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# A hard nut to crack! Implementing supply chain sustainability in an emerging economy

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ABSTRACT

In the last decade, sustainable supply chain management has become a key topic in the sustainability literature as well as a buzzword in industry and policy circles. Although research has made substantial contributions, there is a lack of understanding on how focal companies operating in emerging economies can lead the implementation of sustainability into their supply chains. This research connects and advances the constructs of cleaner production, sustainability and supply chains by exploring a classic case of a focal company operating in an emerging economy that, even facing considerable challenges, has been able to succeed in transforming its entire supply chain. Drawing from stakeholder theory and contingency theory, this research offers four key contributions to the sustainability and supply chain discourses as follows: 1) it proposes an innovation-centered approach to sustainable supply chain management, by adapting and extending the TCOS uncertainty framework; 2) it suggests that the way a focal company manages and is influenced by its established network of relationships shape the evolution of the supply chain sustainability trajectories; 3) it argues that supply chains are dynamic entities and should then be considered and understood through the lenses of evolutionary approaches; and 4) it suggests that the implementation and management of sustainable supply chains are context-specific challenges and therefore theoretical, managerial and policy generalizations are difficult to be achieved.


## 1. Introduction

Sustainable supply chain management has been recently raising significant attention from industry leaders, academics and policy-makers. The debate is currently centered on why supply chains should incorporate sustainability and how sustainable supply chains can actually be implemented and managed. The research literature articulates that supply chains must be managed to achieve higher economic returns to its members (Power, 2005). However, economic objectives cannot be achieved at the expense of the natural environment and/or the society, i.e., financial goals should not be detached from the environmental and social dimensions (Linton et al., 2007; Markley and Davis, 2007; Seuring and Muller, 2008) so that satisfactory solutions for all stakeholders can be achieved (Hall et al., 2012a).

Therefore, careful attention to economic, environmental and social aspects of supply chain operations is what the literature defines as the compliance with the triple bottom line (Elkington, 1998), which requires a balanced focus on those three key sustainability dimensions. Recent studies argue that economic objectives can be compatible with environmental and social objectives (Pagell and Wu, 2009) while others show evidences that the implementation of sustainable supply chains actually leads to commercial success (Zailani et al., 2012). However, even after substantial progress, several studies still claim that the social aspect of sustainability has been often neglected in existing research and practice (Beske, 2012).

Although the previous research has made significant contributions, the literature suggests that there is a dearth of research on the implementation and management of sustainable supply chains in emerging economies (Zhu et al., 2005; McCormack et al., 2008; Cerra et al., 2008). To help filling this gap, this research explores an exemplary case in an emerging economy and builds on stakeholder theory and contingency theory to derive at least four theoretical contributions. First, this paper adapts and extends the TCOS uncertainty framework by linking it to the sustainable supply chain literature as a means to provide a tool to understand and analyze the evolution of sustainability trajectories of supply chains. Second, I propose that the way a focal company manages and is influenced by its established network of relationships shape the

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evolution of the supply chain sustainability trajectories. Third, I argue that sustainable supply chains should be considered and understood through the lenses of evolutionary approaches, where supply chains are initially immature, but they learn and evolve overtime, and eventually incorporate sustainability into their business practices. Finally, I suggest sustainable supply chain implementation and management are context-specific issues and therefore theoretical, managerial and policy generalizations are difficult to be achieved.

In the remainder of the paper, the theoretical framework is discussed through the lenses of stakeholder theory and contingency theory as well as how the issues associated with these research streams may be applied to sustainable supply chain management in emerging economies. The methodology employed in this study is then detailed, followed by an exploratory in-depth illustrative case study in the oil and gas supply chain in Brazil. The paper finalizes with a discussion, implications and contributions of this research as well as avenues for future investigation.

## 2. The theoretical framework

The literature defines sustainable supply chains as the ones that perform consistently well on financial, environmental and social dimensions (Pagell and Wu, 2009). In practice, sustainable supply chains must truly adopt business practices and measures that are consistent with these three pillars of sustainability. If one stage of a supply chain fails in considering, measuring and/or controlling one of these dimensions, that supply chain is then unsustainable and will suffer the consequences of such an ambiguous and risky path.

Another critical element for sustainable supply chains to function well is the collaboration among its members. Collaboration in supply chain demands "aligned objectives, open communication, sharing of resources, risks and rewards" (Soosay et al., 2008:160). Since the literature clearly sustain that supply chain collaboration enhances innovation and sustainability performance (Sahay, 2003; Swink, 2006), the main goal becomes thus to adopt the right business practices to facilitate collaboration (Bello et al., 2004; McCarthy et al., 2013).

Taking a holistic perspective, I argue that relationships and collaborations between supply chain members and other external stakeholders are as important as the collaboration within the supply chain itself. This is because external stakeholders can be a source of risk for supply chains if their concerns are not accommodated. For example, the literature suggests that stakeholder theory is fundamental to understand and manage those complex networks of relationships and conflicting interests (Donaldson and Preston, 1995; Matos and Silvestre, 2013). According to Freeman (1984: 53), stakeholder is "any group or individual who can affect or is affected by the achievement of an organization's purpose", and include multiple individuals or groups such as financial claimants, employees, customers, communities, non-governmental agencies, universities, media, governmental officials, among others (Stubbs and Cocklin, 2008; Jensen, 2010). Studies using stakeholder approaches to address sustainability issues are not rare in the existing literature. For example, Byrd (2007) states that key stakeholders must be involved in the process when pursuing sustainable tourism development. Similarly, Steurer et al. (2005) argue that stakeholder relations management is a powerful mechanism through which organizations can address sustainable development challenges. Particularly related to Brazil, Lourenço and Branco (2013) examine the incentives for Brazilian firms to invest in corporate sustainability by using a theoretical approach that combines a resource-based perspective and stakeholder theory. In the oil and gas industry, Wheeler et al. (2002) explore the case of Shell in Nigeria and conclude that when dealing with local communities in underdeveloped regions, corporations must respond quickly and be able to accommodate social demands, which is likely to bring benefits both for external stakeholders and the business.

In this paper, I apply the stakeholder theory perspective to sustainable supply chain management and, consistent with Matos and Silvestre (2013), argue that managers should make decisions by taking into account the interests of all supply chain stakeholders. This is a complex task indeed, but sustainable supply chains will be able to overcome uncertainties and build the required trust and legitimacy if stakeholders' voices are listened and their concerns are accommodated. If stakeholders' concerns are ignored, the supply chain can eventually suffer reactions from these stakeholders. This in turn puts firms and supply chains in uncomfortable positions and makes them lose reputation and legitimacy in the marketplace, which always negatively affect the financial performance of such firms and supply chains. If firms and supply chains are focused solely on financial goals, these uncomfortable situations frequently occur and can be difficult to overcome.

Focal companies are central agents that can encourage such dialogue-based behavior from all supply chain members. In fact, the literature says that external pressures and incentives put forward by external stakeholders (e.g., government, customers, media, etc) are departing points for sustainable supply chains (Seuring and Muller, 2008; Matos and Silvestre, 2013). The types and intensities of external pressures faced by supply chains depend on the nature of the firms involved, the industry where they operate, the region/country where they are located and the products and services they offer. Therefore, focal companies, supply chain members and external stakeholders are embedded in a particular business environment and consequently face context-specific issues: i.e., in each supply chain these entities will have different views, interests, pressures, values, behavior and attitudes toward sustainability. The definition of business environment involves all relevant physical and social aspects outside the boundary of an organization that impacts on the business decision-making processes (Duncan, 1972; Kumar et al., 1998).

Because of the existing idiosyncrasies associated with each context, I argue that the understanding and management of sustainable supply chains must take a contingency approach (Fisher, 1997). The literature says that when it comes to strategic issues, the decision-making process is situational, depending largely on multiple factors that are unique to a given situation (Hofer, 1975). Several studies in multiple industries use contingency approaches to address sustainability issues. For example, Walker and Jones (2012) draw on contingency theory and specific literature to develop a typology of approaches to sustainable supply chain management. Kunz et al. (2013) argue that contingency theory is a useful perspective to understand how organizations should manage informal networks, remain adaptive and resilient regarding sustainability while Christ and Burritt (2013) draw on contingency theory to develop a research framework to identify the circumstances under which organizations were more likely to engage in environmental management accounting activities. Regarding supply chain sustainable initiatives, Wu (2013) suggests that firms tend to adopt proactive environmental strategies and green innovations during periods of environmental uncertainty, which is an important contingency variable for firm environmental initiatives. I reason that this is also the case of sustainable supply chains in emerging economies, and without a deep understanding of the contextual factors, sustainability decision-making processes are erratic and the management of supply chains becomes extremely challenging.

This research highlights that the combination of stakeholder theory, which recognizes that the effectiveness of the decision-making processes is dependent on firms' and supply chains'

relationships and interactions, and contingency theory, which suggests that the decision-making processes are dependent on the firms' and supply chains' contextual conditions, is a powerful theoretical perspective to understand sustainable supply chain management issues.

## 3. An innovation-centered approach to sustainable supply chain management

Recent literature on strategy and innovation has stressed the importance of accumulating capabilities for firms to achieve enhanced performance (Cohen and Levinthal, 1990; Caloghirou et al., 2004; Teece, 2007; Hall et al., 2012b). This perspective closely aligns with evolutionary approaches (Nelson and Winter, 1982; Silvestre and Dalcol, 2009; Hall et al., 2012a), where firms are initially immature, but they gradually learn over time, accumulating knowledge and capabilities so that they can become able to progressively perform new activities, innovate and absorb new capabilities. I argue that this evolutionary approach can also be adopted to understand supply chain sustainability trajectories, i.e., similarly to organizations, supply chains are also dynamic entities that learn and evolve overtime. This perspective is powerful and useful because the literature argues that an organization cannot compete in isolation, but rather together with its supply chain partners (Lummus and Vokurka, 1999). Thus, a more holistic view, where supply chains rather than isolated organizations are the focus of the analysis, brings new insights and more complete answers to sustainability challenges .

Consistent with Schumpeter (1934), the concept of innovation is referred as the introduction of a new good, a new method of production, a new organizational form, the opening of a new market, and the use of a new source of supply of raw material or semi-finished products. Innovations are seen as recombinations of existing knowledge expressed in one of the Schumpeterian categories above and applied by a particular supply chain. A related concept that is also aligned to sustainable supply chain studies is absorptive capacity (Silvestre, 2013). Absorptive capacity is the ability to understand relevant new external knowledge, assimilate it, and commercially apply it (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998). As absorptive capacity is relevant to organizations, supply chains are also impacted by the absorptive capacity of its members in the extent to which those members are able to absorb and commercialize new external knowledge. According to Tsai (2001), absorptive capacity has significant and positive effects on innovation and performance.

The literature also claim that sustainable supply chains must be pursued through innovation (e.g., organizational and cleaner production innovations) because it requires new mind-sets, innovative business practices and sometimes more comprehensive changes in the entire business model (Silvestre, 2013). In practice, one way to achieve sustainable supply chains is through the implementation of cleaner production innovations at earlier stages of the supply chain sustainability trajectory. The literature suggests that cleaner production reduces companies' risk and the negative effects of the financial crisis (Ortas et al., 2013). However, organizational innovations are simultaneously needed to transform a supply chain because sustainability requires not only technology to protect the environment (i.e., improving environmental performance through cleaner production innovations), but also a proactive entrepreneurial mindset, involving new paradigms, policies, and tools (Bonilla et al., 2010a; Almeida et al., 2013). Organizational innovations are key drivers to balance the three dimensions of supply chain sustainability, i.e., the triple bottom line's economic, environmental and social dimensions. In this paper, I argue that cleaner production innovations are fundamental but not enough for the implementation of sustainable supply chains.

Since innovation is central to sustainable supply chain management (Silvestre and Dalcol, 2007, 2008), I adopt an established framework that was originally created to evaluate multiple uncertainties of radical innovations and adapt it to be used to analyze sustainability trajectories of supply chains. The framework is called TCOS (which stands for technological, commercial, organizational and societal uncertainties), and was originally developed by Hall and Martin (2005) and subsequently extended by Hall et al. (2011). According to Hall and Martin (2005) and Hall et al. (2011), the four types of uncertainties are:

1. Technological uncertainty: the innovations in question must be demonstrably feasible technologically, based upon supply chain capabilities.
2. Commercial uncertainty: the innovations in question must be demonstrably feasible commercially, based upon supply chain capabilities.
3. Organizational uncertainty: The development and exploitation of the innovations must be demonstrably congruent with the supply chain strategy
4. Societal uncertainty: The potentially detrimental societal side affects (i.e., environmental, social or political) of supply chain activities must be recognized and accommodated.

Regarding the application of the TCOS uncertainty framework, Hall and Martin (2005) analyze Monsanto's development of agricultural biotechnology as a means to illustrate the emerging social challenges for companies exploiting radical technologies. Similarly, Hall et al. (2011) explore the radical innovations in the case of automotive biofuel development in Brazil and the uncertainties associated with its evolution. I adapt and extend the TCOS uncertainty model by arguing that it is a powerful and useful tool to understand and analyze not only radical innovations, but also supply chain sustainability trajectories. Because supply chains require innovations to become more sustainable, I suggest that these supply chain innovations are not always radical, but always involve certain degrees of change.

This paper connects the TCOS uncertainty framework to the triple bottom line concept for sustainability. Besides the fact the TCOS framework considers technological, commercial and organizational uncertainties, which are all connected to the economic dimension (because they are related to productivity increase, commercial success and innovation appropriation) of the triple bottom line, it also addresses societal uncertainties (i.e., political, environmental and social uncertainties), which are closely aligned with both the environmental and social dimensions of the triple bottom line.

## 4. Methodology

This research employed a hybrid research strategy encompassing grounded theory and action research. Grounded theory is an inductive method that allows the researcher to build theory while grounding it in empirical observations (Glaser and Strauss, 1967). Instead of beginning with the hypotheses and testing them against the empirical observations, the first step of grounded theory method is to collect data (Silverman, 2011). More recently, some authors have framed the term constructivist grounded theory, which assumes that data and theories are constructed as a result of the researcher's interactions with the field and its participants (Masters, 1995). According to McKernan (1991), action research is a more flexible approach and intends to contribute to practice and research through collaboration and participation. According to

McCutcheon and Jung (1990:146), "indicative of this flexibility is the frequent use of 'interpretive' as an umbrella term that comfortably accommodates interactive and phenomenological perspectives". The literature shows evidences that this research method generates relevant and rigorous findings (Anderson et al., 2001; Pettigrew, 2001).

The research literature also claims that researchers should derive their research questions from practice when using the case study method (Anderson et al., 2001; Pettigrew, 2001). Case study is a useful and appropriate method to investigate contemporary phenomena within a real-life context, especially when the boundaries between the phenomenon and the context are not clearly evident (Yin, 2003). Case study research is a scientific approach that aims to connect theoretical concepts with reality (Pan and Tan, 2011), although positivist tendencies should be put aside to really understand the reality (Weber, 1947; Thomas, 1966). According to Eisenhardt (1989) and Stuart et al. (2002), case study method is the way a researcher can explore and understand non-standard or exemplary situations.

An inductive theory building approach based on an in-depth exploratory case study was used. I have decided to proceed with one exemplary case study in order to augment the depth of analysis, gain experience with the issues related to the field context, and elaborate a more robust argumentation by connecting such issues to the existing literature. A systematic data collection and data triangulation processes were employed by combining multiple techniques for clarifying data and confirming findings. The data presented in this article are based on three distinct key sources: primary sources, secondary sources, and my own experience in working for the Brazilian energy industry for several years. Regarding the primary sources, I conducted 52 semi-structured in person interviews with entrepreneurs, directors, managers and key employees in firms operating in the different parts of the Brazilian oil and gas supply chain. Second, in order to obtain contextual understanding of the situation, I collected publicly available documents related to this particular supply chain. Thus, data were collected from secondary sources by researching firms' websites, documents, industry reports, academic publications, newspapers, and specialized technical journals. Third, opportunities for data triangulation (Stake, 1995; Johnson, 1997) were exploited through numerous unstructured conversations, meetings and negotiations with entrepreneurs, employees, policy-makers, academics and through direct observation during 10 years of work experience in the energy industry in multiple organizations and positions.

## 5. The case of offshore oil and gas supply chain in Brazil

This case study was designed to increase our understanding on how the offshore oil and gas supply chain was able to overcome the technological, commercial, organizational and societal uncertainties and how it has become a leading oil supply chain regarding sustainability through innovation. Nowadays, the oil and gas supply chain in Brazil is recognized for its remarkable achievements regarding sustainability, which has allowed the country to become energy self-sufficient in 2006 (Silvestre and Dalcol, 2009; Dalla Costa and Souza-Santos, 2012). In 2008, Petrobras (and its supply chain) was ranked the world's most sustainable oil and gas company by Management & Excellence (Noria, 2008).

The evolution and development of the offshore oil and gas supply chain in Brazil happened gradually, accompanying the discoveries of oil fields in different parts of the country. The first oil field, Garoupa, was discovered in 1974 (Petrobras, 2013), and since the early stages, Petrobras positioned itself to become the leading entity of the supply chain subsequent development.

I divided the sustainability trajectory of the offshore oil and gas supply chain in Brazil in five distinct stages, following the evolution of supply chain's technological development and capabilities. These five stages were defined based on the fact that in each one of these periods the offshore oil and gas supply chain (and Petrobras as the focal company) faced different kinds of uncertainties and achieved challenging milestones. I segmented the five stages based on the supply chain's technological development, which has been substantially driven by Petrobras' Deepewater Technological Programs (PROCAP). During these programs, commercial, organizational and societal challenges have also been considered and addressed. In line with what Hall et al. (2011) suggest for the biofuel evolution in Brazil, this case shows that the uncertainties from each stage were completely or partially overcome before the supply chain evolved and encountered other uncertainties from the subsequent stage that needed to be addressed later. The five stages are:

- *1st Stage – Pre-PROCAP*: between the 1970s and 1985;
- *2nd Stage – PROCAP 1000*: between 1986 and 1992;
- *3rd Stage – PROCAP 2000:* between 1993 and 1999;
- *4th Stage – PROCAP 3000*: between 2000 and 2011;
- *5th Stage – PROCAP Future Vision*: started in 2011 (in progress).

For each of the first four stages, I explain and present a table below with the main technological, commercial, organizational and societal uncertainties (TCOS framework) faced by the three key stakeholder groups: the focal company itself, the supply chain as whole and the external stakeholders. I also point out how the supply chain addressed the emerging uncertainties and evolved to the following stages. It is important to note that the uncertainties faced by these three different stakeholder groups are interconnected in certain way since they are all embedded in the same context (business environment). I comment on the fifth stage briefly because it is still in progress and results are not available yet.

### 5.1. 1st Stage – Pre-PROCAP: 1970s–1985

The 1st Stage is called Pre-PROCAP and took place between the 1970s, when the first discoveries of offshore oilfields were made in the country, and 1985 (Table 1). Regarding the focal company, during this stage there was a lack of technical base within Petrobras. Oil and gas exploration, development and production were tied to too challenging technological issues to resolve. Petrobras then started building infrastructure and engineering support in Brazil. The company also started absorbing routine capabilities from pioneer suppliers to learn how to deal with the technological challenges in growing water depths. Commercially, high development costs associated with deep water fields were observed. However, due to relatively constant discoveries of new oilfields, economic feasibility of offshore oil and gas operations in Brazil became a reality to the company. In terms of the organizational uncertainties, there was a lack of absorptive capacity within Petrobras, and during this phase the company took predominantly a passive learning approach based on routine capabilities.

Regarding the supply chain as a whole, during the 1st Stage there was a lack of high-technology content suppliers. However, new oilfield discoveries attracted integrated multinationals supplying high-technology goods and services to the country, securing knowledge and routine capabilities transfer through long-term contracts with Petrobras. During this stage, the scarcity of specialized suppliers increased the cost of oil and gas offshore goods and services and imported equipment from elsewhere was a frequent solution. Because of this unmet and growing demand, numerous other firms migrated from various countries attracted by the growing operational volume of the supply chain, while several

**Table 1**
1st Stage (1970s–1985) – Pre-PROCAP uncertainties.

| Uncertainties | Entity | | |
|---|---|---|---|
| | Focal company | Supply chain | External stakeholders |
| Technological | *Lack of technical base within the company:* Petrobras attracted and started absorbing routine capabilities from suppliers | *Lack of technology content suppliers:* large integrated multinationals suppliers arrived in Brazil, establishing long-term contracts with Petrobras | N/A |
| Commercial | *High development costs associated with deep water oilfields:* Due to a relatively constant discoveries of new fields, Petrobras reached commercial feasibility for several oil and gas operations in Brazil | *Supplier scarcity and high cost:* Numerous other firms migrated from abroad attracted by the growing operational volume of the supply chain. Numerous local start-ups emerged from knowledge spillovers | N/A |
| Organizational | *Lack of absorptive capacity:* Petrobras was taking predominantly a passive learning approach based on routine capabilities | *Unbalanced relationships with suppliers:* large integrated multinational suppliers were the main sources of knowledge and routine capabilities | N/A |
| Societal | N/A | N/A | *Lack of freedom of speech:* Under military dictatorship, external stakeholders (e.g., media, government, universities) were all apparently positive about the supply chain's environmental and social standards |

local start-ups emerged from knowledge spillovers. In terms of the organizational uncertainties, this 1st Stage was marked by unbalanced relationships between Petrobras and large integrated multinational suppliers like Schlumberger, Halliburton and Baker Hughes. During this stage, these companies possessed strong bargain power because they constituted the main sources of knowledge and routine capabilities.

Regarding the societal uncertainties, this period was driven by the lack of freedom of speech due to the military dictatorship that governed the country for 21 years (1964–1985). Petrobras was owned by the government and controlled by the militaries, and there was no venue to discuss or point out any social or environmental demands. Therefore, external stakeholders (e.g., media, government, universities) were all apparently positive about this new development and the industry environmental and social standards. A democratic government stepped up in 1985, the last year of this stage.

### 5.2. 2nd Stage – PROCAP 1000: 1986–1992

The 2nd Stage coincides with the PROCAP 1000, which was the Petrobras' Deepwater Technological Program for exploration, development and production of oilfields in water depths of up to 1000 m, and took place between 1986 and 1992 (Table 2). Regarding the focal company, during this stage Petrobras lacked an active role in technology design and development. In order to

**Table 2**
2nd Stage (1986–1992) – PROCAP 1000 uncertainties.

| Uncertainties | Entity | | |
|---|---|---|---|
| | Focal company | Supply chain | External stakeholders |
| Technological | *Lack of an active role in technology design and development:* Petrobras started actively pursuing learning through R&D partnerships, joint ventures and other knowledge transfer mechanisms with suppliers, universities, R&D institutes and oil companies. | *Lack of central leader within the supply chain:* Petrobras consolidated itself as a central player and the focal company for the offshore oil and as supply chain in Brazil. Key suppliers shifted from source of routine capabilities to source of innovative capabilities | N/A |
| Commercial | *PROCAP 1000:* In 1986, Petrobras created the Deepwater Technological Program – PROCAP 1000 to develop a complete set of technologies to reduce costs and allow production in water depths of up to 1000 m. | *Distance from local suppliers:* PROCAP 1000 enabled Petrobras to get closer to key local suppliers by developing technological solutions to specific operational problems. Building ties, increasing integration and enhancing communication allowed for supply chain integration and collaboration | N/A |
| Organizational | *Avoiding blue sky projects:* Petrobras focused on applied projects that were closely related to the operational needs (not pure research), and numerous patents emerged. Cenpes had an important role during this stage. | *Appropriation issues:* Petrobras appropriated innovation benefits by transferring new technological knowledge to few local suppliers (free of charge) so that costs and quality of supplied goods and services were improved. | N/A |
| Societal | N/A | N/A | *Growing awareness:* with the diffusion of the idea of sustainable development and corporate responsibility coupled with the technological development, accidents and the impacts of these events gained visibility to the general public generating media backlash and consumer pressure |

mitigate this uncertainty Petrobras started actively pursuing organizational learning through R&D partnerships, joint ventures and other knowledge transfer mechanisms with suppliers, universities, R&D institutes and other oil operators. Numerous patents were registered during this stage, and in 1985, Petrobras was the first company to undertake a subsea completion (i.e., the process of putting an oil well into production) in water depth of 383 m without the help of any form of human diving. In 1988, the company repeats the process in water depth of 492 m in Marimba oilfield (Petrobras, 2013). In 1992, Petrobras sets a new world record for oilfield production in water depth of 781 m in Marlim oilfield. To address the emerging commercial uncertainties, Petrobras established 116 R&D projects and more than $70 million of investments through the PROCAP 1000 to develop a complete set of technologies to reduce costs of production at water depths of up to 1000 m. The company also explicitly avoided "blue sky" (i.e., pure research) projects by assuring that all the R&D effort was focused on applied projects that were closely related to the operational needs. Petrobras' research centre (Cenpes) had an important role during this stage.

Regarding the supply chain, during this stage Petrobras consolidated itself as a legitimate technology leader and the focal company for the offshore oil and gas supply chain in Brazil. A strong network of relationships with key local suppliers started to emerge and became the locus for the subsequent innovations. This network operated as a source of knowledge and innovative capabilities through long-term R&D and supply contracts. To address the commercial uncertainties, Petrobras got closer to key local suppliers by developing technological solutions to specific operational problems they faced. Building ties, increasing integration and enhancing communication allowed supply chain members to become true partners. Petrobras was able to appropriate innovation benefits by transferring new technological knowledge and patents rights free of charge to few key suppliers to reduce costs and improve quality of supplied goods and services in the country.

Regarding the societal uncertainties, this period was marked by the growing awareness of sustainability issues, ending with the heated debate provoked by the ECO 92, i.e., the United Nations Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in 1992. With the diffusion of the idea of sustainable development and corporate responsibility coupled with the technological development, accidents in the oil and gas supply chain gained visibility to the general public and generated media backlash and consumer pressure. For example in February 1984 a pipeline leak under a shantytown in the city of Cubatao followed by a series of explosions killed at least 90 people and left more than 500 people missing and in August 1984 an accident with a lifeboat in the Enchova PCE-1 platform in Campos Basin killed 42 employees (FNP, 2008). Politically, this transition period was also turbulent and marked by the impeachment in 1992 of Fernando Collor de Mello, the first directly elected president by the Brazilian people after the military dictatorship.

### 5.3. 3rd Stage – PROCAP 2000: 1993–1999

The 3rd Stage coincides with the PROCAP 2000, which was the Petrobras' Deepwater Technological Program for exploration, development and production of oilfields in water depths of up to 2000 m, and took place between 1993 and 1999 (Table 3). Regarding the focal company, during this stage Petrobras faced technological challenges for oil wells deeper than 1000 m and the company started working with R&D partners to achieve commercial feasibility (reduce production costs) of oil fields located in water depths of up to 2000 m. This effort led to a world production record at 1877 m of water depth in 2000 (Petrobras, 2011). The

**Table 3**
3rd Stage (1993–1999) – PROCAP 2000 uncertainties.

| Uncertainties | Entity | | |
|---|---|---|---|
| | Focal company | Supply chain | External stakeholders |
| Technological | *Oil fields in water depths of more than 1000 m:* technological challenges for oil wells deeper than 1000 m made Petrobras launch PROCAP 2000 | *Incompatible supplier technological capabilities:* PROCAP 2000 also enabled Petrobras' key suppliers to get involved and collaborate in those 20 R&D projects. This allowed focal company and suppliers to develop innovation capabilities together. | N/A |
| Commercial | *PROCAP 2000:* PROCAP 2000 included 20 systemic R&D projects to support Roncador and Marlim Sul oilfields. It was conceptualized as a continuation of the PROCAP 1000 and also involved the development of technologies that allowed for significant cost reductions | *Distance from global suppliers:* Adoption of new ways to organize and manage innovation and joint R&D efforts to solve emerging operational issues. It involved external partners and interactions as essential drivers for commercial success. | N/A |
| Organizational | *Targeting the frontier:* Petrobras started prioritizing projects that allowed the company to reach and expand the frontier of knowledge in some specific areas, in line with a newly devised global strategy. | *Expanding the boundaries:* Petrobras became more interactive and innovative through multiple R&D partnerships. The concept of innovation networks became reality for the company and its supply chain. | N/A |
| Societal | N/A | N/A | *Environmental accidents/health and safety problems:* supply chain was scrutinized by the media and society for its health and safety conditions (especially for suppliers' employees) after a series of accidents with fatalities. Petrobras decided to change its approach to the environmental and social dimensions and ends up winning several awards and later on being recognized as the world's most sustainable oil and gas company |

PROCAP 2000 included 20 systemic R&D projects to support Roncador and Marlim Sul oilfields in Campos Basin. The program was conceptualized as a continuation of the PROCAP 1000 and also involved the development of technologies that allowed for cost reductions in the company's multiple oilfields. Petrobras started targeting and prioritizing projects that allowed the company to reach and expand the frontier of knowledge in deep water development and production, in line with a newly devised global strategy for leadership.

During this stage, the supply chain did not possess the technological capability to support Petrobras operations in the given water depth. Thus Petrobras' key suppliers got involved and collaborated in the 20 R&D projects connected to the PROCAP 2000 in order to find solutions for the emerging operational problems. This strategy allowed the focal company and its suppliers to build innovation capabilities together and reduced the distance between Petrobras and global integrated multinational suppliers, helping the supply chain to adopt new ways to organize and manage innovation. It involved strategies to enhance integration and communication with global integrated multinational suppliers and other external partners through joint R&D efforts and continuous interactions, which worked as essential drivers for commercial success. The supply chain became more interactive and innovative through multiple R&D partnerships and knowledge boundary expansion. In line with Dantas and Bell (2011), the concept of innovation networks became reality for the company and its supply chain. Freitas and Furtado (2001) highlight that during this stage Petrobras took a more central role in technological development contracts (instead of a passive approach as observed in earlier stages), showing a significant technological learning capacity.

Regarding the societal uncertainties, during this stage, as consumer pressure grew, Petrobras and its supply chain was scrutinized by the media and society for its poor environmental performance as well as health and safety conditions (especially for suppliers' employees) after a series of accidents with fatalities. For example, according to FNP (2008), severe oil spills and accidents increased the pressure from media and public including the Paraiba River oil spill (1 million liters in 1998), the Guanabara Bay oil spill (1.3 million liters in 2000), the Iguacu River oil spill (4 million liters in 2000) and the sunk of the P-36 platform (1.5 million liters and 11 fatalities in 2001). These accidents were all results of the technological and commercial efforts during this 3rd Stage. Simultaneously, in 1997, the government put forward the law that broke the Petrobras' monopoly and allowed competitors to develop oilfield operations in Brazil. As a result of the changing business environment and internationalization efforts, Petrobras signed several agreements to start operations abroad. After this stage, Petrobras decided to change its approach by heavily investing on the environmental and social dimensions and ended up winning several awards later on, being recognized as the world's most sustainable oil and gas company in 2008 (Noria, 2008).

### 5.4. 4th Stage – PROCAP 3000: 2000–2011

The 4th Stage coincides with the PROCAP 3000, which was the Petrobras' Deepwater Technological Program for exploration, development and production of oilfields in water depths of up to 3000 m, and took place between 2000 and 2011 (Table 4). Regarding the focal company, during this stage technological challenges for oil wells deeper than 2000 m of water depths made

**Table 4**
4th Stage (2000–2011) – PROCAP 3000 uncertainties.

| Uncertainties | Entity | | |
|---|---|---|---|
| | Focal company | Supply chain | External stakeholders |
| Technological | *Oil fields in water depths of more than 2000 m:* technological challenges for oil wells deeper than 2000 m made Petrobras launch Procap 3000. After this stage, Petrobras realized that technological challenges for any water depth have been overcome. | *Pushing suppliers along:* suppliers had to possess certain technological base and capabilities. Required a major effort from key local suppliers and large integrated multinational suppliers, which were the key partners during this stage. | N/A |
| Commercial | *Ultra-deep water challenges:* Petrobras start working with R&D partners to achieve commercial feasibility (reduce production costs) of oil fields located in water depths of 2000 m and deeper. | *Thematic networks:* Petrobras worked with suppliers from different sizes and types in strategic thematic networks. Brazilian universities represented an important part of these innovation networks, which became more mature, robust and solid | N/A |
| Organizational | *Consolidating leadership at the frontier:* Petrobras continues to jointly develop technology at the frontier of knowledge in key areas related to its operations. The company becomes the leading hub for deep and ultra-deep water technologies and exports them to several parts of the world. | *Existing technological bottlenecks:* Petrobras' research centre (Cenpes), located in Rio de Janeiro, went under a major renovation and expansion. After completion in 2010, Cenpes became a research complex with more than 300,000 square meters; one of the world's largest centres for applied research. | N/A |
| Societal | N/A | N/A | *Social consequences:* apart from the environmental and health and safety problems, the supply chain has been pressured to address broader social problems such as fishing communities damaged by offshore operations, migration of labour, and lack of infrastructure in the cities where supply chain aperations are located (i.e., traffic jams, lack of health care and schools, high levels of crime and violence). |

Petrobras work with R&D partners through the PROCAP 3000 to address technological issues and achieve commercial feasibility (reduce production costs) of the ultra-deep water oilfields. This new journey led Petrobras to set up two new world offshore drilling records: 1886 m in 2003 and 2777 m of water depth in 2007 both in Roncador field (Petrobras, 2011). Petrobras continues to jointly develop technology at the frontier of knowledge in key areas related to its operations. After this stage, Petrobras announced that technological challenges for any water depth have been overcome, and the company becomes the leading hub for deep and ultra-deep water technologies, exporting them to several parts of the world.

Technologically, the oil and gas supply chain was pushed along by Petrobras. Suppliers had to possess certain technological base and capabilities to participate in the R&D projects with Petrobras during this stage. These projects required a major effort from integrated multinational suppliers, which were the key partners during this stage. The strategy involved jointly effort and development of new capabilities to overcome technological uncertainties. To overcome commercial uncertainties, Petrobras and its supply chain worked together in strategic thematic areas. Brazilian universities represented an important part of these innovation networks, which became more mature, robust and solid if compared with the previous stages. Existing R&D bottlenecks were identified. To resolve this organizational uncertainty Petrobras' research centre (Cenpes), located in Rio de Janeiro, went under a major renovation and expansion. After completion in 2010, Cenpes became one of the world's largest applied research centres encompassing a research complex with more than 300,000 square meters.

Regarding the societal uncertainties, politically, the country was much more stable. However, 114 work related fatalities were reported between 2002 and 2008 inside Petrobras' operational bases, which involved both Petrobras' and suppliers' employees (FNP, 2008). Also, besides the health and safety problems exacerbated by the need to conquer more challenging technological milestones, the supply chain has been pressured to address broader social problems such as fishing communities disturbed by offshore operations, migration of labour that remains unemployed due to low level of capabilities, exacerbating the favelas' problems, lack of infrastructure in the cities that host oil and gas supply chain operations, which generate traffic jams, lack of adequate health care facilities and schools, high levels of crime and violence.

### 5.5. 5th Stage – PROCAP Future Vision: 2011-future

The driver for the 5th Stage (2011 – Future) is what Petrobras is calling "PROCAP Future Vision". In this new version, with the leadership of the focal company, Petrobras, the offshore oil and gas supply chain is focusing on solutions that can dramatically change the current methods and technologies to develop an ultra-deep oilfield. The main goal is to develop and use radical technologies in offshore operations such as nanotechnology (nanoparticles), laser drilling, and new generation of subsea systems for production. One of the reasons for this new challenging stage is the fact that the supply chain is now preparing itself for the challenges of the pre-salt development and production. Pre-salt layer production means that the oil and gas lie below 2000 m deep layer of salt, which is below 2000 m layer of rock under 3000 m of water depth in the ocean (i.e., it may require access to more than 7000 m away from ocean surface). Technological uncertainties associated with these challenges are significant given the hostile and remote conditions. To overcome these technological uncertainties Petrobras has been attracting major integrated multinational suppliers to establish R&D facilities in Brazil. This is a major trend that is currently happening in Brazil. For example, only the Federal University of Rio de Janeiro (UFRJ) is receiving seven R&D facilities from Schlumberger, Baker Hughes, Halliburton, FMC Technologies, Cameron, Usiminas, Tenaris Confab, General Electric, and IBM (Petrobras, 2011). In October 2013, the partnership between Petrobras (40%), Royal Dutch Shell (20%), Total (20%), CNPC (10%) and CNOOC (10%) won the rights to exploit Brazil's biggest-yet oil discovery, the Libra pre-salt oilfield. Commercially, the uncertainties are attenuated by the large size of the pre-salt oil reserves, roughly 14 billion barrels (Seabra et al., 2011; Jimenez, 2013).

For this 5th Stage, organizational uncertainties are larger than ever. Petrobras, supply chain members and other R&D partners are about to face coming discontinuities for deep and ultra-deep water development and production. This can be certainly risky for incumbents, but extremely rewarding if well planned and executed. Regarding the societal uncertainties, there are significant social risks ahead, especially related to employees' health and safety and the pressing ones identified during the 4th Stage (Table 4 – societal uncertainties), which still need to be addressed. In terms of environmental uncertainties, these are currently unclear, ambiguous and still difficult to be identified and measured (Silveira, 2012; Ribeiro, 2012). The only certainty in challenging circumstances like the ones ahead is that both the social and environmental dimensions should be taken very seriously. Since this 5th Stage is currently in progress, its end date and outcomes are still uncertain.

Petrobras' leadership can also be observed when it comes to the sustainability standards and strategies adopted by its supply chain. According to Petrobras former CEO Gabrielli de Azevedo (2009), Petrobras' operations had been hindered by poor environmental performance in the past. For example, in 2000 the company was responsible for major oil spills, and lost a modern floating platform (P-36) after numerous explosions, killing 11 employees in 2001 (Bayardino, 2004). These events, along with public backlash, contributed towards the company's shift in its environmental and social stance, by making extensive efforts to sustain high environmental supply chain standards. The company is now seen as a model for corporate social responsibility within the oil and gas industry (Noria, 2008). The success of Petrobras and its supply chain, in terms of profitability and reputation, was based on the accumulation of sophisticated, world-leading technologies over time while simultaneously addressing environmental and social matters.

More recently, Petrobras has re-positioned itself as an energy company (not only an oil company) and strongly engaged in the biofuels supply chain (Hall et al., 2011). Matos and Silvestre (2013) highlight that the Biodiesel Program, led by Petrobras, was implemented to address in a greater extent the environmental (i.e., renewable energy) and social dimensions (i.e., social component of the Biodiesel Program through Social Stamp rebates). In line with the existing literature, this strategic action reflects the urgency for the maturity of renewable fuels and other innovative ways to incorporate sustainability into production systems (Bonilla et al., 2010b; Mancini et al., 2010).

## 6. Discussion

The literature advocates that emerging economies still lack an adequate regulatory framework for sustainability (Bonilla et al., 2010a; Zapata and Nieuwenhuis, 2010; Silvestre and Silva Neto, 2013). Sustainability policies require compliance from firms and allow supply chains to operate in a more sustainable environment, where firms know the rules and are aware of what they need to do. In practice, sustainability regulations educate, guide and allow supply chains to pursue business profits while still reducing the harm on the natural environment and surrounding communities. However, even facing additional barriers to sustainability often

encountered in some emerging economies (Silvestre, 2013), the oil and gas supply chain in Brazil was able to achieve significant success regarding its sustainability strategy, including the adoption of cleaner production innovations such as minimization of water use (Campos et al., 2005; Prestrelo, 2006), reduction of energy consumption (Oliveira, 2005) and management of industrial waste and chemical residues from offshore oil and gas platforms (Zampollo and Neder, 2013). This research highlights this was not an easy or effortless path, but an outcome of a deliberate and articulated long-term strategy evolving over more than 40 years and involving focal company, supply chain members and a number of external stakeholders.

Our field studies in Brazil also suggest that additional complexity and uncertainty emerge from such environments where the lack of regulatory framework for sustainability and pressing social problems are still encountered. Examples of supply chains in emerging economies facing unforeseen uncertainty and struggling to achieve sustainability performance are numerous (Sahay, 2003; Downie, 2007; Silvestre et al., 2010; Dale et al., 2010; Silvestre and Silva Neto, 2013). However, successful examples of supply chains that have emerged through innovation are not rare in Brazil (Silvestre and Dalcol, 2009; Hall et al., 2011; Matos and Silvestre, 2013). In line with Hall et al. (2012a), we argue that organizations and supply chains should focus on sustainability to achieve relevance to society while the focus solely on financial performance is unlikely to produce fruitful results because, in that case, organizations and supply chains are likely to remain irrelevant.

The literature suggests that without innovation, organizations cannot successfully incorporate environmental and social dimensions and achieve enhanced sustainability performance (Seuring and Muller, 2008; Silvestre, 2013) because sustainability requires cultural and mindset changes (Savitz and Weber, 2006; Carter and Rogers, 2008). Innovations are thus really mandatory when implementing sustainable supply chains. Thus, I argue that the triple bottom line concept must be necessarily connected to the innovation literature and practice. To help addressing this gap the use of the TCOS uncertainty framework provides an opportunity to establish this connection between the theory and practice of innovation and sustainability. There is no apparent reason why studies connect innovation to single dimensions of supply chain performance such as solely financial or environmental measures. This is because the financial, environmental and social dimensions present key interdependences and therefore cannot be fully understood in isolation. Similarly, the investigation of organizations', supply chains' or industries' technological trajectories alone (i.e., not considering other aspects such as environmental and social dimensions) becomes incomplete. This paper adapts and extends the TCOS framework by linking it to the supply chain literature as a means to provide a tool to understand and analyze the sustainability trajectories of supply chains.

Based on the stakeholder theory discourse (Freeman, 1984), this research emphasizes that the way a focal company manages and is influenced by its network of relationships shape the evolution of the supply chain sustainability trajectory. The literature on innovation and learning networks supports this idea. For example, Ibarra (1993) found that organization's relationships (formal and informal) have strong implications on innovation-related activities. Also, Powell et al. (1996) argue that when the knowledge base of an industry is complex, dispersed and expanding, the locus of innovation will be in networks (not in an individual organization). The literature also shows evidence that networks have the ability to perform well when it comes to sustainability initiatives and goals (Ukidwe and Bakshi, 2005; Fadeeva, 2005; Hukkinen, 2008; Moore and Manring, 2009). For example, Manring (2007) highlights the importance of networks to achieve transformational learning and consensual sustainability decisions while van Bommel (2011) suggests that innovation through industrial supply networks is the path to proactive strategies towards sustainability. This is in line with what happened in the offshore oil and gas supply chain in Brazil. Since the industry's knowledge base is complex, dispersed and expanding, Petrobras realized through the evolution of its supply chain that only establishing thematic and integrated networks could give the company the resources it needed. Through Petrobras' leadership, the oil and gas supply chain in Brazil was able to expand and solidify its network of relationships forming a robust set of networks (4th Stage), where (local and global) sources of specific knowledge were efficiently connected, recombined and exploited. The focal company and supply chain were also able to involve local universities, research institutes, union, governmental agencies and other external stakeholders by considering and addressing their environmental and social concerns as they emerged. As the case study suggests and consistent with Wheeler et al. (2003), stakeholder theory is related to the creation of value by organizations/supply chains on multiple dimensions (e.g., triple bottom line), with social justice, stability, awareness of the multiple implications of their activities, and willingness to address emerging concerns.

This research suggests that sustainable supply chain management should be considered and understood through the lenses of evolutionary approaches (Nelson and Winter, 1982). As per firms, I argue that supply chains are initially immature, but they learn, acquire new capabilities and evolve overtime. Based on this contribution, I assert that the importance and dynamism of the perspective of supply chain sustainability trajectories are not reflected on the existing literature as it should be. Evolutionary approaches have the ability to add the active nature of supply chains and their dynamics. At certain point of their trajectories, supply chains become ready to address emerging technological, commercial, organizational, political, environmental and/or social uncertainties towards the incorporation of sustainability into their business practices, as our case study suggests. In fact, Smith et al. (2005) suggest that selection pressures continuously challenge established regimes, which consequently make transitions to more sustainable regimes. I propose that connecting evolutionary theory to the sustainable supply chain discourse (as oppose to single organization theories) provides a broader perspective that is effective in understanding a wider range of phenomena related to supply chain innovation approaches, evolution of supply chain sustainability trajectories and other dynamic and relevant aspects associated with supply chain management (e.g., collaboration, integration, ownership).

This research also suggests that sustainable supply chain implementation and management are context-specific issues. Consequently, theoretical, managerial and policy generalizations are difficult to be achieved for sustainable supply chains. Drawing from contingency theory (Lawrence and Lorsch, 1967), I suggest that when analyzing and implementing sustainability into supply chain operations, no set of best practices can be drawn linearly from previous successful cases. The business environment (including the focal company, supply chain members, external stakeholders and associated relationships and dynamics) within which a supply chain operates directly shapes its sustainability trajectories. As per our case study, the trajectory of the offshore oil and gas supply chain in Brazil is indeed context-specific, since contextual factors play a crucial role and cannot be detached from its core decisions. Therefore lessons cannot be fully transferred to or from other supply chain contexts.

## 7. Conclusion

This paper brings at least four key contributions and associated avenues for future investigation. First, this paper adapts and

extends the TCOS uncertainty framework by linking it to the sustainable supply chain literature as a means to provide a tool to understand and analyze the evolution of supply chains sustainability trajectories. I highlight the need for a better understanding of the interdependences, trade-offs and impacts of each of these uncertainties to supply chain sustainability trajectories. I also encourage further research on the application of the TCOS uncertainty framework to the evolution of sustainable supply chains in different industries (e.g., natural resource-based, high-technology, service) and settings (other emerging economies, developed and developing countries). Of special interest, I call for further research on the role played by societal (political, environmental and social) uncertainties on supply chain sustainability performance. Second, I propose that the way a focal company manages and is influenced by its established network of relationships shape the evolution of the supply chain sustainability trajectory. Thus, I call for further research on the interaction between stakeholder theory and the sustainable supply chain management discourse. Moreover, the interdependences and trade-offs between both social capital and networks and supply chain sustainability performance are required to be better understood in the future. Third, I argue that sustainable supply chains should be considered and understood through the lenses of evolutionary approaches. I also call for further theoretical and empirical research on the relative importance of path dependency to sustainable supply chains. Finally, in this paper, I suggest sustainable supply chain implementation and management are context-specific issues and theoretical, managerial and policy generalizations are difficult to be achieved. I observe the need for identifying and better understanding the contextual factors that influence supply chain trajectory shifts regarding sustainability. More interestingly, how and why these shifts vary in terms of their intensity, direction and length of time in different settings and industries. I also encourage further research on practical examples of supply chains that were able to successfully incorporate sustainability into their business practices in different industries and countries.

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