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**How are radical innovations developed? An analytical framework to examine radical innovations based on the Values of Cohesion approach.**

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**Abstract**

Our research proposes an analytical framework to examine radical innovations in the Kuhnian sense, based on the comprehension of the values of cohesion of a paradigm. We define radical innovation as the resultant of both a mode of production as a systemic conformation, and an institutional mode. Our research complements existing systemic studies on radical innovations, but under a different vision. Our approach takes into account the structural dimension that maintains a paradigm cohesive. The proposed framework is grounded on the structuralist approach, typical of studies of Human/Social Sciences (e.g., the works of Cl. Lévi-Strauss, F. de Saussure, W. Dilthey). This perspective enables the study of those factors that are manifested as a virtuality: as a belief, an ideological symbol, a cultural value, etc. Our framework was conceived to capture the virtualities, which express the conditions for the development of radical innovations. The proposed analytical framework based on values of cohesion - VCF is constituted of three analytical dimensions: the wheel of relationships, the force of cohesion, and the steps of transmission. The proposed VCF was validated to examine the potential for radical innovation in the change of raw materials sources for the Brazilian chemical

industry, from fossils to renewables. The results of the qualitative field research evidence those virtualities as factors of cohesion of a paradigm. Our research contributes to revitalize the debate on the role of business strategies and governmental policies for the development of radical innovations.

## **How are radical innovations developed? An analytical framework to examine radical innovations based on the Values of Cohesion approach.**

Our research proposes an analytical framework to examine radical innovations in the Kuhnian sense, based on the comprehension of the values of cohesion of a paradigm. We define radical innovation as the resultant of both a mode of production as a systemic conformation, and an institutional mode. Our research complements existing systemic studies on radical innovations, but under a different vision. Our approach takes into account the structural dimension that maintains a paradigm cohesive. The proposed framework is grounded on the structuralist approach, typical of studies of Human/Social Sciences (e.g., the works of Cl. Lévi-Strauss, F. de Saussure, W. Dilthey). This perspective enables the study of those factors that are manifested as a virtuality: as a belief, an ideological symbol, a cultural value, etc. Our framework was conceived to capture the virtualities, which express the conditions for the development of radical innovations. The proposed analytical framework based on values of cohesion - VCF is constituted of three analytical dimensions: the wheel of relationships, the force of cohesion, and the steps of transmission. The proposed VCF was validated to examine the potential for radical innovation in the change of raw materials sources for the Brazilian chemical industry, from fossils to renewables. The results of the qualitative field research evidence those virtualities as factors of cohesion of a paradigm. Our research contributes to revitalize the debate on the role of business strategies and governmental policies for the development of radical innovations.

## Introduction

One of the key questions of business strategies and governmental policies in different countries is how to achieve a position of sustainable competitive advantage in a globalized society.

Despite the complexity of the matter, which entails multiple analytical dimensions, many scholars of different areas of knowledge point out the development of radical innovations as a decisive condition for achieving social and economical successful results (Schumpeter, 1976; Tushman & O'Reilly, 1996; Christensen, 1997; McDermott & O'Connor, 2002; Godin, 2002; OECD, 2005; Perez, 2005). In those studies, a radical innovation is commonly defined as the kind of innovation that disrupts a paradigm.

Traditionally, innovation literature<sup>1</sup> considers innovation, radical or not, under a positivist perspective. The major part of innovation literature examines an experience only by its immediate causes, and not based on the systemic context where the experience is rooted. Thus, this literature considers radical innovations as a result of a specific organization's successful strategy, and accordingly, as a pre-defined entity which determines a change of pattern. The studies under systemic, institutional and social approaches explore the interaction between the innovating organization and the several agents of the environment in which it operates. However, all these analyses are limited both to the elements individually and to their relationships; they do not regard the systems as a whole.

Existing research on radical innovations is important to explain the characteristics, drivers, and relationships between causes and effects within a process of radical innovation, both at the innovating organization-level and within its internal dynamics. Some studies (e.g. Perez, 2005, 2008; Wolfe, 2010) describe the external and internal historical social factors and the relationships between them that determine a process of radical innovation, which is essentially systemic. However, that research does not delve into the understanding of the factor that keeps a paradigm cohesive. Being a social event, radical innovations should be studied in the context of these Human/Social Sciences that recognize the scope of social structures.

Our research considers radical innovations, i.e., the ones associated with a paradigm shift in a Kuhnian sense, as primarily determined by a systemic composition of both a mode of production and an institutional mode. Therefore, to analyze a process of radical innovation, it becomes crucial to comprehend what keeps an institutional system amalgamated or cohesive as a social structure.

In the several theoretical developments in Social/Human Sciences, the structuralist analysis became the general term to designate the difference between a pure functionalist analysis and a "gestaltic" analysis. Under the first, the physical/utilitarian aspects of life explain the social institutions. Within the second, an unifying factor designates the unity or cohesion of a social system, and it has precedence over the material, utilitarian, functionalist aspects. In this sense, an anthropological (or

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<sup>1</sup> In this research, innovation literature denotes the literature that specifically addresses theoretical and empirical studies on "innovation."

sociological) identity will always determine the ways by which a society adopts this or that function. This anthropological identity is usually given by a virtuality - a myth, a symbol, a fundamental value, a belief, and so forth.

Under a different approach from the systemic frameworks that are employed in the studies of innovation literature, the approach to examining radical innovations adopted in our research encompass the understanding of the virtualities – the ruling of collective wills, individual interests, "economic laws", technologies, political frameworks, etc., which support a certain systemic conformation as a unified field, and that are given before the system can be recognized as such.

Accordingly, our research proposes an analytical framework for examining radical innovations - the Values of Cohesion Framework - VCF, considering those virtualities.

The proposed framework is constituted of three interdependent and complementary analytical dimensions: the wheel of relationships, the force of cohesion and the steps of transmission. The analysis is not restricted to the examination of the social relations as an algebraic whole, but instead it tries to fundamentally identify and understand the entities that keep a paradigm prevailing.

The proposed VCF was validated with respect to its analytical capability to examine the potential for radical innovation embedded in the change of sources of raw material for the Brazilian chemical industry, from fossils to renewables.

The results of the qualitative field research evidence the prevalence of those virtualities as factors of cohesion of a paradigm.

It is important to note that our research complements existing systemic/institutional studies that address processes of radical innovation, but under a different approach. The proposed approach takes into account the structural dimension that can establish the conditions for the development of radical innovations.

Our discussion is organized as follows. We begin with a brief discussion of how innovation is studied by innovation literature. Then we outline the studies that specifically address radical innovations within this literature. We observe their most obvious limitations to the analysis of processes of radical innovations. We turn to explore how radical innovations are socially produced. Next, we summarize the structuralist perspective based on values of cohesion, typical of studies in the field of Social/Human Sciences. We then propose an analytical framework for studying radical innovations, grounded on the values of cohesion approach - the Values of Cohesion Framework - VCF. Finally, we show an example of the use of the proposed framework, and discuss the results.

### **Approaches and analytical frameworks for studying innovations**

The analyses of determining factors for successful innovation, be it radical or not, have been usually developed under the Resources-Based View -RBV – the organization capacity and ability to innovate (e.g., Barney, 1991; François et al., 1999; Hamel & Prahalad, 1995; Penrose, 1959), and/or the Market-Based View -

MBV (e.g., Ghemawat, 1999; Porter, 1980) - the exploitation of market demand and governmental incentives. Other studies analyze innovation processes, underlying the cognitive dimension – learning as well as tacit and explicit knowledge, as drivers of innovations (e.g., Cohen & Levinthal, 1989; Nonaka & Takeuchi, 1995; Rosenberg, 1982; Von Hippel, 1988).

Permeating those points of view, the evolutionary approach and other Schumpeterian approaches (e.g., Dosi, 1988, 1997; Nelson & Winter, 1982; Rosenberg, 1976) account for changes in the technological paradigm, which are considered consequences of innovation processes. These studies debate the dynamical nature of processes of technological change. Moreover, those approaches consider that knowledge and technology are developed by means of a complex institutional interaction, the arrangement of which affects the future trajectory of economic change. In this sense, the evolutionary approach deals with innovation processes in a more encompassing way. It considers endogenous and exogenous elements, which determine technological trajectories and paradigms, emphasizing the economic dimension, both in terms of premises and results from the innovation processes.

The studies under multidimensional (e.g., Kline & Rosenberg, 1986; Murmann, 2003; Nelson, 2005) and systemic (e.g., Carlsson & Stankiewicz, 1991; Edquist, 1997; Freeman, 1995; Lundvall, 1992; Malerba, 2002; Nelson, 1996) approaches consider the innovating organization as the agent responsible for a change. They also explore the interaction between the innovating organization and the several agents of the environment in which it operates.

The majority of existing studies under social approaches (e.g., Callon, Lascoumes & Barthes, 2001; Latour, 2000; Orlikowskiv, 2010; Pinch & Bijcker, 1984) examines an innovation under a constructivist basis and not under an essentialist perspective. They view innovation as a social process, interactively created by collective forms of organization, considering any type of innovation, as a social phenomenon. However, the analysis is limited both to the elements individually and to their relationships; they do not regard the systems as a whole. The same goes for the studies about “social innovation” (e.g., Herrera, 1981) rooted in the idea of appropriate technologies (e.g., Clarke, 1976; Dickson, 1974; Herrera, 1981; Schumacher, 1989; Willoughby, 1990), describing innovation as both an activity and a process for achieving or improving life conditions and social inclusion.

Perez (2005, 2008) points out that the world has gone through five distinct stages of economical growth associated with five successive “technological revolutions”, since the end of the eighteenth century, creating new paradigms: the Industrial Revolution; the Age of steam and railways; the Age of steel, electricity and heavy engineering; the Age of oil, the automobile and mass production; and the Age of information and telecommunications, which began in the 1970, and is arguably still going on today. She describes the systemic nature of radical innovations within a capitalist society. However, Perez (2005, 2008) analysis does not delve into the comprehension of the structures that induce the paradigm shift.

It is worth mentioning that institutional theory as found in organizational studies (e.g., DiMaggio & Powell, 1983; Meyer & Rowen, 1977; Powell & DiMaggio, 1991; Scott,

2001; Suchman, 1995) examines how change in rules, cultural norms, symbols, beliefs, and rituals reshapes organizational fields. They show that the dynamic in the organizational environment does not stem from the availability of technologies and other resources. However, much of the writing in that field has been concerned with either organizational legitimacy or network dynamics. This literature does not specifically analyze processes of radical innovations, although there are studies addressing innovation as an institution (e.g., Avgerou, 2002; Drori et al., 2002; Wolfe, 2010).

The next section describes how radical innovations are considered by innovation literature.

### Radical Innovations according to innovation literature

Figure 1 summarizes specific studies on radical innovation as found in the innovation literature. These studies were identified through the term “radical innovation” in title and/or keywords, along with a search, in the period 1995-2009, and also include Perez (2005) analysis on "technological revolutions".

**Figure 1. Radical innovations according to innovation literature**

Determinants of radical innovations	Concept of radical innovation
Chandy, Prabhu & Antia (2003) - fear of obsolescence of existing products by companies at dominant position.	Products with new performance within the company and market; countries referred in the studies: US, UK, India, The Netherlands, Australia, New Zealand.
Hang & Chen (2008) - seeking disruptive technologies.	
Hoegl & Parboteeah (2007) - creativity of the workforce.	
Leifer et al. (2000) – company strategy.	
McDermott & O’Connor (2002) - management competency, market scope, individuals’ skills.	
Merlyn & Välikangas (2002) - differentiated treatment given to radical innovations at strategic planning.	
Nijssen, Hillebrand, & Vermeulen (2005) - willingness to cannibalize existing products.	
Song & Benedetto (2008) – suppliers’ involvement.	
Stringer (2000) – radical innovation as strategic priority.	
Castiaux (2007) – exploring new knowledge through creative and flexible initiatives.	
Ehrnberg (1995) – competencies to design and to produce the product; physical changes in products; price/performance changes.	
Garcia & Calantone (2002) – new technology that causes simultaneously marketing and technology discontinuities, on both company and market.	
Herrmann, Gassmann & Eisert (2007) and Herrmann, Tomczak, & Befurt (2007) – creation of new knowledge and competencies, cannibalization of existing investments.	
Kostoff (2006) – access to knowledge brought by disciplines and technologies disconnected or disparate from the target problem.	

**Figure 1. Radical innovations according to innovation literature - cont.**

<b>Determinants of radical innovations</b>	<b>Concept of radical innovation</b>
Lettl (2007) – technological lead-users.	
Amara et al. (2004) - risk willingness to reduce knowledge deficits.	Resultant from learning processes; country referred in the study: Canada.
Sandberg (2007) – pro-activeness.	Unidentified demand of consumers; countries referred in the studies: Finland, Europe
Vuolla & Hameri (2006) – business strategy.	
Dahlin & Behrens (2005) - technology and company.	Novelty, uniqueness, impact on future technologies; country referred in the study: US.
Godoe (2006) – rational processes resultant from innovation regimes of companies and government.	Consequent and resultant from changes in technological regimes; countries referred in the studies: Germany, Norway, The Netherlands, US.
Poel (2003) – consumers, suppliers.	
Popadiuk & Choo (2006) – demand, organizational and institutional structure.	
McLaughlin, Bessant, & Smart (2005) - willingness to risk.	New to the company or industry; unstructured process; complex management; launched by new entrants; country referred in the study: UK
Salomo, Gemünden, & Leifer. (2007) - constitution of dynamic capabilities.	High degree of novelty: totally new technological principle that allows for a jump in performance; satisfaction of new needs, displacement of existing products; creation of new markets, redefinition of industries and change of existing value chains; high degree of risk and incertitude; country referred in the study: Germany .
Talke (2007) – extremely analytical, pro-active and aggressive corporative personality.	
Weber & Weber (2007) – company and market.	
Terziovski (2002) - strategies oriented to increase technological competitiveness.	Adoption of an idea or behavior (product, system, policy, program, mechanism, process) new to the user organization that “energizes” products, services and processes intermittently; countries referred in the studies: Australia, New Zealand.
Junkunc (2007) - tacit and high-specialized scientific knowledge.	High degree of incertitude; countries referred in the studies: US, Europe.
Linnarson & Werr (2004) - flexibility, political protection and extensive communication along the established alliances between companies.	
Robeson & O’Connor (2007) - management system that encourage learning, experimentation and multiple ways to the market.	
Lichtenthaler (2006) - technological monitoring.	New set of engineering and scientific principles that open new uses and market segments, which can threaten the competitive position of incumbents; countries referred in the studies: Europe, US.
Perez (1986, 2004, 2005) - synergic interdependence between a cluster of industries, one or more infrastructural and superstructural networks, and financial capital.	Constellation of technological systems; influences the behavior of the economy as a whole; creates new categories of products, services, systems and industries, and impacts all industries; brings itself many clusters of innovations; affects the dynamics, the cost structure of inputs, and the production and distribution conditions within the whole system, since the involved changes are far beyond the technological trajectories of products/processes; leads to a deep structural change that is the root of every phase of prosperity of the world economy <sup>a</sup> ; countries referred in the study: developed.

Source: Viegas & Bomtempo, 2010.

<sup>a</sup> This is Perez (1986, 2004, 2005) definition of technological revolution.

Figure 1 reveals a lack of consensus about the concept of radical innovation. The distinction between radical and incremental innovation is fundamentally related to the challenges that organizations can face, and to the impact on industry, which are far more complex when they concern radical innovations. All studies try to establish a positivist concept of radical innovation, which is supposed to be valid in every situation. Almost all analyses are based on "normal science" according to the Kuhnian definition.

As outlined in the same Figure 1, the studies primarily examine processes of radical innovation through their internal dynamic at the organization-level. Therefore, they show that a radical innovation stems from a function, activity or linkage of the organization value chain. Few studies consider the cognitive dimension. The economic dimension is the underlying dimension or the fundamental perspective. However, holding the innovating organization as the determining agent of a pattern change seems to be far more appropriate to the analysis of an incremental innovation, since a process of radical innovation is essentially systemic. Perez (2005) amplifies the analytical scope to the social and political dimensions, when she states that sets of technological breakthroughs pervade far beyond their original industries.

The decline and the introduction of a paradigm (as conceived by T. Kuhn) are far more complex than the obsolescence and introduction of a product/service or process. Radical innovations are not only a result of an innovation strategy strictly in the environment of an organization, but they are also determined exogenously, by a conformation of economic, social and political structures, which entails existing relations of power between companies and nations, that can restrain or induce the process of development of radical innovations. These structures are represented by collective willingness, individual wishes, "economic laws", technologies, systems of interests, political forces, etc., that historically prevail in one system of production.

Viegas & Bomtempo (2011) proposed a new conceptualization for radical innovations: radical innovations are resultant of new systemic conformations of both a mode of production and an institutional mode, in a simultaneous effectuation. Mode of production is understood as conceived by Karl Marx, i.e., as not only the mode by which the means necessary to production are appropriated, but also the social division of work; and institutional mode as "actions, rules, social structures, and practices that persist over time and are features of social aggregates that are larger than a single organization" (Murmann, 2003, p.19).

It is not possible to establish a universal conceptualization for radical innovations. A conceptualization valid in a context of a mode of production is different from the one valid in another mode of production. Amplifying the example of Perez (2005), the adoption and diffusion of the combustion engine resulted, and at the same time produced, changes in the individual vehicle, in the production line (mass production, that was also extended to other industries), in the suppliers chain, in distributors and gas stations, in the construction of highway systems. It also enabled the residence and emergence of shopping centers in suburbs, the consolidation of oil mega-companies, the sensation of progress and welfare, the concern for the environment, and the development of alternative fuels, among many other interdependent changes, within a capitalist mode of production. In another society, these developments could be far different: mass production could not exist, consumers

could finish the production of their means of individual transportation in their home districts with the acquisition of assembling kits, and the developments and interactions would be of different dimensions.

Therefore, the development and establishment of radical innovations must be examined through a systemic approach, which should account for the work on the different dimensions that this process encompasses - mainly, those dimensions that express themselves virtually.

Perez (2008) points out that a paradigm shift is only possible by fulfillment of values and aspirations, which are historically determined by the way society shapes each successive technological potential. According to Perez (2008), it is equally necessary the development an institutional innovations. However, she does not explore the instance or entities that keep the cohesion of a paradigm.

Other frameworks existing in innovation literature aim at the management and monitoring of processes of radical innovations, in order to support governmental policies. For example, Constructive Technology Assessment – CTA (Chen, 1979; Genus, 2006; Merkerk & Smits, 2008; Shot & Rip, 1996; Tran & Dain, 2008), Strategic Niche Management – SNM (Geels 2002; Hommels, Peters & Bjicker, 2007; Kemp, Rip & Schot, 2001; Raven, 2005; Schot, Hoogma & Elzen, 1994), and PROTEE - PROCédures dans les Transports d'Evaluation et de suivi des innovations considérées comme des Expérimentations collectives (Latour, 2000; Hommels, Peters & Bjicker, 2007). Grounded on sociotechnical approaches, their main features are the joint learning, the anticipation of outcomes within the market and society, and the feedbacks of this anticipation to the relevant arenas of decisions.

The analytical frameworks for examining the development of radical innovations presented in innovation literature, in recent years, are essentially descriptive and unsatisfactory for analyzing or explaining such processes. They do not go deeply into the comprehension of the external and internal historical social factors or structures, and their inter-relationships that mould the dynamics of a process of radical innovation.

In the next section, we explore how radical innovations are socially produced.

### **How can radical innovations be developed?**

Some studies suggest the existence of other factors that can improve the comprehension of radical innovations, as defined in our research. Nonaka & Takeuchi (1995) remark on the importance of those factors that are beyond the explicit, formal, systematic observations; factors that are intangible, virtual. Godin (2002a,b, 2004, 2005, 2008b) points out the relevance of understanding the underlying values of a concept – the original values. Perez (1986, 2004, 2005) underlines the systemic character and the complexity for the adoption of a new paradigm in a society. Dreifuss (1987, 1998, 2004) emphasizes the meaning of the institutional structure that supports a mode of production present in a globalized society.

According to Perez (2008), a new paradigm can only prevail if economic circumstances change, if it becomes an aspiration of the majorities, if it is a positive sum game between business and society, and if governments become proactive and define a new playing field clearly tilted towards it.

In a context of a genealogical analysis, similar to the one carried out by Godin (2002a,b, 2004, 2005, 2008b) concerning the origin of concepts and indicators belonging to the discipline "Innovation", the social reality considered by Perez (2005, 2008) can be interpreted in a way to allow for a deeper understanding of how radical innovations are socially produced in particular.

Some values and the description of the social reality adopted by Perez (2005) are tacitly those of the bourgeois liberal society formed in 19<sup>th</sup> century, and that would be prevailing until this day - as in Brazil, for example. These values and indicators were, to quote: industrialization, development, economic growth, market expansion, technological development, efficiency, etc., and they were taken as natural concepts, consolidated as common sense until today. Chandler & Mazlish (2005) show transnational companies, for instance, as "leviathans", erecting societies, and not only as economic entities. Arrighi (1998) demonstrates, through the analysis of the GNP *per capita* of different countries, that development and industrialization, as one example, are not equivalent, despite many academics and practitioners consider this postulate as true.

Actually, a broader analysis suggests that those capitalist values are not anymore prevailing. The prevailing mode of production of contemporary society seems to be not a capitalist mode of production in its traditional modalities – commercial, industrial or financial, but a new mode of production, which gained a feudal character, since it became financial also in political sense (Hudson, 2005; Quigley, 1966).

It is the hegemony of that mode of production that allows inferring the existence of a monopoly of knowledge and innovations, which simultaneously sustains and is sustained by the prevailing techno-economic paradigm. Such monopoly is an expression of a rule established by tacit and explicit agreements between the leadership of governments' representatives and transnational companies (Dreifuss, 1987, 2004; Hudson, 2003; Mazlish & Morss, 2005; Morss, 1991; Sklair, 2001).

Knowledge and innovative technologies, radical or not, originated in developed countries constitute an interwoven set that produces a deep re-organization of companies, which gives rise to new objects and forms of research, information, communication, services, people and ideas, establishing frames for all societies. This set of technologies and knowledge, stemming from successive processes of merges and acquisitions of thousands of companies allows the resultant companies – the "strategic corporations" - to operate in various industries, including the media, entertainment and financial services, and further, to determine the activities of scientific and technological research. Moreover, this set of technologies and knowledge enables the exercise of power by the "strategic corporations", while being governed by the strategic corporations themselves (Dreifuss, 1998, 2004).

In order to settle the "techno-economic" paradigm, these complex networks are supported by national States, where governments work as strategic-political pivots

within a coordinated vision concerning the respective societal spaces. They aim at keeping the technological front-position and the consequent economic-political advantage obtained by the strategic corporations and by the country (Dreifuss, 1998; Sklair, 2001). Public policies, concepts, indicators, management procedures, investment rules, socio-institutional structures are established to reinforce and to perpetuate the constituted paradigm (Chandler & Mazlish, 2005; Dreifuss, 1998, 2004; Mazlish & Morss, 2005; Morss, 1991; Sklair, 2001).

A radical innovation is therefore not only directly dependent on an arrangement of technological capabilities, learning, deliberate R&D, R&D investments, relationships with S&T institutions, private or public financial resources availability, nor strictly on national government policies.

The conditions for a radical innovation seem to be determined by tacit and explicit agreements between the leadership of a group of high-representatives of transnational organizations and some governments, which express the silent action of a group of command with feudal characteristics – the “organic elites” (Dreifuss, 1987, p. 24). Those agreements, based on ideological values provide the necessary cohesion for maintain a paradigm.

Thus, radical innovations are determined by a configuration of virtualities - economical, social, political and technological structures. Similarly, radical innovations influence the changes in such virtualities. As a consequence, radical innovations *per se* do not determine a change in a configuration of both a mode of production, and an institutional mode: they are conversely determined by this configuration, under a simultaneous effectuation.

Thus, it is required an analytical framework for examining processes of radical innovation that can account for the structural genesis which maintains a system cohesive as such.

The next section presents the proposed structuralist approach based on values of cohesion for examining radical innovations.

### **A structuralist approach based on values of cohesion for examining radical innovations**

In the epistemology of Human Sciences and in the philosophical tradition, two perspectives were devoted to the examination of a system: the functionalist (e.g., the works of B. Malinovski and A. R. Radcliffe-Brown) and the structuralist (e.g., the works of W. Dilthey, Cl. Lévi-Strauss, K. Marx, and F. Saussure) perspectives. Under the functionalist perspective, a system is a summation of the elements and their relationships; it is *ex post*. The study of the system results the same as the study of its elements and their inter-relationships. Under the structuralist perspective, the system is simultaneously an autonomous entity – structure that governs the elements and their inter-relationships. The structure is *ex ante*; it is the system that gives order and meaning to the elements. It is an agglutination or *gestalt* that precedes and determines the parts and their relationships. In social life structures are represented in the form of a symbol or a value, as a shared belief, i.e., as a “virtuality” (Viegas & Bomtempo, 2010)

Those virtualities are the basis and also organize the reality of a social experience. The functionality and relationships between elements can be examined when this principle has been observed. However, not in the sense of the webs, as proposed by M. Foucault, but as social organizations grounded on beliefs, symbols, values, ideologies, etc.

The following examples from I. Nonaka & H. Takeuchi, B. Godin, C. Perez and R. Dreifuss writings indicate the concept of structure.

The concept of structure concerns something “primarily tacit - something not easily visible and expressible”, as Nonaka and Takeuchi (1995, p. 8) state, but this statement should not be understood as only concerning the psychological content, as suggested by these authors when they describe the way Western companies operate, while compared to their Eastern counterparts: “much more crucial than processing objective information”, it becomes crucial “sharing an understanding of what the company stands for, where it is going, what kind of world it wants to live in, and how to make that world a reality” (p. 9)”. According to them, “knowledge also embraces ideals, values, and emotion, as well as images and symbols” (p. 9).

Social structures, empirically manifested, are the background for the promotion of the economic activities, becoming thereby ideological, as exposed by Perez (2005), to the extent that it establishes a new paradigm that guides individual decisions and the interactions of entrepreneurs, investors, researchers, consumers and private and public managers; but which is beyond a “constellation of generic technologies” and inter-related organizational principles of each technological revolution.

Different structures define and recognize different definitions of innovation, as presented by Godin (2005).

The concept of structure explains this new character of domination that aims to promote as natural the acceptance of new standards skillfully set forth by those companies and governments of the political establishment, and which constitutes an “advanced capitalist” mode of production, as Dreifuss (1987, 2004) points out.

In Brazil, for example, the train railroads were all dismantled, in the sixties, on the argument of inefficiency, echoed by the media. However the consolidation of the oil and the automotive industries in that country was in fact the political interest. As a result, innovations in trains, either radical or incremental, were not promoted, nor developed, nor adopted (e.g., the train of magnetic levitation – maglev; the train of air propulsion – aeromovel®; or the many monorail projects).

The knowledge of a structure denotes the knowledge of both the physical system, and the virtualities, which maintain the elements unified, functioning and signifying as a whole. Several approaches that present themselves as systemic do not actually analyze the cohesive factor in the productive system, as a social structure.

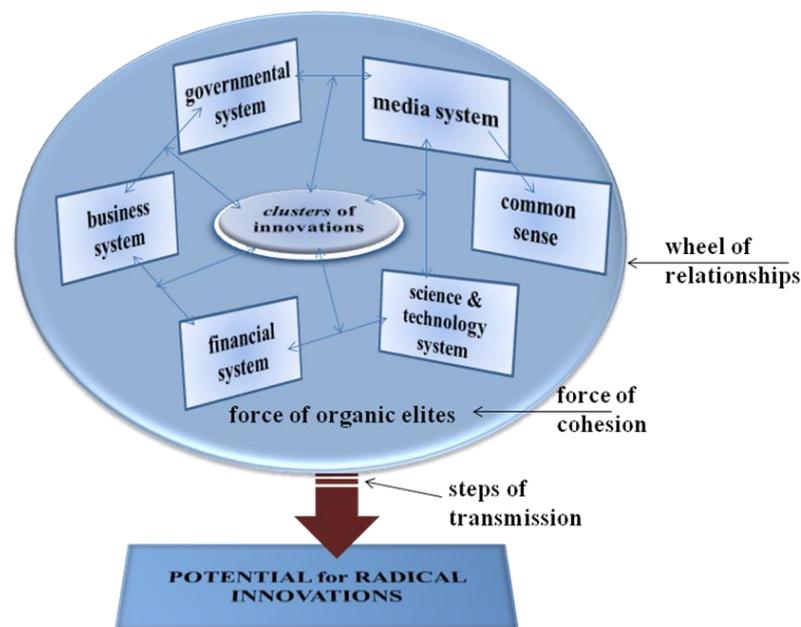
In the next section, we present the proposed structuralist analytical framework for examining radical innovation.

## An analytical framework to examine radical innovations based on the values of cohesion approach

The proposed analytical framework for examining radical innovations, based on the values of cohesion approach, the Values of Cohesion Framework - VCF takes into account the existing political relationships between companies and States, which are capable of inhibiting or inducing radical innovations.

Figure 2 represents the VCF with its three interdependent and complementary analytical dimensions – the wheel of relationships, the force of cohesion and the steps of transmission. These three dimensions are not easily empirically distinguished.

**Figure 2. Analytical framework based on the values of cohesion approach - VCF to examine radical innovations**



Source: Viegas e Bomtempo (2010)

The analysis of the *wheel of relationships* examines social systems of production, technological systems and their interactions.

It makes an assessment of the relationships between research and technology institutions, private and governmental companies, and financial institutions, represented by their top management strategies, policies, decisions and actions. These organizations compose the science & technology, business, governmental, and financial systems. They are also responsible for establishing common sense by means of the media.

The analysis of the *wheel of relationships* allows understanding how those strategies, policies, decisions and actions are conceived, implemented, and evaluated: their basis (e.g., studies, analysis, researches); their processes of choice (e.g., methods

for evaluation of alternatives, negotiations involved, degree of autonomy, criteria of decision, people concerned, internal and external – initiators, influencers, deciders, transactors); their implementation (e.g., procedures, negotiations involved); their evaluation and control (e.g., selection of indicators, course of actions). The analysis involves the systems as a whole, the systems individually, and their elements.

The analysis of the *force of cohesion* allows the identification of the politics, i.e., what is the power of class that organizes the minor social systems and their inter-relationships that integrate the *wheel of relationships*, and which can determine the conditions for radical innovations. It also evaluates how the cohesion is set up and maintained.

Power of class is understood as conceived by H. Arendt: the human attribute to act in concert, and not as a relationship of command and obedience. This human attribute becomes self-evident by the ability to plan and to conduct political action, without the existence of a formal staff of command.

This power of class is what maintains the cohesion of the *wheel of relationships*, and is the factor that provides concepts, principles, watchwords, rules, and valorative statements, which will eventually condition the social production of radical innovations.

The analysis of the *steps of transmission* examines the dynamics among the powers of class, and how the transmission of the concepts, principles, watchwords, rules, and valorative statements takes place within the different *wheels of relationships*.

According to Dreifuss (1987), the powers of class and their functions are: 1. the organic elites: the formulators and organizers of concepts, symbols, references, as well as researches, studies, analyses, rules, actions and practices; 2. those that dictate the immediate conjunctural actions; and 3. the replicators.

The analysis of the *steps of transmission* also provides information about the representatives of the organic elites: the ones performing as tactic groups with short-ranged and short-termed actions, explicitly applying the words that belong to the organic elites, which are latent in the group, and about the replicators of concepts and valorative statements reiterated as common sense.

The powers of class dynamics should allow comprehending that a single national organization may not have autonomy to develop radical innovations. However, as suggested from mentioned studies (Perez, Dreifuss and others), the social structures and systemic effects that determine radical innovations have a life cycle. Thus, the understanding of the configuration of virtualities should provide elements to allow for the intervention of a State policy into this complex dynamics. For instance, since radical innovations are not only dependent on an innovation strategy nor on the capacity of developing countries to catch up, those countries should position themselves as their own technological frontier, re-shaping the existing relations of power between companies and other nations, therefore inducing processes of development of radical innovations.

The next section illustrates the use of the proposed VCF, with regard to its ability to provide analytical elements for understanding the determinant conditions for radical innovations.

### **The use of VCF to examine the potential for radical innovations**

The conceived framework was employed to evaluate the potential for radical innovation in the change in the basis of raw materials for the Brazilian chemical industry, from fossils to renewables.

The choice of the case study was based on three main points: raw materials as the determining factor of the dynamics of the chemical industry; the use of renewables the structuring element of "green economy"; and the vocation of Brazil to actively participate in this announced paradigm shift.

The case study was an exploratory qualitative field research, which included interviews with seventeen different top executives of different organizations. These organizations compose the five systems: science & technology, business, governmental, financial, and the media. The field research was carried out between August 2010 and March 2011, in Brazil.

Figure 3 shows the respondents' profile.

**Figure 3 - Respondents' profile**

<b>System</b>	<b>Organization</b>
Business	Producers of chemical intermediates and resins from renewable sources, industrial consumers of green packages, high-tech company with no chemical operations.
Financial	Venture capital and <i>private equity</i> private investors, federal bank for development.
Governmental	Federal agency of innovation, federal bank for development, intellectual property office, organization for Latin America development.
Science & technology	R&D centers of universities and of a government company involved with renewable sources.
The media	Scientific print media and broadcast media companies.

Figure 4 shows examples of symbolic factors, which become ideological, and are projected in institutional or social systems, maintaining a paradigm, as illustrated by the declarations of the executives interviewed in the field research.

**Figure 4 - Ideologies that maintain the cohesion of a paradigm**

System	Concepts, principles, watchwords, valorative statements
Business	<p>Brazil seeks the position of first follower.                      Global oil industry defines the dynamics of the Brazilian chemical industry.                      Higher risk investments only shared with the Government.                      Willingness to contribute to the country's sovereignty.                      Renewables as Brazilian vocation.</p>
Financial	<p>Brazil seeks to be fast follower.                      Intra and inter-systems relationships are based on many negotiations.                      Renewables should be supported.</p>
The media	<p>Innovations outside the paradigm do not have scientific vision.                      Only the scientific policy determines the subjects to be published.                      Programs outside the paradigm disfigure the TV.                      Renewables exposed daily.</p>
Governmental	<p>A transversal system runs through governmental bodies and agendas.                      The import substitution model still prevails, also in the media.                      China and Korea as examples to be followed by Brazil.                      Innovation policy is incompatible with macroeconomic policy, in Brazil.                      Investment in technology is function of profitability and risk.                      State induction is essential for the development of radical innovations.                      The role of the Patent Office as bookkeeper rather than guide for types of intangible assets important for the country.                      Permanent R&amp;D teams are crucial for developing radical innovations.                      Competition between organizations is better than collaboration between them.                      People who break rules and advance beyond what is established are essential to the development of radical innovations.                      Companies seek partnership with S&amp;T institutions to reduce costs.                      There is a structural conformation not friendly to radical innovations.                      Renewables are a priority.</p>
Science & technology	<p>The university is organized to develop incremental innovations.                      University-business cooperation does not induce the development of radical innovation, since it answers companies' needs.                      Competition between organizations is better than collaboration.                      Investments in renewables are condition of sovereignty.                      Decisions are political rather than technological.                      There is no Government policy to encourage radical innovations.                      There are expressive barriers to the development of radical innovations, which are beyond the game of business interests.                      Brazilian society is not aware of the role of radical innovations.                      Concepts established by propaganda drive the practice of the biggest Brazilian chemical companies.                      Renewables are sources only for biodiesel and to the Northeast (biodiesel for the Northeast Region of Brazil became a platform of political parties seeking election)                      Green polyethylene will not replace petrochemical polyethylene,                      The policy for exploiting the Brazilian sub-sea determines innovation investments in the chemical industry                      Renewables are anti-globalization                      Renewables are a Brazilian vocation.</p>

It is possible to infer from Figure 4 that the strategies, policies, actions and efforts of the organizations of the different systems orderly seek the development of incremental innovations. Decisions on investments in innovations are taken as moved by a transcendent determination of a target position of first follower - therefore incremental innovations, although there is a consensus among almost all the executives interviewed of the need for investment in potential radical innovations, as a condition for the country's sovereignty, including the use of renewables.

Complementing Figure 4, the literal statements of the interviewees from the different systems, collected in Figure 5, suggest the existence of a unifying element that expresses that conductorship exercised by tacit and explicit agreements between the leadership of transnational groups and some governments.

**Figure 5 - The conductorship expressed by explicit and tacit agreements**

System	Interviewee literal statement
Business	<p>The innovator is a hostage of organizations, interests.</p> <p>A researcher at the company will follow the rules of the company, how not to be tighten?</p> <p>Venture capitalists have the role to stimulate renewable start-ups with the participation of companies such as Dow, Basf.</p>
Financial	<p>To work in partnership, as a team, independent of political parties.</p> <p>To work without agreements, financially independent.</p> <p>To be driven to conceive disruptions means choosing places, much money, and the need of alliances.</p> <p>Looking at the sugarcane mills, agriculture and industry, there are opportunities for national technology, but the microorganisms are brought from Amyris, Novozymes.</p> <p>We need agreements with the media, since it does what it wants; radical innovations are also included; for example, stem cells, GMOs are dealt according to their interests.</p> <p>Since O&amp;G companies have financial resources, they are able to make the transition to renewables; for example, Total bought Amyris.</p>
Governmental	<p>Joint actions between government agencies to attract to Brazil, R &amp; D centers of international companies that support their strategic decisions: they work both on potential radical innovations and at technological frontier.</p> <p>Radical innovations: this is a challenge that Brazil has to face; Brazil does not house headquarters of international corporations able to structure.</p> <p>Any effective policy for radical innovations must involve State induction; it is also dependent on a strategic formulation that value technological autonomy.</p> <p>There is a guideline within all organizations of intellectual property worldwide to not consider patents for certain technologies.</p> <p>Today the news is the danger of nuclear power (a reference to Fukushima disaster), before it was the advantage/safety of it.</p>

**Figure 5 - The conductorship expressed by explicit and tacit agreements - cont.**

System	Interviewee literal statement
Science & technology	<p>Energy balance is the result of minds and interests.</p> <p>There is a lack of technologies on biocatalysts in Brazil.</p> <p>There is no government policy to encourage radical innovations; there is no information for society to discern; there are huge barriers; it is not a business interest game: since I am not strong enough to play, I don't have a discerning society; e.g., economic groups do not allow the aeromovel®.</p> <p>The decisions are political and not technological.</p> <p>Developed countries already handle the subject, and the Brazilian society should understand the benefits of this change. The actors must work in an integrated way.</p> <p>National companies are "sold"; they serve international cartels; there is no nationalist vision.</p> <p>Exogenous technological forces and much money command the national industry.</p> <p>An ethical media is expected; but instead, we have a political media, with powers above "Trigueiros" (Trigueiro, Brazilian TV news top journalist).</p> <p>Brazil pays for news and brings them from abroad, including news on fuels</p>
The media	<p>The media specialized in science, technology and innovation must be the stage for advertising the S&amp;T institutions and a channel to get to the scientific community.</p> <p>Currently, the public TV has operations in distribution and not in production, but politically biased. The proposal for professionalizing the management and also for greater decision-making autonomy was abandoned; the company tried to implement a model similar to that of the BBC, but suffered enormous pressure from private competitors and from retail networks.</p>

In summary, as shown in Figure 6, the proposed VCF with its three analytical dimensions was useful to examine the determinant conditions for the development of radical innovations, as defined in this research.

The results of the field research reveal that the potential for radical innovations, such as in the replacement to renewables in raw materials for the Brazilian chemical industry, is expressed by virtualities that keep a monopoly of knowledge and innovations. They also show that those explicit and tacit agreements, based on ideological values, account for the necessary cohesion to maintain a paradigm.

Furthermore, the findings suggest that such replacement seems to have potential for radical innovation, as the Brazilian "green" vocation; the "glocal" character of renewable investments, and the awareness of the majority of interviewees that renewables can be a condition for national sovereignty.

**Figure 6 - Summary of the results of the field research**

Analytical dimension	Results
Wheel of relationships	<p>Existence of many negotiations and agreements, but not in concert.</p> <p>Strategies and policies based on internal and external studies, following trends, and considering party-political relations.</p> <p>The potential for radical innovation is not considered in strategies/policies.</p> <p>Pursuit of individual success and not of collective success.</p> <p>The media system reproduces the statements of the top management of companies, S&amp;T institutions and government, concerning themes like radical innovations and renewables.</p>
Force of cohesion	<p>Pursuit of the technological dictates of transnational corporations.</p> <p>Significant technological dependence on transnational companies.</p> <p>Government and business actions aim at being leader as first follower.</p> <p>Risk sharing is a canon.</p> <p>Aversion to invest in innovations outside the paradigm.</p> <p>Renewables as condition for sovereignty.</p>
Steps of transmission	<p>The presence and the leadership of transnational companies are essential.</p> <p>Circularity of studies that underlie strategies/policies.</p> <p>Treatment of innovations "in aggregate" – biotec, nanotec without considering national priorities.</p> <p>Business, S&amp;T institutions, government and the media working as tactical groups with short-range actions and also as replicators: absence of the theme sovereignty, associated or not to renewables in their strategies/policies.</p> <p>Search for leadership in the position of first follower.</p> <p>Awareness of the "glocal" character of renewable investments.</p>

## Conclusions

Our research proposed an analytical framework based on the Values of Cohesion approach - VCF for examining the potential for radical innovations, which accounts for their systemic character. These innovations were defined as resultant of a new conformation of both a mode of production, as a systemic configuration, and an institutional mode.

Unlike the systemic approaches found in innovation literature, our analysis aims at identifying and comprehending the entities that maintain a system cohesive. This cohesion is mainly manifested as a virtuality: a belief, an ideological symbol, a cultural value, etc. Therefore, the proposed VCF considers the structural dimension that can establish the conditions for the development of radical innovations.

The structuralist approach allows us to infer that the reality of the mode of production of contemporary society seems to be a new mode of production with feudal characteristics. This mode of production seems to support, and simultaneously be supported by a monopoly of knowledge and innovations. The monopoly is a manifestation of a rule granted by tacit and explicit agreements between the top

representatives of governments and transnational organizations, which are resultant from successive processes of strategic alliances of thousands of companies.

The proposed VCF was validated to examine the potential for radical innovation in the change to renewables in raw material sources for the Brazilian chemical industry. The analysis of the results of the field research supports that the potential for radical innovations is expressed by virtualities, which symbolize the mentioned monopoly. Moreover, the analysis suggests that such a replacement has potential for radical innovation, given the awareness of the use of renewables sources, as a driver of national sovereignty.

Our research contributes to emphasize the complex dynamics of the development of radical innovations. It also contributes to revive the debate on the role of business strategies and governmental policies in this process. Additionally, it opens up a new theoretical space to study radical innovations, within which other empirical data can be interpreted.

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