

INVENTIONS AND SUSTAINABLE INNOVATIONS: THE MODERATOR EFFECTS OF DYNAMIC CAPABILITIES, TECHNOLOGY CHARACTERISTICS AND DEMAND CONDITIONS

José Ednilson de Oliveira Cabral (Unifor)
ednilsoncabral@gmail.com



This paper delineates a conceptual framework about the relationship of inventions externally developed and innovations sustainability levels, regarding economic, social and environmental impacts, at the business unit-level, in the context of distinct firms dynamic capabilities, technological characteristics and market conditions. The model shall be applied to test whether the relationship invention and sustainability level of the derived innovation is influenced by differences in the selected firms' internal and external dimensions namely: 1. dynamic capabilities, such as adaptive capability (to identify market opportunities); absorptive capability (ability to absorb external) and innovative capability (ability to create knowledge); 2. technological characteristics (whatever the name, regime, trajectories, etc.); and, 3. demand conditions (evolution and trends). The research question: how differentiated by dynamic capabilities, by technology characteristics and by demand conditions are the sustainability levels of innovations developed outside firms, in the Brazilian agro-food chain? Hence, a bibliographical research about the themes was carried out and an in-depth study of the selected literature was undertaken. Specifically, we revise the proposed theoretical approaches; critically assess the suggested analytical models; and conclude with an integrative model focusing on the relationship above. From this revision, we could model that a firm possessing higher levels of adaptive, absorptive and innovative capabilities focuses on adopting innovations which bring not only high profits, but also social equity and environmental protection. In this case the firm is orientated by an innovative strategy focused on sustainable outcomes, its dynamic capabilities may direct toward concentrating its assets on developing capabilities, which results in higher levels of sustainability in new products or services. In contrast, the lower levels of adaptive, absorptive and innovative capabilities lead the firm to focus on a cost leadership innovative strategy, which results in lower levels of sustainability in new products or services. Hence, the sustainability of the innovative outcome is greater in firms with high levels of adaptive, absorptive and innovation capabilities, which in turn is affected by technology characteristics and

demand conditions. From this defined framework, we will research how firms evolve on the adoption of technologies externally developed, how this evolution is impacted by capabilities and contextual factors, and how the results reflect sustainability performance, at Brazilian ag

Palavras-chaves: sustainability, technology, innovation, capabilities, demand

Introduction

Nowadays, it is amply shown that many elements other than just the invention (technology device) itself are important for innovation success. Rothwell (1992), for example, suggests an integrated approach of the innovation process which connects the internal functions within firms and to the broader scientific and technological community and to the marketplace, in a complex network of intra- and extra-organizational linkages.

In this work, innovation success means sustainability. According to Millstone et al. (2009) the development, adoption and sustainability of appropriate food innovations require the engagement of adopter's knowledge and capabilities. For them, "in the absence of those capabilities, innovations will either not be adopted or adopted ineffectually or be discarded entirely" (p.10).

As an example of the importance of innovative capabilities to adoption of sustainable innovations, Ockwell et al. (2009) stress that long term, low carbon growth, will happen within developing countries if pursued in such a way as the technology transfer emphasized in political discourses actually facilitate the development of internal innovative capabilities.

For that, Wagner (2008) claims that is of great relevance to know why there is heterogeneity across firms in the capability to pursue sustainability innovation and what underlying capabilities are crucial to realise sustainability innovation.

Besides indigenous innovative capabilities, Ockwell et al. (2009) also stress that a higher rate of agricultural and food innovations with sustainable characteristics should be moderated by technology and demand conditions. In line with this, Millstone et al. (2009) stress that technologies should be appropriate to the socio-economic contexts into which they are introduced to produce an adequate distribution of economic, social and environmental impacts. As an example they quoted the introduction of Green Revolution varieties in the Punjab and the Philippines which amplified the prevailing social inequalities and in the Indian state of Kerala and in Formosa/Taiwan where the effects were socially more beneficial and widespread, due to different and more equitable distribution of land ownership.

Hence, we advance that the effect of contextual conditions and of firm-specific aspects can help to assess the differences in sustainability levels of adopted technologies.

This is in accordance with Teece et al. (1997) attention on what leads to sustainable competitive advantage in conditions of rapid environmental and market change. In this work, rather than competitive advantage we are concerned with sustainability.

Hence, in this paper the goal is to delineate a conceptual framework about the relationship of inventions externally developed and innovations sustainability levels, regarding economic, social and environmental impacts, at the business unit-level (farms and food firms), in the context of distinct firms dynamic capabilities, technological characteristics and market conditions.

The research question: how differentiated by dynamic capabilities, by technology characteristics and by demand conditions are the sustainability levels of innovations developed outside firms, in the Brazilian agro-food chain? In other words: which factors moderate the achieved sustainability level of innovations, whose invention was developed

externally to the innovating firm? The proposition is that the sustainability level of an innovation achieved by innovating firms do not relies solely on inventions but also on other elements.

In methodological terms, the paper is characterized by a bibliographical research and an in-depth study of the literature about the relationship between development and adoption of innovation in food firms and the moderators' effects of firms' dynamic capabilities, such as adaptive capability (to identify market opportunities); absorptive capability (ability to absorb external) and innovative capability (ability to create knowledge); and contextual variables, namely technological characteristics (whatever the name, regime, trajectories, etc.); and, demand conditions (evolution and trends). In this direction, we revise the actual trends in the field and critically assess the suggested analytical models. The proposed integration of the revised models in a synthesis not only will base future empirical research but also serve to managers and public policies makers in their work of assess the process of generation, adoption and technology transfer.

This is an important aim since the literature and research about the relationship above is scarce, in spite of a lever in the attention on innovation processes towards sustainable development. This paper adds to this literature by defining a theoretical framework for examining differences in firms' innovative-related activities and the implications of these activities for a firm's performance and sustainability of the innovative process.

The remaining of the paper is structured as follows: first it is assessed the literature about the relationship development (invention) and adoption (innovation); in the second section it is assessed the literature about the sustainability of innovations; in the third section dynamic capabilities as mechanisms of innovation at firm level are evaluated; the fourth section presents an analysis of the literature about the pressures of technology characteristics and demand conditions on sustainable innovations; the moderator effects of dynamic capabilities, technology characteristics and demand conditions on the relationship invention and sustainability of innovations is assessed in the fifth section; and, the following section presents the devised conceptual model for the analysis of this relationship. Then, the paper is finished with the concluding remarks.

1. Invention and Innovation

To achieve the goal of this paper we need to make explicit the important distinction in the literature between invention and innovation. Following Freeman & Soete (1997) invention refers to the discovery of new methods or materials, i.e. the discovery of new knowledge, whilst innovation refers to attempts to commercialize an invention. As Fagerberg (2005, p.4) put it invention is the first occurrence of an idea for a new product or process, and innovation is the first commercialization of the idea.

In a problem solving framework proposed by Beckenbach and Daskalakis (2003, p.23), 'invention and innovation are distinct as well as interdependent processes embedded in an institutional and social environment'. Although in many cases it is hard to distinguish one from another, in the majority of cases, according to Fagerberg (2005), they are developed in different organisations, present a considerable time lag between them, and demand different roles of inventors and innovators. As Van de Ven (1986, p. 591) observed "while the

invention or conception of innovative ideas may be an individual activity, innovation (inventing and implementing new ideas) is a collective achievement of pushing and riding those ideas into good currency”.

For Khilji et al. (2006, p.532), since ‘an invention is converted to successful innovation only through parallel, directed interactions among organizational, scientific, and market aspects’, it is just ‘one step, with innovation being the whole business process that creates change from invention, development, design, and production to marketing’.

However, according to Beckenbach and Daskalakis (2003), invention as a specific stage of the innovation process is generally neglected in evolutionary economics. For them, this appears to be a somewhat outdated assessment of invention, since invention and innovation are mixed in institutional contexts and present a lot of feedbacks between them.

Here, we will investigate the specificity and the interdependence of invention and innovation assessing the outcome in sustainable terms.

2. Sustainability of Innovations

According to Werbach (2009) the growing evidences of damages caused by environmental catastrophes around the world, ‘have increased the recognition that economic prosperity is intimately entwined with environmental and social sustainability’ and ‘societies and the business that generate economic prosperity are searching for new sustainable patterns of development’ (p.322-3). As detached by Bryson and Lombardi (2009), the rise of the concept of sustainable development in the 1990’s have lead to the inclusion of environmental and later social issues into business decision-making.

In spite of this recognition, there is not a clear consensus on how sustainability-ideas should be formulated (Carrilo-Heromisilla et al., 2009). However, Berns et al. (2009) found in their research that 64% of experts surveyed used one of two widely accepted definitions: the so-called Brundtland Commission definition or the triple bottom line definition, both of which incorporate economic, environmental and social considerations. In this line, Werbach (2009, pp.7-8) stresses that ‘a successful strategy for sustainability is different from and much bigger than just “green”: it must take into account every dimension of the environment in which your business operates – social, economic, and cultural, not just the natural environment’.

According to Bos-Brouwers (2009) sustainable innovation has become nowadays the focal point to deliver evidence for the commitments of companies to the triple P (people, planet and profit) bottom line.

Hence, sustainability is defined here in accordance with the proposal presented by the Brundtland Commission to the UN since it is the most well-known definition of what had become known as sustainable development: “meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987, p.43). From this definition, Dyllick and Hockerts (2002, p.131) suggest the definition of corporate sustainability ‘as meeting the needs of a firm’s direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities etc), without compromising its ability to meet the needs of future stakeholders as well’. This concept is a new and evolving management paradigm since acknowledges that although profit (economic

dimension) is a must for the firm survival, it is not enough for the overall sustainability of a corporation, demanding for this the integration of social and environmental dimensions.

In turn, ‘sustainable innovations are defined as innovations in which the renewal or improvement of products, services, technological or organizational processes not only delivers an improved economical performance (sustain economic growth), but also an enhanced environmental (conserve the environment, minimize environmental impact and protect the natural environment) and social performance (improve quality of life and quality of employment), both in the short and long term’ (Bos-Brouwers, 2009; Yakovleva & Flynn 2004). The integration of economic, social and environmental aspects distinguishes sustainable innovations from conventional ones (Bos-Brouwers, 2009; Yakovleva & Flynn, 2004). Hence, not every innovation achieves sustainability.

Also Yakovleva and Flynn (2004) show that concerns about sustainability arise either as a direct result of technological developments or as a by-product, as exemplified by the case of the food system where ‘the global sourcing strategies of food manufacturers and retailers is dependent upon innovations in distribution, storage and packaging. There are also, however, a number of benefits that will arise from innovations in the food industry or allied sectors. These will include reductions in waste up to the point of retail sale and more efficient use of energy per unit of output’ (p.227-8).

Hence, the role of firms’ dynamic capabilities on sustainability of innovations is analysed in the next section, and after the role of technology and demand.

3. Dynamic Capabilities

This section presents the result of an in depth analysis of the literature about dynamic capabilities as internal determinants of sustainable innovations.

Nelson (1991) suggests the sustainability of competitive advantage will depend on the extent to which the firm is able to develop capabilities for innovation. Specifically in the case of sustainable innovations, according to Nidumolu et al. (2009), firms face different challenges at each stage and must develop new capabilities to tackle them.

This suggestion dates back to proposals, pioneered by Penrose (1959), that resources and capabilities are the basis for innovations. In these proposals, a set of in-house resources and capabilities, broadly defined to incorporate inelastic productive resources, is claimed to give rise to intra-industry heterogeneity and idiosyncratic (firm-specific) sources of competitive advantage.

The resource-based theory (RBV) foundation is that firms are heterogeneous with respect to their resources and capabilities, which are the basis of the firm growth and competitive advantage. Hence, the strategy literature has put in the last years a considerable attention to understand how firms create, maintain, and enhance these capabilities.

Amit and Schoemaker (1993), Teece et al. (1997), amongst others, distinguish resources from capabilities. Resources refer to firm-specific assets, tangible and intangible, such as physical, financial, human and organization (Barney, 1996). Hence, these resources form stock of available factors owned or controlled by an organization (Amit and Schoemaker, 1993). Examples of resources are production plants, property, organizational routines, workers’ skills, reputation, structure, and brand name. Capabilities involve the use

and adaptation of a set of resources based on accumulated organizational or collective experience, to fulfill the objectives of the firm and provide it with a competitive advantage. In short, capabilities refer to the capacity to deploy the resources of an organization (Amit and Schoemaker, 1993). Resources and capabilities provide competitive advantage when they are difficult to imitate, replicate, or substitute. While resources can be tradable in (nearly perfect) factor markets, capabilities cannot, since they are firm-specific, i.e. created inside firms over time. Hence, authors as Mahoney and Pandian (1992) stress which firms' asymmetries are not defined by the ownership of resources, but by the way that they use these resources (capabilities). Wang and Ahmed (2007), refer to resources as the 'zero-order' element of the hierarchy, since they do not persist over time and hence cannot be a source of sustainable competitive advantage.

The "dynamic capabilities approach" (Teece et al., 1990), is built upon this resource-based theory (RBV). However, as Priem and Butler (2001) stressed RBV is essentially a static theory since it does not explain the evolution over time of the resources and capabilities that form the basis of competitive advantage. Hence, one should not just view a firm as a bundle of resources, but note also the 'mechanisms by which the firms learn and accumulate new skills and capabilities, and the forces that limit the ratio and direction of this process' (Teece et al., 1990, p.11). In this sense, Teece et al. (1997:516) define 'dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments'.

According to Wang and Ahmed (2007), although the notion of dynamic capabilities complements the premise of the RBV, capabilities and core capabilities, and has leveraged vigour into empirical research in the last decade, several issues surrounding its conceptualization remain ambivalent. However, based on the empirical advancement about the subject, they suggest that dynamic capabilities can be analysed by its three main elements: adaptive capabilities, absorptive capabilities and innovative capabilities.

Based on the literature, Wang and Ahmed (2007) define adaptive capability as a firm's ability to identify and capitalize on emerging market. They stress that adaptive is different of adaptation and that measures in the literature of the former are multidimensional, as those proposed by Oktemgil and Gordon (1997) including a firm's ability to adapt their product-market scope to respond to external opportunities; to scan the market, monitor customers and competitors and allocate resources to marketing activities; and to respond to changing market conditions in a speedy manner; and those proposed by Gibson and Birkinshaw (2004) evaluating whether firm's management systems lead the firm to respond quickly to changes in the market and evolve rapidly in response to shifts in its business priorities.

Absorptive capability is defined, following Cohen and Levinthal (1990) seminal proposal, as 'the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends... the ability to evaluate and utilize outside knowledge is largely a function of the level of prior knowledge'. Hence, the development of this capacity is path-dependent which demands a continuous investment to maintain a technical capability in that area.

This absorptive capacity is often reflected in the firm's innovativeness and its ability to exploit new knowledge (Zahra & George, 2002) and is pivotal to the firm's innovative activities (Cohen & Levinthal, 1990). This idea represents a wide consensus and in consequence, according to Abreu et al. (2007), has been widely researched at the level of firms, sectors, regions and nations.

Innovative capability refers to a firm's ability to develop new products and/or markets, through aligning strategic innovative orientation with innovative behaviours and processes (Wang & Ahmed, 2004). In turn, Dodgson et. al. (2008 p.97) define 'innovative capabilities as bundles and patterns of skills used by firms to formulate and implement an innovation strategy involving the creation, extension and modification of those resources used for innovation'. In line with this, Bell (2009) defines innovation capabilities as the 'capabilities needed to imagine, develop and implement new configurations of product and process technology and to implement changes and improvements to technologies already in use'.

Innovative capabilities, according to Pekka and Thomas (2006) cover besides technological capabilities also aspects of management and organization in order to move from technological chance to innovation. For them (p.70), 'the innovative capability of a firm relies on its innovative system, which is embedded in the firm's resource base, management system, organizational structures and business routines'. Hence, the preconditions for innovativeness demands more than R&D activities, alone. 'Innovative capabilities are defined as the firm's capabilities to generate customer value by developing and introducing to the market new products and services or reducing the costs induced by the value creation process' (Pekka & Thomas, 2006). Hagedoorn and Duysters (2002) also stress that innovative capability concerns the specific expertise and competence related to the development and introduction of new processes and products.

In turn, Subramanian and Youndt (2005), Sen and Egelhoff (2000), amongst others, classify innovative capabilities by two different types: incremental and radical. Accordingly, Incremental innovation capabilities are focused on improving existing products and processes; and radical innovation capabilities are focused on developing new products and processes based on entirely different concepts and theories.

With this classification of innovative capabilities according to directions of innovations, we turn in the next section to the role of technology and demand on sustainability of innovations.

4. Technology Characteristics and Demand Conditions

According to Yakovleva and Flynn (2004, p. 237) 'There are four major pressures for the development of sustainable innovations within food supply chain. These are: technology - energy-efficiency, standardization of products and food safety; regulation - EU and UK environmental legislation, strategies and policies in terms of sustainable development, animal welfare and food safety; market - willingness of companies to increase their market share, explore new markets, respond to consumer feedback and decrease employee costs; society - environmental concerns, packaging, waste generation and health issues'. Here, we will analyse the role of technology and demand.

Bell (2009) analysing the cases of changing both the rate and direction of innovation in developing countries claims that this involves not only a supply side perspective (technology transfer) but also the creation and accumulation of capabilities to generate innovation, forces and signals of demand for innovation, and the wider institutional and political context of innovation.

In this sense, Knell (2010) stress that ‘in the context of specific industries and markets, the technological choices of individual innovators and users shape the search for novelties, but the rate of diffusion and economic impact of innovation is closely related to the emerging demand for new products and processes’.

Yakovleva and Flynn (2004, p.237) give us the example of standardization of chickens by size which results from three interrelated factors: firstly, pressures from supermarkets on suppliers to produce consistent products to fit package sizes and shelving requirements (demand-pull); secondly, total mechanization of the slaughtering and processing stages, which requires standardization of products on the line (technology-push); Thirdly, search for an efficient feed-weight ratio (mixed).

Wang and Kafouros (2009) found that the influence of international trade, FDI, and R&D on innovation performance is moderated by technological opportunities or the set of possibilities for technological advance. In this direction, Fagerberg (2005) following historians of technology points that the economic and social effects of an innovation depend in great measure of the specific nature of the technology base.

5. Invention and Sustainable Innovations: The Role of Dynamic Capabilities, Technology Characteristics and Demand Conditions on the Relationship

One can conclude with the analysis above that the relationship between inventions externally developed and innovations sustainability levels is by no means straightforward, since it is mediated by internal capabilities and contextual factors. This section presents a review of the proposed models.

According to Knight and Cavusgil (2004) organizational capabilities are the main sources of firms’ performance. Hence, firms develop knowledge and capacities that make them innovative, which in consequence, leverage their performance up.

As Nelson and Winter (1982) stressed the superior ability showed by some firms to innovate and, consequently, create new knowledge, motivates the development of organizational capacities, comprising of internalized routines and core capabilities. These capacities are linked with superior performance in firms, especially in competitive or challenging environments. For them, an established innovative behaviour makes firms more capable, which in turn is linked to performance. Hence, the relationship firms’ capacities and innovation, in a dynamic way, is bidirectional and mediated by environmental aspects.

In turn, according to Lee et al. (2006) the technological capacity of firms limits the use of the numerous technological options open to them. Hence, Lee et al. (2009) stress that the search for technology opportunity is bounded by technology capability analysis, which affect both the areas in which firms choose to do business, and how successful they will then be in such areas.

Bell (2009) stresses the importance of support to building local capabilities in order to improve sustainability since innovation takes place both in specialised research centres and in organisations in the form of minor modifications to a new technology at every level of values chain.

Chandy et al. (2006) found that firms vary in converting promising drug ideas into launched drugs, due to some factors, such as focus on a moderate number of ideas, in areas of importance, and in areas in which they have expertise.

Kesidou and Demirel (2010) found that organisational capabilities affect the decision of the firm to undertake and increase investments in eco-innovations, whilst demand factors only affect the decision of the firm to undertake these kinds of innovations.

Pekka and Thomas (2006) stressed that capabilities are needed both to exploiting existing technologies and for adopting, combining and employing high-tech technologies, especially in low-tech industries. Besides internal capabilities, the authors also stress that contextual dimensions such as technological opportunities, appropriability conditions and market competition shape the intensity and focus of innovation activities of a firm.

Analyzing the experience of biotech firms in translating inventions to innovations, Khilji et al (2006), propose a model based on a complex interaction of activities influenced by three main sources: marketplace dynamics, organizational capabilities, and scientific and technological knowledge.

From above, we can suggest that the levels of innovations sustainability of the adopted technologies by firms are limited by the technological-innovative capacity of them; by technology opportunities; and by demand factors, with

6. Inventions and Sustainable Innovations: The Model

With the research we intend to measure the sustainability effect of new technologies developed to and adopted in the Brazilian agro-food chain and to advance in the understanding of the moderators' effects of firms' specific and contextual variables on innovative processes and outcomes (sustainability). This section presents the relationship to be assed in the empirical research.

From the review, we can propose a research model (Figure 1) that sustainability levels of adopted technologies are moderated by three capabilities, technology characteristics and demand conditions. In other word, we propose that the sustainability level of innovations depends not only of the inventions per se (or conceptions outside the innovative firm), but also of firms' specific variables, such as adaptive, absorptive and innovative capabilities, and contextual variables, such as technology characteristics and demand conditions.

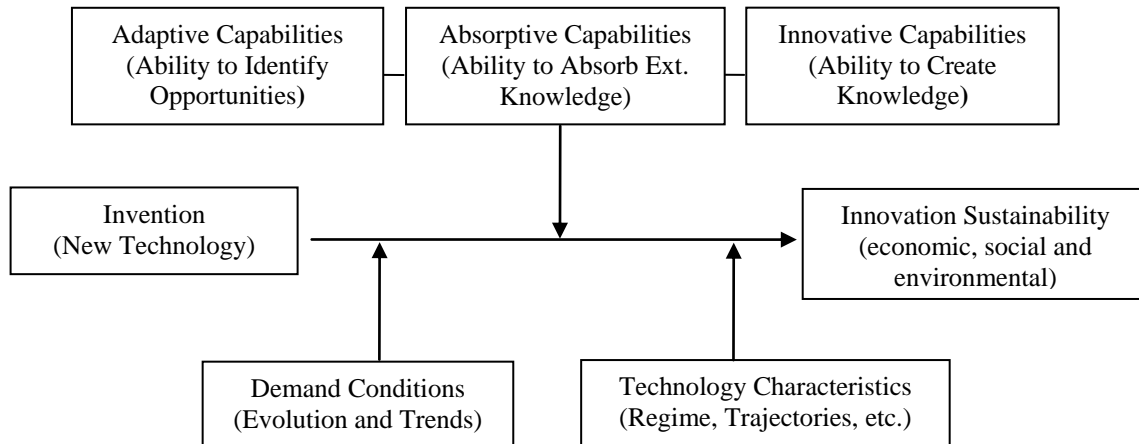


Figure 1. The relationship invention and sustainability of innovations

Hence, we question whether:

1. Diverse inventions lead to different sustainable outcomes, which are the results of sustainability levels of innovation in the presence of different capabilities, technology characteristics and demand conditions? In other words, which aspects are likely to influence the sustainable levels of adopted inventions?
2. Dynamic capabilities affect sustainable outcomes of innovations?
3. The relationship invention and sustainability level of innovation is also influenced by technology characteristics and demand conditions?

Concluding Remarks

This paper, after in-depth evaluation of the literature about some sources and impacts of innovation, delineate a multidimensional model of the relationship amongst invention and innovation.

The model goes in the direction to assess what Ely and Bell (2009) propose regarding Directionality of innovations “The role for innovation in the current context is not merely to drive economic growth, but rather to contribute to objectives of development and **sustainability**, as defined by different actors, at different levels. This may include economic growth (at least in the least productive economies), but prioritises those forms of growth which are more equitable in their distribution of benefits and risks (see below for a discussion of distribution), and which are environmentally sustainable”.

The model will be applied in one research to measure the sustainability effect of new technologies developed to and adopted in the Brazilian agro-food chain and to advance in the understanding of the moderators’ effects of firms’ specific and contextual variables on innovative processes and outcomes (sustainability).

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