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Towards Corporate Production Systems: Collaboration and Upgrading in Supply Networks of the Brazilian O&G Industry

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Abstract

In the course of about the last decade and half, Brazil experienced a revival in its industrial policy efforts. New institutions and forums were created to increase coordination between government and business sectors, while traditional developmental institutions experienced a considerable increase in their budgets in order to fund modernization, internationalization and R&D activities of companies. In parallel to these initiatives, the government adopted protectionist measures in different sectors. To date, the best known policy has been the local content requirements (LCR) in the oil and gas sector. Launched in 1998, LCR has since 2003 evolved to cover a broad array of equipment and services based on a rationale of securing demand and creating new opportunities for firms operating in Brazil. Despite government claims that the LCR policy has been crucial for the maintenance and creation of thousands of jobs – particularly in the shipbuilding industry – there is little systematic evidence about how LCR has effectively contributed to the consolidation and strengthening of links between oil companies and the different tiers of suppliers operating in the sector. Beyond producing in Brazil, it is important to know how companies have been producing. Particularly in highly internationalized and technology-intensive sector such as offshore oil exploration and production, the relationship between operators and firms in different segments of the supply chain defines the patterns for upgrading and innovation in production systems. Therefore, it is crucial to know whether the incentives created by LCR are either allowing for new collaborative partnerships or just reproducing historical hierarchical patterns between domestic and foreign firms. Aiming to fill in this gap, the paper analyzes data from a survey conducted with directors and managers of 558 firms in the Brazilian O&G sector. Based on this data we build an index that measures the level of client-supplier collaboration and upgrading for the O&G sector. The results show that there is a high level of collaborative upgrading in the sector, suggesting that policies such as LCR can be important instruments to stimulate upgrading of domestic companies in a technology-intensive sector such the offshore O&G.

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«After we got the contract to build the module for the shipyard, we had to hire a weld inspector level 3. You know, we had heard about the existence of level 3 inspectors. Apparently, they are common abroad. But then we had to find one of these qualified inspectors in Brazil in order to assure the quality of our work was according to our client standards." Production Manager, CMI Montagem Industrial

"We have about 120 suppliers for our X-mas tree factory in Brazil. They have been traditionally suppliers to other sectors and we have a special program for developing their production standards in order to supply us." Supplier Manager, Aker Solutions.

Introduction

For developing countries, industrial upgrading has been a key challenge to compete in the global economy (Berger, 2012). While many companies choose to compete in low-end markets by keeping both wages and costs low, few have been able to move up the ladder in terms of increasing productivity and higher technological content. For policy-makers, particularly those from Latin American countries, finding strategies that contribute for companies to achieve the latter has proved to be a particularly difficult task. Different mixes of protectionist measures and incentives for exports and R&D investments have predominated in the region since the so-called 'renaissance' of industrial policy during the 2000s. In this regard, Brazil has been a paradigmatic case. New institutions and forums were created to increase coordination between government and business sectors (Schneider, 2009), while traditional developmental institutions experienced a considerable increase in their budgets to fund modernization, internationalization and R&D activities of companies. In parallel to these initiatives, the government adopted protectionist measures in different sectors. However, even with such aggressive approach Brazilian industrial production and exports of medium and high tech manufactured products in general has been falling dramatically in recent years and manufacturers have been struggling to become part of global supply chains (Kasahara and Botelho, 2016).

An important question is to know to what extent the recent industrial policy efforts of the Brazilian state have created opportunities for local companies to climb the ladder of productive upgrading. To date, a popular policy in Brazilian debates has been the local content requirements (LCR) for the oil and gas (OG) sector. Launched in 1998, LCR has since 2003

evolved to cover a broad array of equipment and services necessary for exploration and development of offshore oil fields. For critics, the policy represents a burden for oil companies, which have to deal with the technological and project limitations of Brazilian-based suppliers. Consequently, increased costs and delays are often mentioned as disadvantages brought by the policy. On the other hand, LCR supporters argue that it not only creates jobs through securing demand to companies operating in Brazil, but also allows Brazil-based companies to upgrade their production systems, as they become suppliers of a sector with high quality and technological standards.

Although LCR can represent a regulatory context, in principle favorable to industrial upgrading, there are limited theoretical frameworks and empirical evidences to understand how such process could take place in general and whether it is happening in the Brazilian O&G sector. Recent theoretical analyses of the political economy of Latin America and Brazil – mainly inspired by the Varieties of Capitalism (VoC) framework – have little to say about upgrading due to its static bias and reliance on broad and complex reforms that could create "good" institutional complementarities for companies to upgrade (Schneider, 2013). Industrial policy advocates also tend to emphasize more the importance of the State in coordinating private sector efforts and funding innovation than understanding specific sectoral dynamics and firm strategies to upgrade (Mazzucato, 2013; Stiglitz and Lin, 2013). Even the literature about global value chains (GVC), surprisingly lack analysis about the highly internationalized upstream O&G sector.[1]

The lack of studies in the international literature of upgrading about the offshore O&G industry in emerging countries is more striking due to its characteristics of being both capacity and knowledge-intensive requiring capable companies along the whole supply chain. Particularly for middle-income countries with a developed manufacturing sector, such nature of the offshore O&G sector represents a singular opportunity for companies to upgrade. Furthermore, harnessing this potential could lead to broader positive spillovers, as productivity growth and improvement in standards of suppliers in lower tiers spread across sectors. This could bootstrap an emerging economy like Brazil from its middle income and stagnant productivity trap.

[1] An exception is Bridge (2008).

In order to fill this gap, we need to look systematically at which companies react and how they do so to the incentives and opportunities created by sectoral policies for upgrading. To develop an understanding of such dynamic, we have to bring back in sectoral specificities into our analysis, acknowledging that national institutional settings interact directly with different technological dynamics, industrial structures, and patterns of organization of the value chain (Crouch et al., 2009).

Based on combined evidences from qualitative case studies and a survey conducted with 558 suppliers for the Brazilian O&G sector, we make three main claims. First, there are evidences that the LCR policy have contributed to open the market for Brazilian companies, particularly for newcomers and those who were previously suppliers to other sectors. Second, the process of upgrading and improvement seems to be more relevant for companies that were already suppliers for the O&G sector, but located outside traditional industrial areas, such as the state of São Paulo. Third, the process of upgrading seems to be driven more by inter-firm collaboration than by complementary policies to LCR adopted by the Brazilian government. Such dynamics identify the emergence of a more collaborative corporate production system (CPS) (Herrigel, 2015) than the assumptions about the hierarchical variety of capitalism identified in Latin America – and derived to Brazil – would assume (Schneider 2013). This paper also seeks, in a complementary way, to analytically explore the possibilities of upgrading in the oil industry supply chain, a complex, globalized, supply-driven and high-value-added industry.

The limits of VoC and the possibilities of upgrading

Current interpretations of Latin American political economies have been strongly influenced by the VoC approach developed by Hall and Soskice (2001). Schneider's *hierarchical* variety of capitalism is the more encompassing and careful adaptation of the VoC framework for the Latin American context (2013). His description of a low-skill equilibrium as the main characteristic of the region is a good synthesis of the main challenges facing Latin American economies. The lack of incentives for Latin American business groups and companies to invest in skills and specialize in low-tech sectors due to competitive pressures from multi-national companies (MNCs) who keep their research and development (R&D) centers abroad creates a vicious circle that do not stimulate upgrading and innovation. In parallel, Latin American

political institutions also strive to promote broad institutional reforms (e.g. improvement of both access to and quality of education) that could alter important aspects sustaining this sub-optimal equilibrium. The problem here is that, while we have a good explanation for why Latin American companies would choose a "low road" of business strategies, we lack an explanation for why some companies might in fact choose a "high road" and why this might be more relevant for specific sectors

Within the hierarchical typology, upgrading and innovation do not find natural endogenous causes. Exogenous shocks, such as opening of markets, are the natural reasons for domestic companies to modernize. However, deleterious effects normally are expected to follow these shocks. On one hand, domestic companies would have few incentives and conditions to compete equally with incoming MNCs and foreign products. On the other hand, for those who prove to be competitive, a merge with or acquisition by a MNC is a natural path. Furthermore, MNCs would have very few incentives to transfer knowledge to and stimulate upgrading of their local suppliers, as holding tight to R&D capacities is a key competitive advantage. Secondly, the specialization of domestic companies in low-tech sectors, such as natural resources and services, as a strategic response to foreign competition would also restrain considerably possibilities for modernization.

This pessimistic view about the role of MNCs and natural resource endowment of Latin American countries neglect important nuances when we look at specific sectoral dynamics. First, MNCs can play a positive and leading role in upgrading domestic suppliers, particularly in sectors that produce sophisticated, techonology-intensive, products. Gereffi and Sturgeon (2013) point out, for instance, that Brazil has been successful in attracting key first-tier suppliers in important sectors which hold the promise of integration in global value chains (GVC), such as consumer electronics. The recent opening in Brazil of manufacturing units by Foxconn – the largest original equipment manufacturer (OEM) in the world and the main supplier for Apple – is as an example, as fiscal incentives were conditioned to a gradual increase in the use of local suppliers. Second, the extraction of natural resources, despite considered as a low-tech sector, can require high levels of technology and expertise. The offshore oil industry, for instance, relies on a large supply chain of equipment and services that is more complex, technologically more challenging and adds more value locally than consumer electronics. Countries such as Canada and Norway are examples of sophisticated industrial development based on the

consolidation of domestic suppliers for oil and mining companies. As our survey results show, despite these assumptions, a natural resource sector dominated by MNCs first-tier suppliers such as the upstream O&G sector can be favorable to structural upgrading and innovation.

A CPS approach for the O&G sector

Against the VoC assumption about the behavior of the MNCs, we assume here that first-tier suppliers of sophisticated offshore O&G equipment (e.g. subsea components) can have rather positive effects. First, in a passive way, the higher standards of the industry generate incentives for local companies willing to become part of MNC's supply chain to improve and upgrade their products and services. Secondly, as MNCs need qualified suppliers they have incentives to work actively in the upgrading process of local companies, characterizing a more collaborative relationship than a simply hierarchical. The offshore O&G supplier network has, thus, the possibility of constructing new relationships that go beyond the assumptions and dynamics expected in the VoC framework.

Such context demands more flexible theoretical framework in which companies can build new strategies and relationships in a context of uncertainty. In this regard, the Corporate Production System (CPS) literature provides an alternative narrative of possibilities building of an endogenous firm-based transformation of two components of the HME VoC model for Latin America (Herrigel and Zeitlin 2010). It does so by advancing a different role for MNC subsidiaries in collaboration for upgrading and, complementary, in their contribution to overcome the obstacle of low levels of education and vocational skills (Wilkins 2010). The point is that both MNCs and local companies establish more open-ended, experimentalist, and positive relationships than normally conceived.

Herrigel (2015) argues, for example, how team/stakeholder driven systems of formal procedures have transformed corporate culture today:

> "Their experimentalist character enhances the capability of companies to negotiate uncertainty in their market and technological environments by encouraging organizational recomposition in response to challenges. When they are working properly, experimentalist systems foster and diffuse both

> organizational and technological innovation within companies and across supply chains (Helper et, al 2001; Sabel 2005, Spear 2009, Herrigel 2010, Herrigel et al 2013). As such, they enhance the competitiveness of manufactures in advanced political economies and induce continuous upgrading of producers and regions in emerging economies (Herrigel et al 2013)." (Herrigel 2015: page 1)

At its core, the CPS literature has a pragmatic-experimental theoretical foundation that challenges many premises of the VoC framework. Within the confines of this paper, it is not possible to synthesize the mounting empirical evidence levelled in its criticism. It suffices to say that this line of criticism, although believing in the need to advance understanding of the problems of variety and change in the action of political economy, it bluntly affirms that "this progress cannot be achieved within the fundamentally static and structuralist VoC paradigm…" (Herrigel and Zeitlin 2010: page 668).

More than continuity and complementarities, this pragmatist approach highlights how actors are capable of creative strategic moves and reforms of institutions. Economic and political actors make innovative use of regional and sectoral VoC systems to sideline extant national systems, revealing that historically within them there is a profound heterogeneity in firm strategies, organizational arrangements and governance types (Crouch et al., 2009). Institutions are understood more as resources that shape scope of possibilities for actors experimenting in the present than elements that determine these possibilities. Moreover, pragmatists decry that by dislocating the structural determination from institutional arrangements to the national political economy traits, and in some cases capitalism itself, these authors fail to capture the dual role of interpretation and ambiguity involved in processes of institutional reproduction or change:

> "The Streeck-Thelen-Mahoney trajectory makes it difficult to capture the simultaneous recomposition of actor identities and interests along with institutional rule arrangements in the process of change. In this manner, the alternative camp, deeply influenced by pragmatist conceptions of creativity and social action, pushes the argument into a critique of structuralist versions of institutionalism itself. Rather than fruitlessly searching for a stable point of origin where the definition of actors or their interests can be anchored, the alternative pragmatic position takes the ambiguities of interests and identities as foundational. It focuses on the dynamic processes through which interacting players jointly seek to define the problems they confront and develop strategies for tackling them." (673)

This alternative perspective aims to go beyond the question of how historically contingent institutional arrangements change. To do so, it follows the evolution of self-recomposing relations in the political economy through the exam of institutions in contingent and provisional ways at moments they become important for the resolution of problems of relations among actors. That way, the pragmatist approach probes the question of how actors' problem-solving efforts continually lead to the recomposition of social relations within the economy. Its research program is, hence, more actor-centered. It pays attention to the scope of possible actions by analyzing differences in industrial practice across various national (and regional) political economies over time and their influence on how actors creatively reshape their strategies and governance arrangements.

Herrigel's (2015) research on experimentalist systems in manufacturing multinationals suggests that "formal experimentalist governance systems create trans-nationally coherent, self-recomposing systems in which neither center nor locality "controls" or "directs" either its own actions or those of the other…. designed to manage (and optimize) growing global interconnectedness." (1). He says that as firms attempt to construct corporate production systems and implement them throughout their global operations three sorts of common obstacles arise: hierarchical insulation, stakeholder exclusion and inadequate empowerment resources for participants. However, they are "continually regenerated by the experimentalist dynamics of the CPS's themselves. The revision of commonly agreed upon frameworks frequently redefines power relations and stakeholders, creating new possibilities for insulation and exclusion." (2)

Opening the black box of the O&G supply chain in Brazil

Recently the political economy of the O&G sector in Latin America, particularly in Brazil, has been subject of great interest. Authors supporting or reneging the resource curse have driven an important part of the debate. Others have discussed it as proof of late success of early phases of the Brazilian developmental state (Brooks and Kurtz, 2016) or as evidence of continuity and upgrade of the previous effort to develop downstream capabilities (i.e. refining) (Randall, 1993). Whether adopting an institutionalist or structural approach, the analytic focus has been on Petrobrás. In different forms, these works portray a neo-functionalist approach by

retrospectively tracing back endogenous historic accumulation of capabilities – mainly human resources – to Petrobrás and by attributing almost exclusively to the company the recent success in finding ultra-deep offshore reserves.

This line of reasoning is argued by Brooks and Kurtz (2016) in their analysis of the Brazilian oil sector. According to them, the investment in industrial diversification and qualified human resources promoted by previous developmental efforts were successful in avoiding the main institutional endowment trap (or path dependency) that could lead to a resource curse. The nature of these capabilities is to be found in the "capital legacies of statist industrialization – even in the more liberal contemporary era – [that] have helped to create virtuous cycles of economic development and natural resource abundance" (p.4).

Despite the importance of engineers and geologists from Petrobrás in the offshore discoveries that started in the late 1970s, this approach ignores the fact that the company was more competent in adapting foreign technologies to local conditions rather than being responsible alone for breakthroughs. As Tyler Priest (2016) points out:

> "Petrobras's ability to discover and develop large offshore oil fields, however, was not the result of indigenous innovation or invention. From its founding in 1953 to the great discoveries of the 1980s, the company relied on a constant infusion of outside geological, geophysical and engineering expertise. To extract offshore oil, Petrobras borrowed concepts tested elsewhere and tapped into a mature, global oil-services industry by hiring contractors in all aspects of operations." (p. 55)

In that sense, Petrobrás has relied on the shoulder of giants of global contractors specialized in different phases of upstream activities. Global players of the offshore exploration such as Aker Solutions, FMC Technologies, Technip, and Schlumberger have all manufacturing units in Brazil. Yet, none of the major studies about the oil industry in Brazil have analytically addressed its suppliers network and whether the technological challenges involved in offshore exploration and production activities have been translated in upgrading of sub-suppliers and how LCR have influenced this process. Our survey is an effort to fill this gap.

Survey design

To run a survey on suppliers of the upstream of the Brazilian O&G sector implies knowledge about the universe of existing companies. Besides being a highly diversified supply chain,

contrary to some countries in which one can find directories and rosters of suppliers, in Brazil there is no official list that covers this universe properly. The best available rosters are the ones made by the Oil Industry National Organization (ONIP). ONIP is a sectoral business association founded in 1999 and is responsible for managing a company directory of suppliers for the OG sector operating in Brazil. The directory was created with the aim to make visible to private domestic, and foreign oil companies the existing suppliers installed in Brazil. For this reason, it includes many companies that would like to be suppliers, but are not actually in the O&G sector. Due to its voluntary membership, another limitation is that this list contains only suppliers that believe it is advantageous to be in it. More recently, due to the growth of the shipyard industry, ONIP created a new directory dedicated to this sub-sector called *Navipeças*. This directory, however, suffers from the same limitations described above.

To deal with this limitation, we pursued two strategies to filter ONIP's directories. First, we took advantage of Brazilian transparency laws and downloaded all public available contracts of Petrobrás from its website.[2] As Petrobrás is by far the main oil company in Brazil, the majority of companies in the O&G sector are its direct or indirect suppliers. Therefore, having a contract with Petrobrás is a good indicator of involvement with the O&G sector. Secondly, we obtained from the National Agency of Petroleum (ANP), a list of all companies that have presented a certificate of local content (LC) between January 2009 and December 2014.[3] Our procedure was to cross-check all four lists using the official tax identification number – available in all of them – as our index. In the process, we followed two criteria: 1) if a company has ever had a contract with Petrobrás, it was considered a supplier; and 2) if a company has ever presented a LC certificate, it was also considered a supplier. We obtained a universe of 2,538 companies distributed in the categories presented at Table 1.[4]

Based on the different stratum of our universe, we assumed that companies holding contracts with Petrobrás and being in two or more lists were companies more integrated in the O&G upstream supply chain. Therefore, we oversampled these strata in our planned sample. Within

[2] Available contracts cover the period from 1987 to 2014. However, before 2010, the number of contracts available is very small in comparison to the 198,074 just for 2014.
[3] Following Brazilian regulations, suppliers and sup-suppliers must issue certificates to oil companies proving how much of their inputs costs are acquired locally.
[4] We excluded from our universe companies that were providers of services such as cleaning, legal counsel, and accounting. We also collapsed the tax identification codes of companies and their subsidiaries. After this process, 852 companies were excluded from our universe.

each stratum, we applied random sampling. However due to problems of non-response, the realized sample deviated from the original plan.

For the survey implementation, we hired a well-established survey company (Instituto Ver), who administered it by phone during October 2015 and February 2016.[5] The protocol was to contact executive officers, directors, presidents, or vice-presidents to answer the survey. In order to increase the response rate, we obtained the endorsement of the Brazilian Institute of Petroleum (IBP) – a business association for oil companies. The endorsement was informed by the interviewers and presented in the cover letter sent by email after the first call. As a result, we obtained 564 answers with 65% being from top executive officers and directors, and the remaining from managers and supervisors.

Table 1 – Universe, planned/realized sample, and weighting

				Sample							
		Universe		Planned			Realized			Weighting	
		N	%	N	%	U/P	N	%	U/R	%R - %U	%U / %R
Petrobras contracts	LC	712	28	160	27	4,5	91	16	7,8	-12	1,7
	LC/Onip	184	7	80	13	2,3	78	14	2,4	7	0,5
	LC/Navipeças/Onip	246	10	100	17	2,5	98	17	2,5	7	0,6
	Onip	581	23	110	18	5,3	141	25	4,1	2	0,9
	Navipeças/Onip	312	12	90	15	3,5	109	19	2,9	7	0,6
	LC	503	20	60	10	8,4	48	8	10,5	-12	2,4
	Total	2538	100	600	100	4,2	564	100	4,5	0	1,0

Who answered the survey?

Due to the lack of previous surveys about supply chains in Brazil and particularly about the O&G sector, it is difficult to have a benchmark for our descriptive statistics.[6] Nonetheless, we believe we obtained a representative sample of suppliers covering a wide range of companies positioned in different tiers of the supply chain. As seen in table 2, the almost 88% of the

[5] This period was characterized by a particularly intense crisis in the Brazilian O&G sector caused by a combination of corruption scandals and a sharp fall in oil prices. Besides increasing the time required to complete the survey, we acknowledge that answers may be biased by the negative economic context.
[6] A study from IPEA published in 2010 about Petrobrás' suppliers do not distinguish between companies focusing on upstream and downstream activities.

companies in our survey were owned or controlled by Brazilian capital. However, as we do not have a clear idea of the distribution of origin of ownership in our universe, it is not possible to say whether our sample is biased or not.

In terms of percentage of revenue coming from the O&G sector, we obtained a polarized distribution with 40% declaring that a less that 25% of their revenues come from the O&G sector, while 30% saying that more than 75% of their revenues originated from it (Table 3). This distribution is a good sign of representativeness of the large scope of the O&G supply chain and that we were able to achieve companies that are in lower tiers.

Table 2. Company ownership/control

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Foreign ownership/control	68	12,1	12,1	12,1
	Brazilian ownership/control	491	87,9	87,9	100,0
	Total	558	100,0	100,0	

Table 3. Revenue from O&G sector

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0% - 25%	218	39,1	40,3	40,3
	26% - 50%	90	16,2	16,7	57,0
	51% - 75%	69	12,4	12,8	69,8
	76% - 100%	164	29,3	30,2	100,0
	Total	541	97,0	100,0	
Missing	DK/DA	17	3,0		
Total		558	100,0		

Regarding the number of employees, our sample was highly concentraded on small and medium sized companies. Although small and medium sized companies may be predominant, this distribution was probably caused by common difficulties in obtaining the participation of large companies in this type of survey.

Table 4. Number of employees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	01- 09	65	11,6	12,1	12,1
	10 – 19	65	11,7	12,2	24,3
	20 – 49	125	22,4	23,3	47,6
	50 – 99	104	18,7	19,5	67,0
	100 – 499	139	24,9	25,9	92,9
	≥ 500	38	6,8	7,1	100,0
	Total	537	96,1	100,0	
Missing	DK/DA	21	3,9		
Total		558	100,0		

An interesting aspect from our sample is the location of 40% of respondents in the state of São Paulo – the cradle of Brazilian industrialization and still hosting most of the manufacturing of capital goods and equipment in the country. Not surprisingly, the state of Rio de Janeiro comes in second place, as the main Brazilian offshore oil fields are located on its coast.

Table 5. Location by State

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AL	2	,4	,4	,4
	AM	9	1,5	1,5	1,9
	BA	37	6,6	6,6	8,5
	DF	2	,3	,3	8,8
	ES	27	4,9	4,9	13,7
	GO	1	,2	,2	13,9
	MG	34	6,1	6,1	20,0
	MT	2	,3	,3	20,3
	PA	2	,4	,4	20,7
	PE	5	,8	,8	21,6
	PR	27	4,8	4,8	26,4
	RJ	119	21,2	21,2	47,6
	RN	17	3,1	3,1	50,7
	RS	25	4,4	4,4	55,1
	SC	19	3,5	3,5	58,6
	SE	4	,6	,6	59,2
	SP	228	40,8	40,8	100,0

	Total	558	100,0	100,0	

In terms of exporting activities, most of our sample is composed by non-exporting companies or with feeble participation in world markets. This is not surprising as in recent years the demand of Petrobrás alone has providing enough activity for local suppliers. Furthermore, it has been a goal of industrial policy in recent years to raise exports and internationalization of O&G suppliers.

Regarding age of the company and the time it has been a supplier for the OG sector, we created four categories for these two variables. The cutting line of 13 years or less old used 2003 as a reference year – as the first government of President Lula initiated a more stringent LC regulation. The second category from 14 to 18 years old represent the period between the liberalization of the OG sector in 1998 and the voluntary system of LC – when oil companies would offer freely bids of LC. The third represents companies that have been in Brazil since the beginning of the offshore exploration at the Santos Basin in 1977. The fourth category of companies with age of 40 or more years old represent a group of companies that existed before any significant upstream activity in the country and probably have been suppliers for downstream activities for Petrobrás. Looking at table 7, we see that about 60% of our sample are composed by relatively established companies with age of 19 years old or more. However, looking at table 8 we observe that almost 60% of our sample is composed by companies that became suppliers of the O&G sector after 1998. These simple frequencies suggest an important redirecting of consolidated companies towards the expansion period of the OG sector in recent years.

Table 6. Number of exporting years (2001-15)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	327	58,6	58,6	58,6
	1	45	8,0	8,0	66,6
	2	19	3,4	3,4	70,0
	3	24	4,2	4,2	74,3
	4	11	2,0	2,0	76,3
	5	7	1,3	1,3	77,6
	6	16	2,8	2,8	80,4
	7	9	1,5	1,5	81,9

	8	5	1,0	1,0	82,9
	9	6	1,0	1,0	84,0
	10	8	1,5	1,5	85,5
	11	6	1,0	1,0	86,5
	12	7	1,3	1,3	87,8
	13	8	1,5	1,5	89,3
	14	25	4,4	4,4	93,7
	15	35	6,3	6,3	100,0
	Total	558	100,0	100,0	

Table 7. Company age (years)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 - 13	118	21,2	21,6	21,6
	14 - 18	93	16,6	16,9	38,5
	19 - 39	235	42,0	42,8	81,3
	40 or more	103	18,4	18,7	100,0
	Total	548	98,3	100,0	
Missing	System	10	1,7		
Total		558	100,0		

Table 8. Years as O&G supplier in Brazil

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 – 13	232	41,5	41,5	41,5
	14 – 18	98	17,5	17,5	59,0
	19 – 39	180	32,2	32,2	91,3
	40 or more	49	8,7	8,7	100,0
	Total	558	100,0	100,0	

Local content perceptions and collaborative upgrading in client-supplier relationship

The survey was designed with three main sets of questions. The first was a series of statements about how LC affected different aspects of companies' activities, such as entry in the OG

market, R&D effort, training, delivery times, and production costs.[7] As LC is a widely-debated policy in the Brazilian OG sector, our goal was to measure to what extent companies considered it relevant to their activities. The second asked about companies' internal practices and business strategies, such as existence of training programs for human resources, investment, certification, strategic partnerships, and product innovation regarding their OG activities. Our goal was to measure whether companies have been particularly dynamic because of their participation in OG sector. Finally, the third asked companies about their practices as in the supply chain, as both suppliers and clients. We asked about the existence of development programs to suppliers and about their participation in such programs. Further, we also asked them to evaluate how their relationship with clients and suppliers in the OG sector led to changes in management practices, production processes, and productivity in general. As the simple frequencies to these questions (see Appendix A) are difficult to interpret, we developed and ran several regression models to test perceptions about LC; propensity to collaborative practices conducive to upgrading; and perception of whether their relationships with other companies in the OG sector affected their development. Due to the multi-dimensional characteristic of these sets of questions, we decided to build composite indexes from a factor analysis and include them on our models. Lastly, as we were especially interested in impacts on manufacturing companies, we excluded from our analysis service companies. Therefore, the N was reduced.

The factor analysis aim is to build more robust measures of theoretical concepts, by analyzing the correlations between observed variables and the underlying concept that cause them. In the following example, we see that the correlations between these five variables form a measurement of the collaborative upgrade in the supply chain.

The commonalities represent how much of the total variance of each variable is shared with the underlying concept and the load factor is the importance of each variable, their level of correlation to the underlying concept. As can be seen below, most of the variables has important commonalities and factor loadings. The special importance of the items that measure the

[7] The answers to these questions were framed either as Yes/No or as a 1 to 5 Likert-scale, where 1 was strongly disagree and 5 was strongly agree. However, due to a very small number of answers in some categories, we decided to transform them all Likert-scale questions in dummy variables for an easier presentation of frequencies and operationalization in our linear regression model.

adoption of new management practices stands out, both in favor of O&G customers and suppliers.

The fit for the model is quite adequate. As expressed by their eigen-value, explained variance and Cronbach's alpha. The eigen-value of 2.03, the minimum parameter would be 1, reflects the existence of information redundancy in the multidimensional space formed by five variables. It is precisely this redundancy that is captured by the factor analysis. The common factor, expressed by the correlations between these variables, captures approximately 40.5% of the total variance of all five variables. Another way to see the same thing would be the Cronbach Alfa expressed in the correlation general scale between 0 and 1, which shows the degree of reliability of the linear combination of these variables. A 0.62 value can be considered adequate, although below the 0.7 limit, recognized as ideal by most experts.

The results of these factor models were used to building factor indexes, through the Regression method. It is noteworthy that, for this use, the low degree of commonality of an item does not affect the final measure calculation, since the impact of each item, its factor loading, is weighted by its contribution to the covariance to the set of items, its commonality.

Table 9. Collaboration index (Likert Scale)

	commonalities	**factor loads**
27a New organizational and managerial practices adoption for the O & G clients	0.27	0.52
27b O & G clients to help products and services improvement	0.10	0.32
29a Main suppliers very collaborative relationship	0.24	0.49
29b New organizational and managerial practices adoption for the O & G suppliers	0.48	0.69
29c Help O & G suppliers to improve products and services	0.24	0.49
Eigen-value = 2.03 / variance explained = 40.53% / Cronbach's alpha = 0.62 Maximum Likelihood extraction. Direct Oblimin rotation.		

Table 10. Local Content Quality Evaluation index (Likert Scale)

	commonalities	**factor loads**
33a Local Content contributes to the company O&G market entrance	0.41	0.64
33b Local Content contributes to the company increase in R&D effort	0.44	0.66
33c Local Content contributes to the company increase in professional training	0.73	0.86
33d Local Content contributes to the company increase in products and services quality	0.72	0.85
Eigen-value = 2.7 / variance explained = 67.7% / Cronbach's alpha = 0.84 Maximum Likelihood extraction. Direct Oblimin rotation.		

The indexes were corrected from a 5-point Likert scale to a 0-10 scale, in which 10 means high. As tables below show, the average result for the collaborative upgrading index was reasonably high (7.1 out of 10), while the result of the Local Content quality evaluation index can be considered low (3.1 out of 10).

Company age	Collaboration	Local content quality evaluation
1-13	7.2	2.9
14-18	7.4	3.0
19-39	7.2	3.2
40 or more	6.9	2.9
Total	7.1	3.1

Company property structure	Collaboration	Local content quality evaluation
Foreign ownership/control	6.4	2.8
Brazilian ownership/control	7.3	3.1
Total	7.1	3.1

O&G Specialist (revenue)	Collaboration	Local content quality evaluation
0% - 50%	7.0	2.9
51% - 100%	7.4	3.1
Total	7.1	3.1

Company size	Collaboration	Local content quality evaluation
< 100 employees	7.3	3.0
>= 100 employees	6.8	3.2
Total	7.1	3.1

Location	Collaboration	Local content quality evaluation
Other states	7.4	3.1
São Paulo state	6.9	3.0
Total	7.1	3.1

Table Z. Models Results Collaborative Upgrading index

Models	***1***		***2***		***3***		***4***		***5***	
Variables	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**	**Sig.**
Intercept	7.00	0.00	7.14	0.00	*6.51*	0.00	5.54	0.00	3.67	0.00
Brazilian Control (>50% property)	0.84	0.02	0.83	0.03	*0.80*	0.03	0.78	0.04	0.90	0.01
O&G Specialist (>50% revenue)	0.61	0.02	0.55	0.03	*0.60*	0.02	0.60	0.02	0.35	0.18
Large Company (>100 employers)	-0.51	0.08	-0.35	0.22	*-0.39*	0.18	-0.40	0.16	-0.19	0.48
SP Location	-0.59	0.03	-0.53	0.05	*-0.55*	0.04	-0.55	0.04	-0.64	0.01
O&G Supplier 1-13 years (Local Content Second Round)	--	--	--	--	-0.50	*0.25*	-0.50	0.25	-0.95	0.00
O&G Supplier 14-18 years (Local Content First Round)	--	--	--	--	--	--	-1.01	0.04	-1.33	0.00
O&G Supplier 19-39 years (Petrobras major oil discovery)	--	--	--	--	--	--	-0.81	0.06	-0.99	0.01
O&G Supplier 14-39 years (From major oil discovery to LC first round)	*-0.55*	*0.04*	--	--	-0.87	*0.04*	--	--	--	--
O&G Supplier 1-39 years (Since major oil discovery)	--	--	*-0.73*	*0.07*	--	--	--	--	--	--
O&G Supplier 40+ years (First providers)	0.13	*0.67*	--	--	--	--	--	--	--	--
Local Content Quality Impact Index (Factor Score, base 10)	--	--	--	--	--	--	--	--	0.19	0.00
AIC	**1,380.7**		**1,432.5**		***1,432.9***		**1,434.7**		**1,075.9**	
N	**245**		**254**		***254***		**254**		**206**	

OBS. 2: A amostra total de empresas dos setores de fabricação de equipamentos e insumos totaliza 294 empresas, na amostra não ponderada.
OBS. 1: O AIC é uma medida do erro do modelo, menores valores indicam menor erro. Os modelos foram organizados de forma decrescente pelo AIC. Diferenças em número absoluto maior do que "2" são consideradas significativas.

Our argument is that specific dynamics of the offshore O&G industry would favor not only upgrading, but a more collaborative type of upgrading. The high technology nature and high technical standards of the industry would demand suppliers to upgrade their management and production to provide to first-tier suppliers and oil operators. On the other hand, foreign first-tier and oil companies would have to adjust production and management to local conditions. Due to the project-base characteristic of the industry, there would be incentives not only to upgrade by the suppliers themselves, but the clients would have incentives to help in the process to increase reliability and quality of suppliers.

Our collaboration index captures both dynamics: 1) upgrade by the company because it is a supplier or a client of the O&G sector; and 2) collaboration between clients and suppliers that lead to process or product upgrade.

Inteviews with suppliers illustrate these possible mechanisms of upgrade. Companies in the steel-producing pole of Ipatinga (interior of Minas Gerais state), for instance, that were previously suppliers for the steel and mining industries, had to improve and adapt production lines to provide modules for shipyards. Despite collaboration from clients had not been particularly emphasized, it shows the potential of upgrading inherent to the sector. The case of Aker Solutions, however, shows how foreign first-suppliers contribute actively to the upgrading of their suppliers. Aker has a program for suppliers to help them not only in improving production, but also in management.

If this dynamic were correct, a local content requirements (LCR) policy would make sense as it tries to "force" upgrading and collaboration between suppliers and clients by making mandatory for oil operators and their first-tier suppliers to use domestic companies. Despite the controversy about its design, LCR could be seen as an instrument to help domestic companies to upgrade and enter internationalized supply chains such as the O&G. Conversely, for O&G MNC first tier suppliers, which manage global corporate production systems, have potential advantages in having a diverse pool of local suppliers. Local equipment and services development and deployment specificities provide for continuous incremental process innovation, and cumulatively radical innovation occasionally, as well as productive process error-correction when properly monitored. Full local supplier development through collaborative upgrading with the goal of a medium term integration into their global CPS is therefore a strategic component of competitiveness.

Looking at the descriptive statistics of the Collaboration index (Table X), we can say that the "collaborative upgrading" is quite high, at 7.1 in average. However, following our reasoning about the specificities of the O&G sector, are there underlying variables that explain how this index behave?

The fact that being a Brazilian company increases in almost 1 point the collaborative upgrading index is not surprising as we expected that local companies had more to benefit from being part of the O&G sector. Also, not surprisingly, companies that are O&G specalists (defined as percentage of revenue coming from the O&G sector) are also more likely to engage in

collaborative upgrading. These companies are more obviously pressured to upgrade while better positioned in the supply chain to become preferential partners of first-tiers MNCs.

The size of the company (as number of employees), however, did not present significant results, suggesting that collaborative upgrading might occur along both small, medium, large companies in a more diffuse way.

The result that companies outside the state of São Paulo benefit more from collaborative upgrading could be interpreted as a product of the more verticalized productive structure of the traditional manufacturing industry in the state. Simultaneously, it can reflect the more decentralized structure of the offshore O&G supply chain.

Puzzling, however, is the result that relatively traditional suppliers – that have been suppliers from 39 years to 14 – are less prone to collaborative upgrading when compared to both young suppliers (13 years or less) or very old ones (more than 40 years). The fact that young suppliers are more prone to collaborative upgrading is expected when we consider that new suppliers have more to catch-up. On the other hand, very old suppliers might be affected by recent changes in technological standards of offshore projects with the advancement of deep sea exploration and production. Or, another potential explanation is that they are contributing more actively to the upgrade of other suppliers. The main problem with this result is that an important group of suppliers that are relatively experienced as suppliers, is not engaging more in collaborative upgrading.

As our index of evaluation of the LC policy shown in the model 6 of the Table Y is small but very significant, we can interpret these results as an effect of a dual dynamic. On the one hand, companies that evaluate positively LC have engaged slightly more in collaborative upgrading since the sector demands require improvements. On the other, companies that criticized the LC for its increases in cost and time also engaged slightly more in collaborative upgrading, seemingly pointing out that the answer to the limitations imposed by the LC is through collaborative upgrading.

Conclusion

The promotion of industrial upgrading in a globalized economy is one of the greatest challenges pressing policy-makers in developing countries. In recent years, Brazil has reinvigorated its industrial policy through a combination of instruments and initiatives focusing different sectors.

The OG sector, with its LC policy, has been object of a lot of discussion. However, most analyses have focused on the role of Petrobrás in driving investment and promoting technological breakthroughs, neglecting the realities of companies that generate the necessary competencies under conditions of uncertainty for the OG sector: the suppliers.

In theoretical terms, the possibilities for a successful industrial policy in terms of upgrading and modernization of domestic industry seems limited in the Latin American context. Based on our survey results conducted with OG suppliers, we suggest that possibilities for upgrading exist and are taking place. While the LC policy creates a window of opportunity for Brazilian companies to enter the OG sector in lower tiers, it has also attracted relevant foreign suppliers placed in higher tiers to produce in the country. Consequently, different tiers of the supply chain are interacting in positive ways, collaborating and upgrading practices to comply with the high technical standards of upstream activities of the OG sector. While (negative) institutional complementarities definitely play an important role shaping general incentives for companies operating in a national economy, sectoral characteristics and specific global production chain configurations, provide incentives to overcome limitations.

In the complex supply chain of upstream activities of the OG sector, both specialized and non-specialized companies must comply with high technical and quality standards to become suppliers. First-tier suppliers also must push their sub-suppliers to deliver satisfactory products. Furthermore, the project-based nature of upstream activities creates extra-incentives for collaboration and a closer relationship between clients and suppliers. Despite criticisms and needs for calibration, the LC policy seems to have created enough incentives for some domestic companies upgrade themselves in face of the challenges of the OG sector. This paper is an effort not only to bring the firm back in, but also bring it back into their relations with other firms in the vibrant OG sector.

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Appendix A: Who answered the survey?

Due to the lack of previous surveys about supply chains in Brazil and particularly about the O&G sector, it is difficult to have a benchmark for our descriptive statistics.[8] Nonetheless, we believe we obtained a representative sample of suppliers covering a wide range of companies positioned in different tiers of the supply chain. As seen in table 2, the almost 88% of the companies in our survey were owned or controlled by Brazilian capital. However, as we do not have a clear idea of the distribution of origin of ownership in our universe, it is not possible to say whether our sample is biased or not.

In terms of percentage of revenue coming from the O&G sector, we obtained a polarized distribution with 40% declaring that a less that 25% of their revenues come from the O&G sector, while 30% saying that more than 75% of their revenues originated from it (Table 3). This distribution is a good sign of representativeness of the large scope of the O&G supply chain and that we were able to achieve companies that are in lower tiers.

Table A. Company ownership/control

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Foreign ownership/control	68	12,1	12,1	12,1
	Brazilian ownership/control	491	87,9	87,9	100,0
	Total	558	100,0	100,0	

Table B. Revenue from O&G sector

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0% - 25%	218	39,1	40,3	40,3
	26% - 50%	90	16,2	16,7	57,0
	51% - 75%	69	12,4	12,8	69,8
	76% - 100%	164	29,3	30,2	100,0
	Total	541	97,0	100,0	
Missing	DK/DA	17	3,0		
Total		558	100,0		

[8] A study from IPEA published in 2010 about Petrobrás' suppliers do not distinguish between companies focusing on upstream and downstream activities.

Regarding the number of employees, our sample was highly concentrated on small and medium sized companies. Although small and medium sized companies may be predominant, this distribution was probably caused by common difficulties in obtaining the participation of large companies in this type of survey.

Table C. Number of employees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	01- 09	65	11,6	12,1	12,1
	10 – 19	65	11,7	12,2	24,3
	20 – 49	125	22,4	23,3	47,6
	50 – 99	104	18,7	19,5	67,0
	100 – 499	139	24,9	25,9	92,9
	≥ 500	38	6,8	7,1	100,0
	Total	537	96,1	100,0	
Missing	DK/DA	21	3,9		
Total		558	100,0		

An interesting aspect from our sample is the location of 40% of respondents in the state of São Paulo – the cradle of Brazilian industrialization and still hosting most of the manufacturing of capital goods and equipment in the country. Not surprisingly, the state of Rio de Janeiro comes in second place, as the main Brazilian offshore oil fields are located on its coast.

Table D. Location by State

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AL	2	,4	,4	,4
	AM	9	1,5	1,5	1,9
	BA	37	6,6	6,6	8,5
	DF	2	,3	,3	8,8
	ES	27	4,9	4,9	13,7
	GO	1	,2	,2	13,9
	MG	34	6,1	6,1	20,0
	MT	2	,3	,3	20,3
	PA	2	,4	,4	20,7
	PE	5	,8	,8	21,6
	PR	27	4,8	4,8	26,4
	RJ	119	21,2	21,2	47,6
	RN	17	3,1	3,1	50,7
	RS	25	4,4	4,4	55,1
	SC	19	3,5	3,5	58,6
	SE	4	,6	,6	59,2
	SP	228	40,8	40,8	100,0
	Total	558	100,0	100,0	

In terms of exporting activities, most of our sample is composed by non-exporting companies or with feeble participation in world markets. This is not surprising as in recent years the demand of Petrobrás alone has providing enough activity for local suppliers. Furthermore, it

has been a goal of industrial policy in recent years to raise exports and internationalization of O&G suppliers.

Regarding age of the company and the time it has been a supplier for the OG sector, we created four categories for these two variables. The cutting line of 13 years or less old used 2003 as a reference year – as the first government of President Lula initiated a more stringent LC regulation. The second category from 14 to 18 years old represent the period between the liberalization of the OG sector in 1998 and the voluntary system of LC – when oil companies would offer freely bids of LC. The third represents companies that have been in Brazil since the beginning of the offshore exploration at the Santos Basin in 1977. The fourth category of companies with age of 40 or more years old represent a group of companies that existed before any significant upstream activity in the country and probably have been suppliers for downstream activities for Petrobrás. Looking at table 7, we see that about 60% of our sample are composed by relatively established companies with age of 19 years old or more. However, looking at table 8 we observe that almost 60% of our sample is composed by companies that became suppliers of the O&G sector after 1998. These simple frequencies suggest an important redirecting of consolidated companies towards the expansion period of the OG sector in recent years.

Table E. Number of exporting years (2001-15)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	327	58,6	58,6	58,6
	1	45	8,0	8,0	66,6
	2	19	3,4	3,4	70,0
	3	24	4,2	4,2	74,3
	4	11	2,0	2,0	76,3
	5	7	1,3	1,3	77,6
	6	16	2,8	2,8	80,4
	7	9	1,5	1,5	81,9
	8	5	1,0	1,0	82,9
	9	6	1,0	1,0	84,0
	10	8	1,5	1,5	85,5
	11	6	1,0	1,0	86,5
	12	7	1,3	1,3	87,8
	13	8	1,5	1,5	89,3
	14	25	4,4	4,4	93,7
	15	35	6,3	6,3	100,0
	Total	558	100,0	100,0	

Table F. Company age (years)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 – 13	118	21,2	21,6	21,6
	14 – 18	93	16,6	16,9	38,5
	19 – 39	235	42,0	42,8	81,3

	40 or more	103	18,4	18,7	100,0
	Total	548	98,3	100,0	
Missing	System	10	1,7		
Total		558	100,0		

Table G. Years as O&G supplier in Brazil

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 – 13	232	41,5	41,5	41,5
	14 – 18	98	17,5	17,5	59,0
	19 – 39	180	32,2	32,2	91,3
	40 or more	49	8,7	8,7	100,0
	Total	558	100,0	100,0	

Appendix B:

Independent variables:

Brazilian ownership/control – dummy variable with a value of 1 when the company is owned or controlled by Brazilian capital and with 0 when it is owned or controlled by foreigners.

Revenue from O&G – dummy variable with 1 when the company declared to have more than 50% from its revenue from the O&G sector and 0 when it declared less than 50%.

Number of employees – dummy variables with 1 when the company has declared to have more than 100 employees and with 0 when it declared to have less than 100 employees.

São Paulo state – dummy variable with value of 1 when the company is located at the state of São Paulo and 0 when it is located in another state.

Exports (2001 - 2015) – Number of years a company has exported during the period 2001-2015. The source of this variable is official government data and not obtained from the survey.

Years in O&G – number of years a company declared to be a supplier of the O&G sector in Brazil. All segments in the model referred to the category "40 years or more".