectors, including solutions for urban mobility.

The eco-innovation projects are demanded by different clients, which, in turn, require solutions that meet the policies and energy resources of each country, leading Scania to have a high level of flexibility in the development of a portfolio of solutions for each location. This makes the company prioritize the continuous development of modular systems and establishes several partnerships for the development of cutting- edge technology.

Among the eco-innovations in Brazil, the biofuels engines are the most important, including the ethanol, biogas, biodiesel and electrical engines. Scania ethanol engines reduces the emission of greenhouse gases by 80%, 90% of the emission of particulate matter, 62% of carbon oxides and do not emit sulfur in the air. The eco-design strategy is used in Scania Streamline. The new design of truck cabins provide an improved aerodynamics and better performance with reduced fuel consumption, and consequently, the reduction of emissions and use of fossil fuels.

4.6 Barriers in the Diffusion of Eco-Innovation in the Heavy-Duty and Passenger Transportation Sector

The low carbon technology developed for truck and bus ethanol engines is not recent. Scania developed the first project in the 80s at its R&D center in Sweden, and since 1989 it produces buses powered by ethanol in scale. In Stockholm, there are approximately 500 Scania ethanol buses in operation, and 60% of the biofuel used comes from Brazil, with import tax exemption by the Swedish government.

For over 30 years, Scania became a global pioneer for using ethanol engines in its buses and trucks. In Brazil, it maintains its pioneering and is still the only company to produce this technology for trucks and buses. Despite the environmental benefits from the use of ethanol instead of diesel, there are several barriers on its diffusion and commercial viability.

The main impediment in the diffusion of this eco-innovation is related to the cost, not only of the technology but also the high operation cost. The price of the ethanol engine is approximately 10% to 15% higher than the similar powered by diesel. Also, ethanol engine 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. Over the past few years, its price has not been competitive in relation to diesel due to the price control policy determined by the Brazilian Federal Government for the oil byproduct. In this sense, the option is attractive only with government subsidies or to environmentally responsible companies that decide to assume the higher cost by strategic orientation, associated with its image and marketing strategy.

An example is the partnership entered into between Scania, Natura (Brazil's largest company in personal care and cosmetics sector) and Coopercarga. The logistics operator acquired two Scania ethanol trucks to transport the Natura's products, which in turn has a strong strategy in reducing its emissions through the constant search for innovative and sustainable alternatives for its activities.

In 1997, Scania brought two ethanol buses for demonstration in Brazil. However, the sale of the first bus in the country, acquired by the Municipality of Sao Paulo, was accomplished in 2007. Two years later the Municipality acquired the second bus. In 2011, the company improved its technology for engines powered by ethanol aiming to meet the new emission control regulation (Proconve P7), 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 committed to subsidize ethanol at a level equivalent to 70% of the price of diesel until 2013. The local government now assumed the costs of the subsidy.

Scania develops industrial engines to construction, forestry and farming equipment. It is worth noting that the engines produced by Scania for sugarcane harvesters are powered by diesel because there is no market demand for ethanol engines. The very industry that produces ethanol does not use the biofuel in its harvesting machines. This is due to the fact that the industrial engine requires a blend of 95% of hydrous ethanol and 5% of an additive to ignition. The high price of this additive and the fact that ethanol consumption is higher in liters in relation to diesel, make ethanol economically unfeasible, even to its producers.

The company has other technologies for engines powered by biogas, biodiesel, electricity and hybrid, but there is no market demand in Brazil. The barriers in the adoption of these cleaner technologies are related to the higher cost of the product, the price of oil-based fuels are subsidized in Brazil, and the lack of specific credit facilities with subsidized rates. In addition, most transportation operators work with old fleets. It is expected that technology for biogas engines will be adopted in the coming years in the public transportation due to the low cost and the availability of natural gas in Latin America. At the moment, there is only one Scania biogas bus undergoing tests in Brazil.

In the international market, there is a wide variety of heavy-duty trucks and buses powered by renewable fuels. The determinant of the diffusion and adoption of these eco-innovations in European countries are the sustainability-oriented public policies, including substantial subsidies for renewable fuels and for the purchase of buses and trucks with clean technology.

In the European market, Scania has focused its strategy on becoming a full solutions provider. One example is the Scania Ecolution, a new business model concept that was developed by the demand of clients searching for solutions to reduce fuel consumption, and is centered on three pillars: 1) appropriate specification of the vehicle according to the client's transportation demand; 2) training and coaching sessions for the drivers for performance improvements; 3) scheduled maintenance to ensure that the vehicle operates under ideal conditions. In Europe, the fuel represents approximately 35% of the operating cost of a vehicle, while the Ecolution indicates a reduction between 10 to 15% in fuel consumption to clients who purchase the service. The solution, in addition to reducing the customer costs, reduces CO2 emissions, and represents an additional source of revenue for Scania.

The feasibility of this eco-innovation depends on the institutional context of each country, the maturity of the client and the Scania's service provider (dealers). In Brazil, the Ecolution was not implemented yet, because it presents no commercial viability due to the lack of demand. The Brazilian market is not considered mature for high value-added services. Most carriers operate in Brazil with very low margins, are not willing to invest in technologies and services, have old fleets and do not see value in investing in the training of their drivers.

5. Discussion

The main purpose of this study was to analyze the process of development and diffusion of eco-innovations, and understand the influence of public policies in the transportation sector in Brazil. The main determinants of Scania's eco-innovation projects were: market demand (cost reduction and compliance), public policies (environmental regulation, emission standard, economic incentive, business opportunity with the government), technological change (improvement in product quality, energy efficiency, more sustainable inputs) and company-specific factors (technological, innovation and investment capacity) (RENNINGS, 2000; HORBACH, 2005; KEMP AND PEARSON, 2007; HORBACH, RAMMER AND RENNINGS, 2012).

These factors stood out as business opportunities for the company, except for the government influence that, despite being an important factor in driving eco- innovation in Brazil, certain public policies stand out as barriers to the diffusion and adoption of eco-innovation in the transportation sector. Environmental regulations, such as the emission standard and prohibition to use fossil fuels in public transportation in the city of Sao Paulo up to 2018, as well as the economic incentive through the reduction of IPI, were determinants in the eco-innovation projects, promoted cost and risk reduction, and business opportunities (PORTER and VAN DER LINDE, 1995). On the other hand, the Brazilian Federal Government imposes a number of barriers to the adoption of eco-innovations, including the subsidy of oil-based fuels, which makes the renewable fuels more expensive, and the lack of subsidized credit facilities for sustainable products in this sector. These factors lead to the lack of market demand.

Scania innovation initiatives are predominantly driven by increasing the operational efficiency of its products with a reduced use of fuel and emissions through technological changes (DEL RIO GONZALEZ, 2009). The determinants are customer demand, which in turn is pressured by environmental regulations (emission standard) and the reduction of operating costs. Economic factors and compliance (FRONDEL, HORBACH and RENNINGS, 2008; OLTRA and JEAN, 2009) were identified as the main drivers of eco-innovation, where environmental improvement was not the primary goal, but the results achieved (KEMP and PEARSON, 2007).

Scania aims to be the leading provider of sustainable transportation solutions. In this case study, it was possible to identify several eco-efficiency initiatives in its production processes, as well as note its high technological capacity, availability to invest and to assume risks in the development of eco-innovations. By analyzing its portfolio, it was possible to notice the difference in the maturity of countries where the company operates related to the adoption of sustainable technologies. In Europe, Scania sells products with different technologies based on renewable fuels, and already found commercial feasibility to new services with high value-added that result in environmental benefits (NIDUMOLU, PRAHALAD and RANGASWAMI, 2009), such as the Ecolution. In contrast is the Brazilian market, at an initial phase to a large- scale adoption of sustainable technologies that have been made available by Scania for decades.

Although the biofuel technologies have been disseminated for a long time in Brazil, its adoption is slow and there is no large-scale production of buses and trucks powered by renewable fuels. The study showed that the absence of *relative advantage* in the adoption of renewable fuels, due to the high cost, is the main attribute that inhibits the adoption of this eco-innovation in scale. In addition, the eco-innovation may not present *observability*, since the results of its adoption may not be visible to others. With regard to all other attributes, according to the Diffusion of Innovations Theory, the eco-innovation is *compatible* with the need for new technologies that reduce emissions; there is no level of *complexity* in its use, as the engines adaptations do not impact the end user, and the innovation can be experimented (*trialability*) through the vehicles that are made available for tests by Scania (ROGERS, 1983).

The absence of relative advantage and observability in the adoption of biofuel technologies (ROGERS, 1983), associated with the overlapping of public policies that are controversial in some respects, and the lack of subsidies to enable eco-innovations in the country are barriers that prevent the advance of business and government strategies that contribute to the development of a virtuous context geared towards sustainable development.

6. Concluding Remarks

Managerial implications

Renewable fuels are important drivers of innovation systems towards sustainability, the basic foundations for the development of a low-carbon economy. There is a noticeable delay in the diffusion and adoption of eco-innovations in the transportation sector (heavy-duty buses and trucks) in Brazil. Clean technologies based on renewable fuels have been developed, disseminated and are available for decades. However, their adoption is slow and depends on government actions to impose restrictive standards and provide a set of market incentives to economically enable these eco-innovations, such as subsidies to the operations and supply of biofuels at competitive prices. If on the one hand fuel consumption has reduced by means of more efficient technologies, on the other hand, the exponential growth of bus fleets and heavy-duty trucks generates a greater accumulation of emissions. Political strategies should foster innovation systems towards sustainability that consider the economic development concurrently with the limits of ecosystems (ABRAMOVAY, 2012), in coordination with innovation and environmental policies (RENNINGS, 2000). This context poses challenges and many opportunities to the private sector in guiding 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. But the market demand in the sustainable transportation sector will not be made possible without government intervention at the local, state and global levels. It is not just a matter of improving the aspects of eco-efficiency in the production processes, but to collectively rethink the government strategies, business strategies and the consumption patterns of contemporary societies.

Academic implications

In the literature review, we have found several quantitative studies (econometrics) on the determinants of eco-innovation. One of the suggestions for future studies is to analyze these articles and identify opportunities for a sectorial qualitative analysis in view of these results. The main limitation of the study was the use of the single case study method, which makes it impossible to generalize the results. However, the study provides important information for improvement in future studies, which should consider increasing the number of corporate cases in the same sector, in order to deepen the sectorial analysis and enable the development of recommendations for public policies aimed at fostering eco-innovation projects. In this sense, contributing with recommendations for the development of innovation platforms geared towards sustainable mobility and transportation.

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