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Chasing Eco-advantage: Unravelling Who Creates and What Determines

Radical Eco-Innovations in Brazil

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Abstract

The recognition of global-scale environmental threats gained room into international discussions since the second half of the 20th century, and with it much attention goes to how businesses address their environmental concerns. This paper draws a map of eco-innovative activities within Brazilian firms, their motivations, processes and results, based on data from an unprecedented survey carried out with 98 Brazilian firms in 2012. The purpose of the paper is to describe the profile of firms according to their approaches to eco-innovation; in special, we want to highlight what factors contribute to the occurrence of radical eco-innovations. Besides a descriptive analysis of the outcomes of the survey, this study used a PROBIT econometric model in order to test what determinants of eco-innovation improve the probability of having a radical outcome of the innovation. Results show that market-driven regulatory determinants, along with R&D activities

focused on environmental outcomes increase the probability of radical innovations to take place. Two main conclusions are worth stressing: first, that radical eco-innovations take place in firms with a focused strategy to attend a specific niche market of technological innovations. By providing alternatives to the existing technology and production methods, those firms will make possible the transition towards a new paradigm of production, in a greener, carbon free economy. Second, the regulatory push seems to be helping create markets for the new, environmentally beneficial technologies or products, and should therefore be strengthened in order to allow an even broader dissemination of greener production practices.

Chasing Eco-advantage: Unravelling Who Creates and What Determines Radical Eco-Innovations in Brazil

INTRODUCTION

The recognition of global-scale environmental threats gained room into international discussions since the second half of the 20th century. Awareness came up with the somewhat recent scientific observation that “the rapid and accelerating technologically driven modification of our natural surroundings has changed them beyond the wildest Neolithic dreams” (Grey, 1993:464). These risks stimulated consciousness about the necessity of transitioning towards more sustainable use of natural resources.

Light has been shed on the environmental capacity to resist to our patterns of development, creating skepticism over utilitarian frameworks in which natural resources are 'taken for granted'. Environmental responsibility consequently contrasts with previous understandings of progress as inevitable marches forward, assuring mastery over natural resources (Cohen, 1997). Instead of exogenous to human activities, natural systems are complex and co-evolving dynamics, directly affected by technological trajectories and social behavior.

Effects of technologies towards nature consequently raised questions about whether past trends of prosperity can be broadened (or even sustained) in future (Clark *et al.*, 2005). The need for a better harmonization between economic development and the nature calls for a drastic change in the ways that businesses impact the environment. For this to take place, a new paradigm for production, consumption and disposal is required. However, changing paradigms is never an easy task. It demands innovative efforts to bring up alternatives that combine the needs of the economy, society and environment.

Innovations are, therefore, central to this debate. They are concomitantly sources of environmental threats and mechanisms for finding a way out, for escaping from a potential unwanted future (Zizek, 2011). The last feature is represented by what has been labeled as eco-innovations: novelties in processes, products, services and business models that can reduce man-induced environmental impacts. The imperative here, according to Jacobs (1997: 9), is shifting “onto a new path of economic development in which technological advances and social changes combine to reduce, by an order of magnitude, the environmental impacts of economic activity”. This path should be pursued through exploiting opportunities for innovation that concomitantly enhance environmental and economic performance.

Eco-innovations are thus a tool with which firms engage in the shift to a new paradigm of capitalism production. Despite its importance, little is known about the subject, especially in an emerging country such as Brazil. In order to contribute for a better understanding of the Brazilian “eco-innovative” landscape, this paper draws a map of eco-innovative activities within Brazilian firms, unraveling their motivations, processes and results. We present data from a recent and unprecedented survey carried out with 98 Brazilian firms in 2012. The purpose of this paper is to provide an overview of how Brazilian firms are tackling environmental issues related to their businesses and whether they are seizing the opportunity to make such issues a source of competitive advantage. We pay special attention to the group of firms that perform radical eco-innovations. These firms are the ones that will make possible the transition towards a new paradigm of production, in a greener economy.

The remainder of this paper presents, at first, the theoretical background concerning innovation for sustainability and conceptualizes eco-innovations. Later we present our database and research methods. We run a probabilistic regression to find out what factors contribute to the

occurrence of radical eco-innovations among Brazilian firms. We conclude with some reflections on the findings of the econometric exercise while linking them with theoretical frameworks.

THEORETICAL FRAMEWORK

Innovation for sustainability

Written by a commission convened by the United Nations, the Brundtland Report was as a milestone for the institutionalization of the term ‘sustainable development’ and its further integration into political agendas (Sachs, 2000). Sustainability here brings in its core the idea of satisfying current needs without jeopardizing needs of future generations (WCDE, 1987). This term mingles together concerns that are not necessarily new, such as poverty, disruption of livelihoods, and threats to 'survival of mankind'. In fact, much of this discussion has been casted in terms of a balanced integration between social, economic and environmental dimensions – the so-called triple bottom line (Elkington, 1998).

Sustainable development as a concept has spread quickly and became central in political agendas, strategies of firms, and agreements conducted by international organisations. Indeed, the concept raised by the Brundtland Report was further reinforced and specified by international meetings. Rio-92 stated principles on forests, climate change, biodiversity and issued the Agenda 21, mobilizing the establishment of blueprints of desired actions (UNCED, 1992). Meetings conducted ten and twenty years later, namely the Johannesburg World Summit, and the Rio+20, reaffirmed commitments in pursuing sustainable alternatives through the engagement of nations, firms and civil society (Kates *et al.*, 2005).

The role played by innovation to chase sustainable pathways has varied between scepticism and optimism, both among scholars and political representatives. In several international discussions, such as Rio-92, Johannesburg Summit, and Rio+20, the tone has been of harnessing innovation so to achieve the goals linked to an environmentally sustainable human development. Indeed, with the rapid spread of sustainability throughout political agendas, efforts to implement sustainable development have emphasized the lack of technical knowledge, rather than social and political mobilization (Clark *et al.*, 2005). Other organisations, such as NRC (1999:7), bring a different perception, stressing that a successful transition towards sustainability “could be achieved without miraculous technologies or drastic transformation of human societies”; requiring, on the other hand, capabilities, social learning and political will to shift to alternatives that are already viable with existent technologies.

Though with distinct emphasis on the relevance of radical technologies to leapfrog unsustainable trajectories, it seems clear that innovation, in its broad meaning, occupies a central place in these discussions. This is because innovation is linked to *change*, and sustainability discourses made clear that society cannot follow the same behavioural and technological tracks pursued in the last centuries.

In order to better understand the role played by innovation in discussions around sustainability, it is important to conceptualize what innovation means, according to evolutionary economic theories. It can be characterized as a continuous, cumulative, systemic, non-linear, path-dependent and generally chaotic process (Van De Ven, 1986; Tidd, 2001). Innovation consists not only in commercializing new products, services or technologies, neither only in generating new processes or business models. It also aggregates processes of market diffusion, as well as absorption and imitation of novelties created somewhere else – as long as they bring an

underlying learning process, which stimulates new dynamic capabilities (Teece, 1998). Moreover, they can be classified in terms of impacts they generate – can be engendered as radical (disruptive) or incremental (Freeman and Perez, 1988; Christensen, 2000).

Innovation for sustainability thus includes new services, products, processes, technologies, business models, as well as diffusion of existing novelties, as long as they help shifting towards the new paradigm of sustainable development. They can be essentially different to each other, having different impacts and targeting different objectives. However, to be qualified as ‘sustainable’, it is essential that these novelties – combined with change in social behavior – contribute to a future in which environmental responsiveness, social inclusiveness and economic performance are better harmonized.

In this context, innovation with a positive environmental impact became a specific field of investigation, and the term eco-innovation became disseminated. Next section presents the conceptualization of the term and a review of the literature on the types and determinants of eco-innovation.

Eco-innovations: concepts and determinants

Innovation is a critical concept for dealing with environmental vulnerabilities and strengthening the resilience of nature towards possible disruptions within its boundaries. The Stockholm Resilience Centre is one among a handful of organizations investigating “biophysical boundaries at the planetary scale within which humanity has the flexibility to choose a myriad of pathways for human well-being and development” (Rockström, 2009:6). In its preliminary analysis, humanity has transgressed three boundaries (namely climate change, biodiversity loss and nitrogen cycle). Despite knowing what the boundaries are (and impacts of human activities

upon them), the study recognized significant uncertainty about thresholds for environmental change beyond return; duration over which system's boundaries can be transgressed; and nature's ability to return to safe levels (Rockström, 2009). The search for solutions to such threats demands finding new relationship patterns between society and the nature, which will ultimately drive the economic actors towards a new paradigm of production, consumption and disposal.

These environmental burdens are, in fact, not seen exclusively as constraints to human activities, but also as opportunities for economic and social prosperity. Environmental harm by industrial operations can be seen as “unnecessary waste, inelegant design, and longer-term comparative disadvantage” (Cohen, 2006:41). These win-win situations – both for economic and environmental performances – have been described, for instance, by Hart (1997) and Porter & Van de Linde (1995).

While Hart presented opportunities for firms to drive innovation and to crystalize a growth trajectory through the internalization of environmental concerns, Porter and Van de Linde postulated (and confirmed) a hypothesis that environmental regulations foster efficiency and innovativeness – and, accordingly, are not constraints to economic activities, as commonly presented in political discourses, but rather opportunities for driving competitiveness. Indeed, previous works corroborate the importance of environmental regulations for the occurrence of eco-innovations in German (Horbach *et al.*, 2012) and English companies (Demirel and Kesidou, 2011).

Similarly, authors from the self-nominated 'ecological modernization' challenged the trade-offs between economic activity and the sake of nature, focusing on simultaneous improvements in human welfare and environmental stewardship. Initially proposed by Huber, this theory describes a hyper-rational strategy for correcting ecological harms of contemporary

practices (Cohen, 1997). By encouraging flexible and precautionary governmental and industrial strategies, society is able to spur green innovations and continuous improvements towards environmentally-friendly technological trajectories. These new technological paths should be pursued through exploiting opportunities for innovation to enhance environmental performance of industrial processes, and modernity is seen as a new phase of civilization, in which a super-industrialization is organized around sophisticated environmental technologies (Cohen, 2006).

Following this optimistic perspectives towards technical solutions to environmental hazards, several studies dating from the 2000s have embarked in the task of conceptualising eco-innovations, which can be synthesized in the following:

Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or manner of doing business that is new for the organization (developing or adopting these) and that results, through the life cycle, in a reduction of environmental risks, pollution and other negative impacts of the use of resources (including the use of energy) compared to relevant alternatives (Kemp and Pearson, 2007: 7).¹

When dealing with eco-innovation, the gain can be translated as environmental benefit attained (cleaner air, more available water, etc.), as well as economic outcome for the firm. Innovations can be essentially radical or incremental; the radical ones being discoveries that completely disrupt with the current course of things, the incremental ones adding significant improvements to the already existing products or processes. Besides that, eco-innovations can fit into different categories, described on Table 1.

¹ By relevant alternatives is understood the technologies and/or processes in use in organizations at the moment of implementation of the innovation (Kemp and Pearson, 2007)

Insert Table 1 about here

The first category covers the environmental technologies. These may be remedial (end-of-pipe), which seek to reduce the impact caused by an existing technology; or they can also be clean alternatives to the usually more polluting technologies. The second category covers the methods of organizational management that incorporate environmental issues. This includes the strategies applied to production processes and the whole infrastructure and logistics of companies for the reduction of environmental impacts. Internal audits, staff training and even waste and pollution prevention schemes are examples of this category (Kemp and Foxon, 2007).

In third place come the environmentally beneficial products and services, such as green certifications or biodegradable products. As regards services, these can include works of waste and pollution management, environmental consultancy, among other services that seek to reduce the environmental impact resulting from productive activities. The last category covers the innovations of systems, which “involve a wide range of changes in technological production, knowledge, organization, institutions and infrastructures and possibly changes in the behaviour of consumers.” (Kemp and Foxon, 2007: 9). It covers alternative systems of production and consumption that are more environmentally beneficial than existing systems. An example of a system innovation is organic agriculture and renewable energy systems (like the one required for electric cars). Such innovations act comprehensively, reaching a wide range of actors and reverberating in various sectors of economic activity.

The definition of eco-innovation prioritizes the result over the motivation of the firm to innovate. If the environmental result was intentionally reached or if it occurred by chance, little is known by the current literature. Learning about the determinants of eco-innovations, however, is central if eco-innovations are to be systematically fostered.

Four factors can be considered the main drivers of eco-innovations, according to the literature (Belin *et al.*, 2009; Horbach and Rennings, 2012). These are: regulations, market factors, firm-specific factors and environmental concerns. They are presented on Table 2.

Insert Table 2 about here

Environmental regulations are viewed as a way to induce firms to internalize the externalities created by their activities. As such, they would impose extra costs for firms and act as constraints for competitiveness. Porter and van der Linde (1995), however, introduced a different perspective to this matter by claiming that environmental regulations force firms to innovate and improve resource efficiency and productivity. Regulations would therefore increase turnover and profits (Porter and Linde; 1995; Bernauer *et al.*; 2006; Belin *et al.*; 2009).

Market factors are the pressures on companies brought by consumers and competitors. Customer demands are proven to be a strong driver of firm behaviour. In regard to environmental concerns, consumers are increasingly aware of threats, and equally interested in knowing what firms are doing about it. Therefore, there are several opportunities for creating new products and services that better suit to these new market demands.

Factors internal to the firm, on the other hand, are mainly its technological and innovative capacities, its strategies, key-competencies, as well as the search for higher productivity, eco-efficiency and other cost reduction benefits (Bernauer *et al.*, 2006).

Pure environmental motivations are those based on strong ethical values driving firms to do the right thing, regardless of regulations or consumer pressure. It is strongly built on the top management values that encourages the firm to take their role in society very seriously (Bansal and Roth, 2000).

METHOD

Sample and Data Collection

The present study is based on an unprecedented survey carried out with Brazilian companies in manufacturing and services sectors. The survey was conducted between May and July, 2012. A stratified random sample was utilized, with companies of different sizes. Ninety-eight (98) companies replied to the questionnaire. Such a sample is within the 95% reliability interval with significance of 10% expected for populations between 50 and 100 thousand, the approximate number of companies existing in Brazil (Rea and Parker, 2005).

The survey design was based on an extensive literature research on similar surveys carried out earlier; also, the Brazilian Innovation Survey (PINTEC) questionnaire design was used as a base when similar questions were applied.

The main purpose of the survey was to provide a broader understanding of eco-innovation in Brazilian firms. For that purpose, the questionnaire is divided into five sections: A- general company data; B- general information on the innovative activities of the company; C-

objectives of the environmental innovations; D- processes of the environmental innovations; E- results of the environmental innovations.

Section A contains questions regarding capital ownership, revenues, share of revenues obtained from exports. Firms were also questioned about the importance of environmental issues for the business, as well as about the existence of initiatives related to environmental management (ISO 14001, sustainability report, among others). Section B presents questions regarding their innovative activities, the amount invested, the occurrence of R&D activities and the sources of funds intended for innovation. Section C inquires more specifically about the occurrence of eco-innovations and their nature. Section D deals with the processes involved in the innovation activity; in special, the sources of external knowledge used and whether cooperative arrangements for innovation had taken place. Finally, section E enquires about the results of the eco-innovation, as well as the possible obstacles faced in its realization or which prevented it from being successfully implemented.

Categorizing firms according to their eco-innovative drive

Our quantitative analysis departs from an earlier categorisations of firms proposed by the MEI Project, according to their innovative approach to eco-innovation, which can be essentially passive or proactive (Kemp and Foxon, 2007). We consider that the decision to eco-innovate or not reflects the firm's engagement with environmental issues, that can also be categorised from denial to strong commitment. This engagement evolves with time, as firms matures or forcedly complies with environmental concerns. It is also significantly affected by the capability of firms to foresee competitive advantages from a more responsible, "green-wise" strategy. We merge

Kemp and Foxon (2007)'s categories of eco-innovativeness of firms with a 4-stage taxonomy proposed by Esty and Winston (2009) to classify firms according to their environmental strategy:

- 1) **Eco-resistance:** firms that have no eco-innovative activities and no environmental strategy, simply ignoring the environmental concerns around them;
- 2) **Eco-compliance:** a second stage in which firms tackle environmental issues due to regulatory pressure by implementing or developing eco-innovations but with no specific strategy for such;
- 3) **Eco-efficiency:** firms that intentionally implement eco-innovations, either developed in-house or acquired from others with the purpose of achieving better performance, especially better efficiency in the use of resources;
- 4) **Eco-advantage:** firms that undertake eco-innovations strategically, developing green products, services or technologies as their core business, or as a significant share of their activities. This group of firms most often undertakes radical innovations that modify the way things are done or replaces products or processes that are environmentally prejudicial.

Stages 1 and 2 represent a reactive approach to environmental issues, whereas stages 3 and 4 reflect a proactive positioning of firms. Firms on stages 3 and 4 are working with two important aspects of the environmental impact in their businesses: the downside and the upside. Firms on stage 3 are most focused on reducing the downside, notably reducing costs and keeping risks at the lower possible level. Stage 4 is achieved when firms try to enhance the possibilities

on the upside of the environmental issue: generating revenues from creating and exploring new market niches (Esty and Winston, 2009).

Figure 1 presents the four categories, establishing a relationship between the environmental commitment of firms, their eco-innovative efforts and the potential of value generation present in each level of commitment and innovativeness. As the firm's eco-innovative effort increases, so does the possible value generation obtained from the result of the innovation. In other words, it means that, the more strategically firms undertake innovation for the environment, the more it translates into economic (above all, but not restricted to) benefits of this effort.

Insert Figure 1 about here

This categorisation will later in the paper be applied to our sample of Brazilian firms in order to provide us an overview of the current engagement of firms to the environmental issues and how passive or proactively they are positioning in this regard.

Research Questions and Hypothesis

This work aims at investigating the following research questions:

- What are the drivers of radical eco-innovations among Brazilian firms?
- What is the profile of firms that are bringing radical eco-innovations to the market?

In order to trace the profile of radical eco-innovative firms we run an econometric model that tests the following hypotheses:

- *H1: Firms that carry out R&D activities with the specific purpose of generating environmentally beneficial products have a higher propensity to generate radical eco-innovations*

It is widely acknowledged that companies with internal R&D activities achieve better results in science-based innovation (Pavitt, 1984), generating novelties with higher impact. Earlier studies have established a relationship between the presence of R&D activities and the occurrence of eco-innovations both in Brazilian (Young *et al.*, 2007) in German and French firms (BELIN *et al.*, 2011). Nevertheless, no studies were found relating the existence of environmental R&D to the occurrence of specific types of eco-innovations. It seems reasonable to expect that such strong and targeted effort of R&D is related to radical innovations.

- *H2: Firms driven by market determinants have a higher propensity to generate radical eco-innovations.*

It seems reasonable to expect that firms driven by market determinants, in special the purpose of creating new market segments, will generate more radical innovations than other determinants – whereas regulatory policies tend to drive firms to adopt innovations in specific areas, such as waste and recycling.

- *H3: firms that establish partnerships for innovation have a higher propensity to generate radical eco-innovations.*

The literature on eco-innovations tells us that firms have much to benefit from the establishment of cooperative arrangements (Belin *et al.*, 2011; Hart, 1997). A variety of actors/stakeholders involved in the innovation process brings different knowledge and reduces risk, costs and uncertainty. Previous studies have observed that the establishment of cooperation influences positively the probability of occurrence of eco-innovations (Belin *et al.*, 2011; Arruda *et al.*, 2012). Moreover, since eco-innovations are often linked to knowledge that is at the frontier – facing higher uncertainty and requiring more complexity than business-as-usual – those would be most benefited by cooperative arrangements in the innovation process. External partnerships increase the range of knowledge and capabilities available in the innovative process.

Next section presents the general descriptive findings as well as the results of the probabilistic regression, so to test the three above-mentioned hypotheses.

Econometric Model

The dependent variable of our model is *radical innovation*. It assumes value 1 ($Y=1$) when firms report that the outcomes of their innovation process were new to the world; it assumes value 0 otherwise ($Y=0$). Due to the binary character of the dependent variable we use a probabilistic regression that can be briefly described as follows: the occurrence of a radical eco-innovation is influenced by several factors that are summarized by a vector x . Therefore, we need to estimate the following probability:

$$\text{Prob}(Y=1|x) = F(x, \beta)$$

We assume that the sample has a normal distribution: $\text{Prob}(Y=1|x) = \Phi(x'\beta)$. The parameters β reflect the impact of marginal changes in x on the probability (Greene, 2008: 772).

The variable describing the *determinants* of eco-innovation can be classified into the following categories: regulatory push/pull; technology & factors internal to the firm; market determinants; environmental concerns. It assumes value 1 when the firm reports each of the determinants as their main motivation to eco-innovate.

The variable *size* is obtained from the natural logarithm of the firm's net revenues. The variable *cooperation* is binary and takes value 1 when a firm reports having established cooperative arrangements for innovation, and value 0 otherwise. The variable *age* is the natural logarithm of the number of years of the firm's foundation. The variable *EMS* is binary and assumes value 1 when firms have adopted environmental management systems, and 0 otherwise. The variable *foreign* is binary and assumes value 1 when the firm is mostly owned by foreign capital, and 0 otherwise.

RESULTS

General Results of the Survey

In general terms, we can say that Brazilian firms from our sample are aware of environmental issues that affect their businesses. They are addressing these issues through a series of initiatives (waste management programs, energy consumption reduction plans, EMS, creation of a "sustainability team" within the firm, among others). Innovative approaches, in special the more radical and disruptive innovations, are nevertheless limited to a specific group of firms.

From the 98 firms that replied to the survey, 47% reported having carried out eco-innovations in 2011. One third of such were organisational innovations mostly referring to waste

recycling or energy reduction initiatives. New environmentally beneficial products or processes represent 38% of the innovations carried out among the sample. The creation of cleaner technologies was reported only by 28% of the sample.

When we asked about the determinants for carrying out eco-innovation, we were surprised to acknowledge that environmental concerns were the key determinant for only 13% of eco-innovative firms. The creation of new businesses was alone the main determinant – 28% of firms reported this as their key driver to eco-innovate. Cost reduction was the third most important factor (22%), followed by the search for brand reputation/image improvement (20%). Regulation was only mentioned as the central determinant for 13% of firms.

Such results seem to suggest that in Brazil there are some key aspects to be observed: regulatory policies seem not to be signalling to the market in regard to potential market creation, or do not exist sufficient regulations to generate market shifts. The fact that a good share (a third) of eco-innovations relate to waste recycling is evidence that one important governmental policy – the Solid Waste National Program (PNRS, in Portuguese) – is moving firms to action, but still limits to compliance.

Other important (and quite surprising) aspect is that approximately a quarter of eco-innovative firms have the purpose of creating new markets and/or expanding to new business niches. This group is of special interest due to the fact that their products – mostly technologies, but possibly also management systems – when disseminated in the economy, will enable other firms to perform their productive activities in a more environmentally positive way. This niche of firms has eco-innovations as their core business and has a strategic approach to the environmental concerns.

We now shift our attention to the kinds of eco-innovation the firms in our sample have undertaken, according to the categories presented in the Method section. First, there is the group of non eco-innovators, that we named “eco-resistance”. Such firms opt for turning a blind eye to the environmental issue. This is our largest group, comprising 54% of firms.

The second category, representing a stage ahead in the firm’s responsiveness to environmental issues, “eco-compliance”, has 16% of firms. Many of these firms are driven by regulations recently established in Brazil and are acting in order to comply with these requirements. Most eco-innovations reported by this group of firms refer to incremental innovations aimed at reducing waste generation, water consumption or energy expenditures.

“Eco-efficiency” is the stage where 20% of the sample stands. The search for better performance while saving natural (non-renewable) resources is the determinant of this group’s approach to the environment. Firms at this stage are one step ahead of the earlier stage, as their eco-innovations have a characteristic of concerning with cost reduction.

The “eco-advantage” stage has only been achieved by 10% of the sample. Most firms at this stage are generating knowledge and launching innovations that are radically changing markets and production processes. Unfortunately this is the smallest group, but a central one, as these companies are leading the “green competitive wave”. Among this group are technology-based firms that have an eco-innovation as their main product, setting the environment at their core business.

The distribution of firms from the sample in the four categories proposed in the paper are presented on Figure 2.

Figure 2 Here

In order to have a better understanding of the profile of firms within this last group and what drives their radical eco-innovative behaviour, the results of the probabilistic regression (whose model was previously described in this work) is elucidated in the next section.

Probabilistic regression

Table 3 brings the results of our probabilistic regression, which had a (binary) dependent variable: the occurrence of radical innovations (taking value 1 for yes, 0 for no). Explanatory variables were those mentioned in the hypotheses raised: the different motivations reported by firms to eco-innovate; the existence of R&D activities specially focused on environmentally positive outcomes; the establishment of cooperative arrangements for innovation.

We also asked firms about their age, capital ownership, revenues (in order to measure firm size) and whether they have environmental management systems (EMS), used as control variables.

As expected, the existence of R&D activities specifically oriented to the achievement of environmental outcomes proved to have a positive effect on the occurrence of radical eco-innovations. Once more it became evident that radical outcomes usually demand considerable investments in research and development. In the case of eco-innovations, this tends to be even more important. Indeed, eco-innovations are often more science-based than the ones emerging within traditional systems, as a shift to environmentally friendly alternatives sometimes diverges from the prevailing sociotechnical regimes. We therefore accept hypothesis 1.

Regarding hypothesis 2, two different results came out. First, we corroborated our hypothesis that firms driven by market determinants, and in special those in search of new market segments, have radical innovations as an outcome. We expected that firms driven by compliance motivations would not generate radical innovations, as they mostly adopt innovations developed elsewhere, or lead to end-of-pipe innovations (Horbach *et al.*, 2012). Nevertheless, results have shown that, differently from expected, regulatory determinants also have a positive effect on the occurrence of radical innovations, though not so intensively as market determinants.

A possible explanation for that is the fact that, once recent policies are driving firms to adopt cleaner production processes, some firms are benefiting from this new demand by providing firms with technologies that enable them to adopt cleaner production methods. In this case, some of the radical innovative firms would be operating exactly in the sectors that regulations have already been established. The solid waste program, as earlier mentioned, has boosted firms and raised numerous innovative initiatives among Brazilian firms. Hypothesis 2 is therefore accepted, but the positive effect is extended to the regulatory determinant.

Furthermore, cooperative arrangements for innovation had a positive sign in our model. However, results are non significant in the model. We cannot draw any strong conclusion in this regard, and therefore hypothesis 3 cannot be accepted. The control variables used in our model did not show either significant results and, therefore, conclusions cannot be drawn in this regard. Only the variable referring to firm age had a positive and significant result, suggesting that firms already established in the market have a stronger propensity to develop radical innovations. It seems reasonable to relate such positive effect to the accumulation of experience and knowledge by the firm, contributing to more successful innovative efforts.

Insert Table 3 about here

CONCLUDING REMARKS

The purpose of this paper is to present data from an unprecedented survey of Brazilian firms mapping their eco-innovative patterns. We draw special attention to the group of firms that have achieved the stage of “eco-advantage”, in order to find out what drives radical innovation and what are the main characteristics of this group.

Our results show that the main innovation determinant influencing radical outcomes regards market-driven factors, specially the purpose of creating new market segments. This result corroborates with theoretical observations suggesting that spurring green innovation can be seized as opportunities, instead of mere constraints to economic activity. These opportunities are both to fulfill the existing demands of consumers for environmentally friendly products (and services), as well as to emulate preferences while creating new market segments. The later tends to be potentially disruptive, as it generates new technological trajectories, business models, products and services.

Other important determinant of radical eco-innovation consists on regulations, due to the imperatives of complying with environmental policies. This observation supports the Porter hypothesis and the perception that environmental regulations can stimulate competitiveness of firms by forcing them to invest on energy efficiency and waste reduction, pay greater attention

on their product's life cycle, and so forth. This result in the Brazilian scenario is similar to the findings in other countries, such as England and Germany, and diverges to the widespread idea that weak environmental laws have positive impact on competitiveness of countries. Although weak laws might attract multinationals unwilling to cope with high environmental standards, strong laws are capable of crystalizing a growth trajectory through stimulus to innovative behaviour.

It is also important to bring to attention the fact that regulatory policies, though not yet a main driver of eco-innovations in Brazilian firms, already show its power in creating market for specific technologies and environmental solutions, such as waste management. It signalizes the strength that policies have to shape environmental impacts of businesses.

Performing R&D activities oriented to environmental outcomes, as expected, has also proved to have positive effect on the occurrence of radical eco-innovations. This goes along with the widely acknowledged theoretical description that internal R&D achieves better results in science-based innovation (Pavitt, 1984), such as disruptive novelties involving environmental stewardship. It is interesting to observe, though, that R&D activities are usually tagged to technology-pull (sometimes mission-oriented) initiatives, while this study has shown that market pressures are among the most important determinants to generate eco-innovations.

Furthermore, the descriptive results presented in the previous section stressed the existence of this special group of radical eco-innovators in our sample of Brazilian firms. Even though they exist, their size is still rather limited. It means that there are few firms seizing the opportunities raised by deliberately increasing environmental concerns into their strategies. On the positive side, the existence of the group *per se* means that the opportunities do exist and could be seized by many other firms.

Finally, it is important to stress that this study was limited to 98 enterprises. Although the sample includes enterprises from different sizes and sectors, it is not representative of the Brazilian landscape. Enterprises were targeted according to their potential to contribute to the understanding of determinants and profiles of eco-innovators, not aiming to characterise or generalise the findings to the whole population of Brazilian firms. This work also focused on testing specific hypothesis through the use of econometric tools and descriptive statistics, and, therefore, a later qualitative in-depth study would contribute to better understand the variables and their interconnection.

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Table 1. Taxonomy of Environmental Innovations

Innovation	Examples
Environmental Technology	<ul style="list-style-type: none"> - Technology of pollution control - Clean technologies - Technology of green energy
Organizational Innovation	<ul style="list-style-type: none"> - Schemes of pollution prevention - Environmental management - Management of the value chain
Innovation of Product and Service	<ul style="list-style-type: none"> - Ecologically beneficial products - Ecological and/or less resource intensive services
Green Innovation of the System	<ul style="list-style-type: none"> - More ecologically beneficial alternative systems of consumption and production

Source: adapted from Kemp and Foxon, 2007.

Table 2

Regulatory push/pull (R)	<ul style="list-style-type: none"> - implementation of environmental policies - anticipation of environmental regulations
Technology & factors internal to the firm (I)	<ul style="list-style-type: none"> - cost economies - better productivity - innovation in organizational management systems

	<ul style="list-style-type: none"> - R&D activities - networks, cooperation
3. Market determinants (M)	<ul style="list-style-type: none"> - growing awareness of consumers about environmental issues - expectation of increase of participation in new market segments
4. Environmental Concerns (E)	<ul style="list-style-type: none"> - environmental concerns from the company

Source: based on Belin, Horbach & Oltra (2009) and Horbach and Rennings (2012).

Figure 1: Categories of firms according to their eco-innovative approach

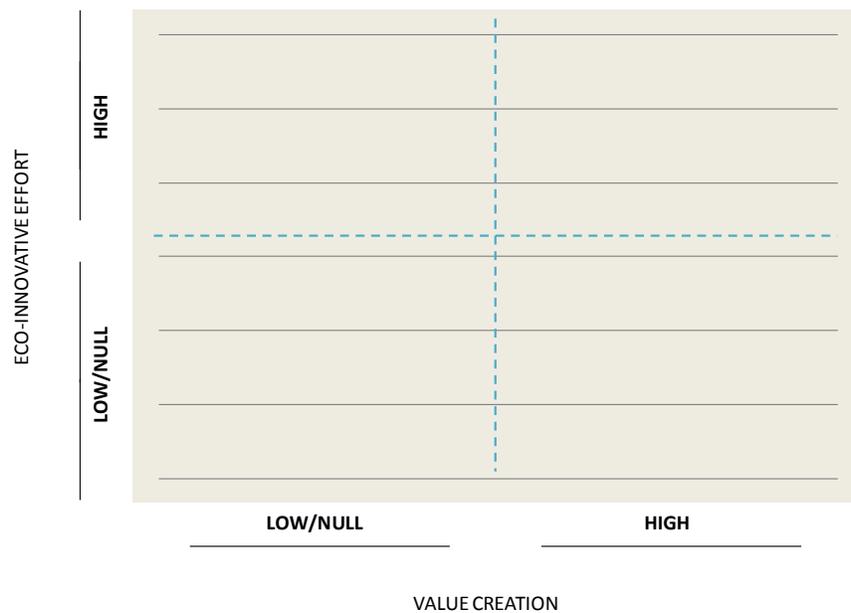


Figure 3: Distribution of firms from the sample in the proposed categories



Table 3: results of the Probit regression

Dependent Variable: Radical Eco-innovation (yes=1; no=0)	
size	-0.118 (0.0987)
E_R&D	1.719*** (0.578)
market	1.760** (0.858)
Environment	1.007 (1.009)
Internal	1.294 (0.823)
Regulation	1.725* (1.009)
COOP	0.00755 (0.572)
EMS	-0.702 (1.214)
age	0.0144* (0.00809)
foreign	0.146 (0.656)
Constant	-0.1 (2.06)
N	56
Prob> Chi2	0.0006
Pseudo R2	0.4376
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	