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Plugging into global production networks: density, distance, division and the local context of Brazil's oil and gas sector

Sören Scholvin, Mariane Françoso, Moritz Breul, Patrícia Mello, Maurício Serra, Adriano Borges, Paula Bastos

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Plugging into global production networks: density, distance, division and the local context of Brazil's oil and gas sector[1]

Sören Scholvin [2]
Mariane Françoso [3]
Moritz Breul [4]
Patrícia Mello [5]
Maurício Serra [6]
Adriano Borges [7]
Paula Bastos [8]

Introduction

Economic globalisation is not only about trade increasing amongst countries. It has fundamentally changed economic processes insofar as it enables companies to split chains of production and commercialisation into various segments, which spread all over the world. As Gereffi (2014) notes, the global economy is therefore marked by a shift from trade in goods to trade in capabilities, tasks and value added (see also: WTO and IDE-JETRO, 2011). Global value chains and global production networks (GPNs) 'have become the world economy's backbone and central nervous system' (Cattaneo; Gereffi; Staritz, 2010, p. 7). Coe and Yeung point out that 'organizationally fragmented and spatially dispersed production networks constitute a new form of economic structure that increasingly drives the complex global economy and its uneven developmental outcomes' (2015, p. 1).

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(2) Research fellow at the Institute of Economic and Cultural Geography – University of Hanover – Germany.

(3) PhD student at the Institute of Economics – Unicamp – Brazil.

(4) Research fellow at the Institute of Geography – University of Cologne – Germany.

(5) PhD student at the Business Administration School of São Paulo – Getulio Vargas Foundation – Brazil.

(6) Professor at the Institute of Economics – Unicamp – Brazil.

(7) PhD student at the Public Administration School of São Paulo – Getulio VargasFoundation – Brazil.

(8) Professor at the University of Brasília.

The spatial fragmentation of economic processes means that regional development now depends on how the respective regions plug into GPNs. The GPN approach, which has become one of the most widely used concepts in Economic Geography, hence calls for analysing the interplay of global and regional dynamics: 'Regional development can […] be conceptualized as a dynamic outcome of the complex interaction between region-specific networks and global production networks' (Coe; Yeung, 2015, p. 18). A region's economic configuration – that is, the human and non-human resources available at specific places – has to match what transnational companies need so as to trigger foreign investment. Participation in GPNs, which can also result from endogenous dynamics, constitutes an opportunity for local firms. They gain access to capital and knowledge. Firms that participate in GPNs are, to a certain extent, also disembedded from their home regions and re-embedded into the respective GPNs. Their dependence on home markets decreases and the respective firms gain new opportunities for growth in an increasingly interconnected world.

In this paper we analyse the oil and gas sector in Brazil, focussing on how the sector has plugged into GPNs, what conditions work towards and against processes of plugging-in and what this means for regional development. Brazil's oil and gas sector received a major boost in 2006 because of newly found offshore deposits, which the semi-statal giant Petrobras seeks to exploit in collaboration with overseas partners such as Chevron, Halliburton and Shell. Doing so requires large-scale investment in exploration-related services and technologies. In the federal state of São Paulo there is already a strong participation of local companies in the downstream sector. Upstream activities are being promoted in the coastal city of Santos, which is Brazil's largest harbour and a one-hour drive away from the city of São Paulo, but they still concentrate in Rio de Janeiro, the historical hub of the Brazilian oil and gas sector, where the headquarters of Petrobras and the national offices of its partners from overseas are located. Recently Petrobras has been paralysed by corruption scandals and the global decline of the oil price. This has brought the entire sector to a standstill.

Our assessment of the Brazil's oil and gas sector is based on data retrieved from the fDi markets database provided by the *Financial Times*, the Zephyr database from the Bureau van Dijk, the website 'A Barrel Full' and the Brazilian Annual Social Information Report (Relação Anual de Informações Sociais, RAIS). In addition to that, we refer to seven narrative interviews, conducted in São Paulo and Santos in 2014 and 2015 and in Rio de Janeiro in 2016. This empirical information is analysed with the help of a framework from

the 2009 *World Development Report*. The report handily consolidates causal factors that shape regional development as density, distance and division – the three Ds. Going beyond the *World Development Report*, we argue that the three Ds are influenced by place-specific context factors. Given that the mere participation in GPNs, which can be explained by the three Ds, is not a sufficient condition for regional development, we refine the contextualisation of the sector by making use of the GPN approach, analysing how value is created, enhanced and captured in the oil and gas sector in Brazil. We also elaborate on the influence of different forms of power and embeddedness on the sector.

This paper is structured as follows: it begins with the analytical framework – that is, the three Ds and the GPN approach. The second main section deals with empirics. We assess the recent domestic development of Brazil's oil and gas sector, put it into the context of the internationalisation of Petrobras and regional integration in South America, analyse the influence of the three Ds and elaborate on two science and technology parks, which are located in Santos and Rio de Janeiro and play an important role for the sector. In the third main section we bring the empirical information and the GPN approach together.

Analytical framework

The 2009 *World Development Report* is focussed on three factors that are considered being decisive for economic development: density, distance and division. Density, meaning the agglomeration of companies and consumers, is the essential driver of economic development: 'moving to economic density is a pathway out of poverty both for those who travel on it and, ultimately, for those left behind' (2009, p. 49). In order to explain how economic impulses spread from such agglomerations to the periphery, the World Bank's experts add distance and division as further determining factors: distance is about cost and time to transport goods, information and people; division captures tariff and non-tariff barriers, for instance different business languages. Sound policies, it is argued in the report, facilitate agglomeration to boost density, infrastructural development to overcome distance and regional integration via organisations such as the Common Market of the South (Mercado Comum do Sul, Mercosul) to end division.

Based on a study by Scholvin (2017) on the oil and gas sector in Sub-Saharan Africa, we suggest that the periphery and the semi-periphery of the global economy depend on 'gateway cities' so as to plug into GPNs. Gateway

cities offer a certain degree of density, combined with a sophisticated institutional setting and good transport infrastructure. They connect their respective hinterlands globally. In contrast to the rather crude understanding of density in the *World Development Report*, we define density as the concentration of companies that contribute to a specific GPN. Whereas density is a factor that enables places to plug into GPNs, distance and division are the major obstacles to such processes because they limit the flows that reach a specific place. Scholvin and Malamud (2014) show that the territorial extent of South America, its numerous physical barriers and the virtual absence of transport infrastructure hamper the economic interaction between Brazil, on the one side, and Guyana, Suriname, Venezuela and the Andean states, on the other. In his aforementioned study Scholvin moreover points to the fact that companies based in Cape Town face difficulties due to language barriers – that is, division – when doing business in or with several Sub-Saharan African countries that possess abundant oil and gas resources.

We are aware that the *World Development Report* is not a basic theory. It summarises major debates in Economics and Economic Geography, illustrating causal factors traditionally seen as relevant, and translates them into policy advice: Porter (1990; 1996; 2000) stresses the relevance of geographical clustering for competitive advantages in international trade. Krugman (1991a; 1991b; 1992) argues that location – or proximity – matters much for economic processes. Because of agglomeration economies, there is a strong tendency towards polarisation, for example between a dynamic city such as São Paulo and its hinterland. Economic geographers have criticised Krugman's theory and the *World Development Report* for their oversimplification and because they ignore locally and temporarily bounded context factors (e.g. Martin; Sunley 1996; Rodríguez-Pose, 2010). We agree partly with this criticism and therefore use the three Ds as a starting point, examining how they relate to specific local contexts and the particularities of oil and gas GPNs.

What is more, plugging into GPNs is not a sufficient condition for durable development. It is only a first step. In the 1970s and 1980s researchers such as Dicken (1976); Firn (1975) and Watts (1981) pointed out that peripheral regions became sites for the more routine capital-intensive and low-skilled segments of value chains. Higher level command and conception activities remained in economically more advanced parts of the world. The so-called branch plant investment offered developing countries little in terms of linkage opportunities, reinvestment of profits, skill formation and technology transfer, as

Amin and Tomaney (1995) later concluded. A quite different pattern emerged in the early 1990s. Phelps et al. (2003) and Pike (1998), amongst others, note that so-called performance plants were increasingly marked by autonomy, complex functionality, specialised markets, heightened product and processes technologies and qualified workforces. Opportunities for economic development arose for the host regions of performance plants because of the embeddedness of these plants, for instance through deeper localised backward and forward supplier linkages (Turok, 1993). Moreover the workforce requirements of performance plants became a driver of qualification processes of local labour (Phelps; Fuller, 2000; Raines, 2003).

The GPN approach is not that different from research on branch and performance plants. It sheds more light on context factors of foreign investment, especially institutional arrangements in a quite broad sense. The GPN approach not only addresses how flows shape regions but also how regions shape flows (Coe et al., 2004; Henderson et al., 2002). Coe, Dicken and Hess argue that the approach provides a framework that aims to 'incorporate all kinds of networks relationship' and to 'encompass all relevant sets of actors and relationships' with regard to a specific economic process (2008, p. 272). Arguably the GPN approach is therefore broader than chain concepts[9]. As Sturgeon observes, 'a chain maps the vertical sequence of events leading to the […] consumption […] of goods and services [whereas] a network highlights the nature and extent of the inter-firm relationships that bind sets of firms into larger economic groupings' (2001, p. 10).

Henderson et al. (2002) propose three analytical categories to systematically examine how a specific place plugs into a specific GPN (Figure 1). First, value refers both to the conversion of labour power into actual labour and to economic return or rent generated by the production of goods and services. The latter implies that value may be created through the control of human and natural resources (resource rent) as well as technologies (technological rent),

(9) The filière approach, advanced by French scholars (e.g. Benoit-Cattin, Griffon and Guillemont 1996, Lauret 1983), is useful to map commodity flows and to identify actors that matter to these flows. It does not go further though and lacks a theoretical fundament. Global value chains, conceptualised by Porter (1985, 1990), deal with intra-firm and inter-firm relations. They do not serve the purpose of analysing context factors, which we consider being essential for regional development. Global commodity chains, initially advanced in the volume *Commodity Chains and Global Capitalism*, are relatively close to GPNs. We think, however, that the adherents of the commodity-chain approach overly concentrate on chain governance. Institutional and social context factors have received much less attention. Territoriality has been neglected or treated in a highly aggregated manner, distinguishing between segments of a commodity chain in the Global North and in the Global South.

uneven access to the financial system (financial rent) and infrastructure (infrastructure rent), the development of organisational capabilities (organisational rent), the harnessing of inter-firm relationships (relational rent) and the prominence of brand-names (brand rent). If companies manage to influence policies in their favour, for example trade policies, there will be a policy rent (Kaplinsky, 1998, 2005). Different firms are able to create and generate the different types of rents to different extents.

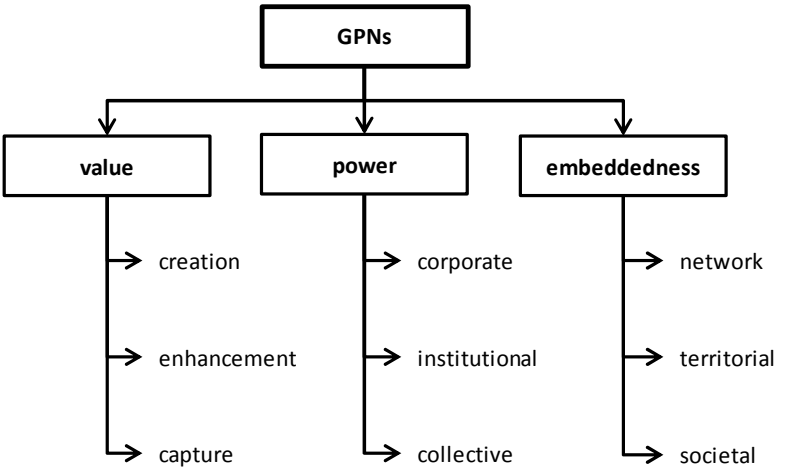
In addition to the mere creation of value it matters how value is enhanced by specific companies at specific places, meaning how they upgrade value creation so as to make existing goods and services better and therefore more valuable. Demand for skilled labour increases at the places that achieve value enhancement and local firms become able to create the more sophisticated types of rents of their own (Henderson et al., 2002). Yet it is one thing for value to be created and enhanced in a region that has plugged into a GPN but quite another for value to be captured by locally. The pertinent issues related to value capture are matters of public policies that affect, for instance, laws on ownership structures and repatriation of profits (Henderson et al., 2002). As Coe and Yeung argue, "for the purposes of economic development, value must be retained within firms, or the parts of firms, based in the territory under question" (2015, p. 172).

The second analytical category that Henderson and his co-authors suggest is power. GPNs – and value capture in particular – are influenced by three forms of power: corporate power is mainly about lead firms controlling their partners; sub-national, national and international authorities exercise institutional power vis-à-vis firms, for example prescribing a certain local content or guaranteeing their foreign investment; collective power is wielded by business associations, trade unions and similar organisations. (Coe et al., 2004) add that co-operative relations between business associations, public authorities and trade unions – meaning organisations that often pursue conflictive interests – are essential for the process of plugging into and benefitting from GPNs.

Bringing power and value capture together, (Coe; Yeung, 2015) distinguish between the strategic partners of lead firms, specialised suppliers, which are industry-specific or multi-industry firms, and generic suppliers. These types of companies characterise a region that participates in a GPN either alone or in different combinations. Strategic partners provide complete or at least partial solutions to lead firms by co-design or development in manufacturing and services. Specialised suppliers are not involved in these activities. They only

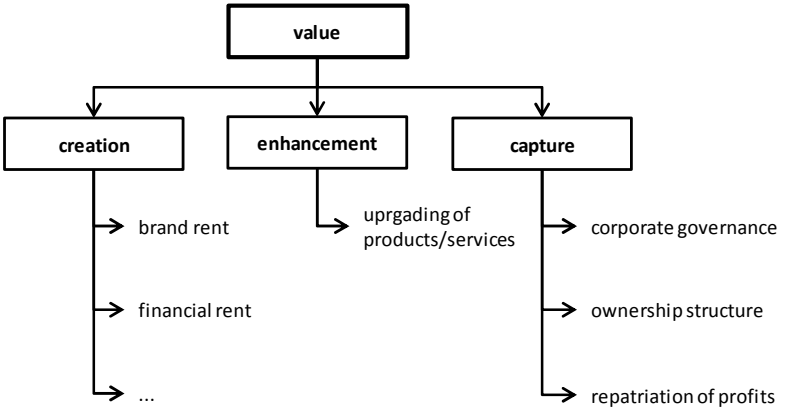
provide intermediate goods and services to the lead firms, wielding less power and capturing less value. The contribution of specialised suppliers differs from that of generic suppliers regarding its sophistication: the latter supply highly standardised and low-value products and services to the lead firm, being even less powerful and capturing even less value.

Figure 1
Value, power and embeddedness



Source: Authors' own draft based on Henderson et al. 2002.

Figure 2
Creation, enhancement and capture of value



Source: Authors' own draft based on Coe et al. 2004.

Third, GPNs are shaped by two forms of embeddedness: network embeddedness captures the economic, institutional and social relationships in which firms participate in GPNs, for example the stability of their relations with other firms in the network or the relevance of the network for their business; territorial embeddedness is about the anchoring of GPNs at specific places – because of its dependence on markets or resources, for instance. Territorial embeddedness is essential for this study because regions that seek to plug into GPNs must outcompete other regions that are able to provide the same inputs to the respective GPN. They also must reinforce the territorial embeddedness of lead firms, virtually tying them down[10]. Henderson et al. (2002) furthermore point out that territorial embeddedness can result from lead firms taking advantage of local networks of medium and small-scale firms that exist prior to sub-contracting.

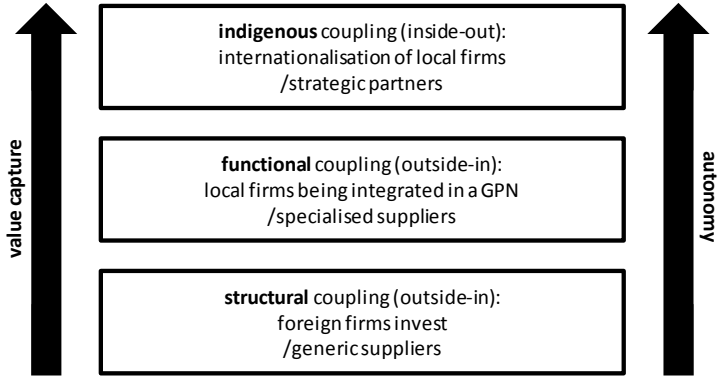
In accordance with the ideas formulated in the previous paragraph, the standard argument in research on GPNs is that 'strategic coupling' decides on whether and how regions plug into GPNs. According to Yeung 'strategic coupling refers to the dynamic processes through which actors in cities and/or regions coordinate […] strategic interests between local actors and their counterparts in the global economy' (2009, p. 213). Institutions – or public authorities in our wording[11] – are decisive for strategic coupling. Coe and Yeung argue that strategic coupling 'needs intentional and active intervention on the part of both regional institutions and powerful global production network actors' (2015, p. 20). Public authorities ensure that regional assets are moulded and shaped to fit the needs of foreign investors, for example through the provision of more advanced infrastructure or education and training programmes that boost the capacities of local supplier networks. Another strategy for public authorities to hold down transnational companies is to encourage these companies to make fixed investment. Being sunk costs, fixed investment is difficult to re-locate. Hence the respective region possesses a rather secure position in the GPN.

(10) Hess (2004) adds societal embeddedness. It covers how firms are positioned within wider cultural and historical context of a specific place. Social embeddedness connects to the literature on varieties of capitalism (e.g. Coates 2005, Hall and Soskice 2001). According debates in South America tie up with the concept of 'extractivism' (e.g. Gudynas 2009, 2012; Svampa 2012). Although the societal embeddedness of the Brazilian oil and gas sector certainly matters, we concentrate on territorial embeddedness, trying to keep the conceptual and empirical extent of this paper manageable.

(11) We use the term public authorities because in our understanding institutions are not organisations. For us institutions are place-specific formal and informal arrangements that determine how companies may organise their business. Public authorities conversely comprise the numerous organisations that shape these arrangements.

Coe and Yeung (2015) distinguish three types of strategic coupling. First, indigenous coupling is about inside-out processes: local firms reach out of a region to participate in GPNs (or to create new ones). These firms are usually quite autonomous and capture a considerable share of the value generated in the respective GPNs. Second, functional coupling is about companies from a region that meet the needs of a GPN. The degrees of autonomy and value capture of companies involved in functional coupling is less than in indigenous coupling, although functional coupling is not necessarily an outside-in process. Third, structural coupling captures outside-in processes: extra-regional firms connect a region to a GPN because of the region's assets. Structural coupling tends to be marked by little autonomy and little value capture for the regional firms. With regard to the aforementioned typology of firms, one may argue that strategic partners of transnational companies and transnational companies themselves carry out indigenous coupling. Functional coupling applies to specialised suppliers and structural coupling to generic suppliers.

Figure 3
Strategic coupling



Source: Authors' draft based on Coe and Yeung 2015.

It is striking, however, that research on GPNs appears to ignore all those regions that fail to plug into GPNs – the regions that are not, or only to a minimal extent, integrated into global economic processes. Adherents of the GPN approach tend to concentrate on cases of success: places that achieve economic development because they are deeply integrated into GPNs. In their seminal article Coe et al. (2004) refer to the car manufacturer BMW and the numerous places that participate in its GPN. The book *Global Production Networks:*

Theorizing Economic Development in an Interconnected World, which summarises the state of the art in research on GPNs, is also marked by this tendency. Even processes of de-coupling, meaning research on places that are, at least temporarily, not integrated into GPNs, is about success stories. Horner (2014), for example, refers to the Indian pharmaceutical industry so as to show how an intended process of de-coupling, followed by re-coupling, allows for economic development.

There is research that addresses the negative features of participation in GPNs. MacKinnon (2013), for example, suggests that the periphery and semi-periphery are marked by unbalanced forms of structural coupling, instead of what is usually understood as coupling in research on GPNs. This implies that there is a need to incorporate concepts such as uneven development and external domination. Yang and Liao (2010) show that a GPN dominated by Taiwanese firms that produce computers does not trigger significant development in the Chinese city of Dongguan because the network is closed in the sense that only Taiwanese suppliers benefit from backward linkages. Phillips and Henderson (2009) elaborate on negative lessons that can be learnt from Malaysia's participation in electronics GPNs.

Still the stories of partial success in the Global South and elsewhere are about places and regions integrated into GPNs. Bridge's study of the oil and gas sector, which is based on the GPN approach, shows 'how extractive industries can provide (limited) opportunities for socio-economic development' (2008: p. 389). These opportunities are assessed from the perspective of value capture, which means that all cases taken into consideration are already plugged into oil and gas GPNs. In order to find out how Bolivia might capture greater benefit from economic globalisation, Murphy and Schindler (2011) analyse value creation, enhancement and capture by Bolivian suppliers of transnational companies in the wood industry. They appear to fail to realise that Bolivia benefits little from economic globalisation because probably the majority of formal and informal Bolivian firms is not involved in GPNs or fail to become involved to an extent that would be sufficient to trigger economic development. The same applies to numerous Brazilian engineering companies in the oil and gas sector, as we suggest below. Returning to the starting point of this section, we hence argue that the failure to plug into GPNs and very limited processes of plugging-in cannot be explained by the GPN approach itself but rather with the help of the three Ds. The three Ds complement the GPN approach, closing a major conceptual research gap.

Brazil's oil and gas sector

The empirical section of this paper begins with an overview of the oil and gas sector in Brazil. We then shed light on the internationalisation of Petrobras, which is Brazil's most important oil and gas company. In addition to existing literature, in particular with regard to regional integration and 'developmentalism', we make use of the aforementioned databases:

- The fDi markets database encompasses comprehensive information on cross-border greenfield investment. It specifies the source, destination and sub-sector of the investment. The specific business functions are assigned to each investment. We use this information to show which segments of oil and gas GPNs have been affected by foreign investment, distinguishing the respective roles of the South America countries.

- The Zephyr database contains information on brownfield investment and shareholder information, allowing us to extract subsidiary-lists for specific companies. The database reveals the locations of the various corporate units. We use it to show key places in South America for Petrobras[12]. Moreover we bring the fDi markets and Zephyr databases together so as to provide an overview of Petrobras's internationalisation.

- The website A Barrel Full lists active oil fields worldwide, specifies which companies operate these fields and also provides information on service providers at each field. A Barrel Full enables us to draw preliminary conclusions on gateway cities in Brazil.

- The RAIS database contains annual information on Brazilian companies, including the economic sub-sectors they belong to, their location and their number of employees. It is particularly suitable for specifying the location of different segments of oil and gas GPNs and showing their recent development. We use this information at the level of the Brazilian federal states and limit our observations to what happened before the country's economic and political crisis.

As a third analytical step, we analyse the three Ds. We refer to seven interviews conducted in São Paulo and Santos in 2014 and 2015 and in Rio de Janeiro in 2016. In order to identify the interviewees, who represent consultancies, private-public partnerships and public authorities, we used the websites of the respective organisations. We also contacted colleagues at the University of Campinas who carry out research on regional development. The

(12) Since the subsidiary level is provided in the Zephyr database, we could assign each subsidiary to the immediate owner (and not only to the parent company) but legal ownership does not necessarily reflect intra-firm hierarchies in terms of decision making, which is why we chose not to use the database this way.

interviews were structured by a set of five guiding questions, slightly adapted with regard to the specific background of each interviewee. Given the narrative character of the interviews, it was possible for our interviewees to add information not covered by any of our questions. Categories defined prior to the interviews and based on the conceptual approach from the previous section helped us to process the notes and recordings taken during the interviews. In this part of our analysis we also refer to two science and technology parks, located in Rio de Janeiro and in Santos. According information has been gathered from existing literature and by web-based desk studies.

Recent domestic developments

Brazil's proven oil resources amount to 15 billion barrels, the second-largest in South America after Venezuela. Almost 95 per cent of the Brazilian resources are located offshore. Eighty per cent are found off the coast of the federal state of Rio de Janeiro. Brazil also possesses the second-largest natural gas reserves in South America, primarily offshore in the Campos Basin. Although offshore exploration and extraction have been going on for decades, large quantities of resources were found only recently: in 2006. These are ultra-deepwater deposits, located below salt layers, which complicates their exploitation[13]. Still Brazil became a net exporter of crude oil in 2009. In 2011 domestic consumption surpassed domestic production again. They reached an equal level in 2015. Throughout all these years Brazil has remained a net importer of refined oil products (Energy Information Administration 2015). The reason for this is that Brazil's refineries are designed to process light crude oil but the new findings are of heavy grades. Hence the newly found resources cannot be completely processed in the country.

Oil and gas resources play an essential role for Brazil's development, accounting for about 60 per cent of the country's energy supply. Domestic energy consumption has nearly doubled during the last ten years because of considerable economic growth (Energy Information Administration 2015). In other words, the economic rise of Brazil is closely tied to oil and gas. President Lula da Silva famously referred to the pre-salt resources as 'the second independence' of his country, during his speech at the inauguration of the Petrobras P-50 Platform in the Campos Basin in 2006. His successor Dilma Rousseff declared in her inauguration speech in 2011 that 'pre-salt is our passport to the future'. Provided

(13) Bicalho et al. (2009) identify five areas where technological solutions need to be developed: anchoring and managing floating devices, associated logistics for natural gas, reservoir characterisation, risers in subsea areas and well drilling.

that the right policies were in place, Brazil had 'for the first time [in history] the opportunity to become a developed nation'. In addition to guaranteeing energy supply and thus creating one of the very fundaments of economic development, the oil and gas sector is believed to trigger industrialisation. Quantitative studies carried out before Brazil's domestic crisis and the global collapse of the oil price suggested very optimistically that 62 per cent of all industrial investment between 2011 and 2014 would be linked to the exploration, extraction and processing of oil and gas (Puga; Borça, 2011).

These pre-crisis dynamics – and many unfulfilled expectations – resulted on the fact that Brazil's major oil and gas findings occurred during the 2000s commodities super cycle, which was largely due to the rising demand from emerging markets, particularly China but also Brazil itself, as well as concerns over long-term supply availability. The oil price peaked at USD 147 a barrel in 2008, fell sharply because of the global financial crisis and increased again afterwards, also on account of the post-Arab Spring crises in the Middle East and the Western sanctions imposed on Iran because of the latter's nuclear programme.

Oil and gas resources, especially the recent pre-salt findings, have been discussed as a key means of Brazil's developmentalism, advanced by the Workers Party (Partido dos Trabalhadores, PT). Developmentalism constitutes an alternative to liberalism based on the Washington Consensus, which shaped Brazil's oil and gas policy prior to 2003, leading to the liberalisation of the sector and the partial privatisation of Petrobras[14]. Scholars such as Bresser-Pereira (2011), Erber (2010), Sicsú, de Paula and Michel (2007) point out that a developmentalist state should facilitate economic development through industrial policies focussed on local content and innovation and investment in strategic sectors, including oil and gas. They stress that equity and human capital are crucial for development; in addition to growing domestic markets and production capacities, which have traditionally been the core of development policy. The state should also design a long-term plan for national development and accordingly influence processes that liberals would leave to market forces (Schutte 2013). Those who are in favour of developmentalism point out that the finding of pre-salt resources itself would not have been possible without long-term public investment in risk technologies, which began in 1955 and has intensified since the 1980s (e.g. Serrani, 2013).

A key component of developmentalism in Brazil has been the creation of the state-owned company Pre-Salt Petroleum (Pré-Sal Petróleo SA, PPSA) in

(14) Garcia Ribeiro and Tahan Novaes (2016) provide a detailed analysis of the fundamental organisational changes that Petrobras has seen since its foundation in 1953.

2009. The PPSA is responsible for administrating pre-salt resources, including the granting of licenses (Law n. 12.304/10)[15]. Along with the PPSA came a system of shared contracts, according to which the Brazilian government not only gains royalties and taxes from the oil and gas sector – some of these incomes go directly to funds for education and health care (Law n. 12.558/13). The oil produced from pre-salt findings is also divided amongst the contractors and the government. If exploration fails, the contractors will carry the financial losses (Law n. 12.351/10). In addition to the Brazilian government acquiring oil from the pre-salt findings, a law was passed in 2010 that specified that Petrobras be the sole operator of each pre-salt project, holding at least 30 per cent of the stakes in production-sharing agreements with foreign partners. Petrobras could (and still can) also take 100 per cent ownership of pre-salt blocs without going through a competitive bidding process (Law n. 12.351/10). In 2016 this legislation was adapted by Brazil's new conservative government, giving Petrobras a right of first refusal: if the company refuses to take a share in new pre-salt projects, the according licenses can be fully granted to foreign investors (Law n. 13.365/16).

Brazil also has strict local content requirements. These requirements commit Petrobras and its partners to source specific percentages of their equipment, services and workforce domestically. A system for certifying and controlling local content has been set up by the National Petroleum Agency (Agência Nacional de Petróleo, ANP). In the bidding rounds for new blocs, potential investors are obliged to contract high percentages of local content in accordance to ANP Resolution n. 19 from 2013 – now replaced by ANP Resolution n. 26 from 2016 – that defines the local content certification[16]. Considering that highly sophisticated technologies for pre-salt, ultra-deepwater exploration are often not available in Brazil, it is not difficult to understand that local content legislation has created bottlenecks and slowed down exploration. The leading role of Petrobras moreover meant, at least until 2016, that exploration and extraction were limited by Petrobras's capacities to invest. Yet local content legislation has provided opportunities for Brazilian enterprises and made foreign companies invest in Brazil, as we explain below with regard to science and technology parks. As a side note, local content legislation also explains the revival of the moribund maritime industry in Rio de Janeiro in the second half of the 2000s (Frassa et al., 2011).

Arguing that the strict regulations on local content have discouraged investment, slowing down the development of the oil and gas sector, the new

(15) The national laws to which we refer are available at http://www4.planalto.gov.br/legislacao.

(16) The resolutions can be accessed at http://www.anp.gov.br/wwwanp/rodada-legislacao.

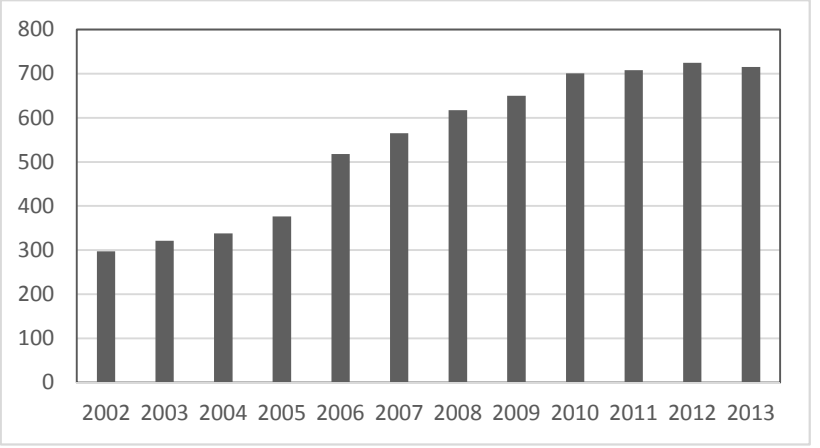
conservative government has recently eased local content legislation. Whereas in some cases more than 90 per cent of the machines, rigs and services had to be acquired in Brazil, the minimum local content in subsea areas of a depth of more than 100 metres now stands at 18 per cent for exploration, 25 per cent for well construction and 40 per cent for collection and disposal system. The local content for the stationary production unit is set at 25 per cent. Local content for onshore projects, which are technically much less challenging, has been decreased to 50 per cent (Presidência da Republica, 2017).

Petrobras's investment – and therefore the entire oil and gas sector in Brazil – has been set back by corruption scandals (Operation Car Wash or, in Portuguese, Operação Lava Jato). The company is under investigation in Brazil and in the United States for bribery and money laundering. So far, the scandals have resulted in losses of more than USD 8 billion, multiple arrests and the resignation of Petrobras's chief executive officer Maria das Graças Foster. Whilst the investigation is ongoing, Petrobras's auditor would not certify its financial statements, which has kept Petrobras from accessing international capital markets, reinforcing the negative effects of falling oil prices. Hence the company has had to undertake a sizeable disinvestment plan so as to raise funds. Petrobras (2016b) now estimates that its production of oil and gas will reach 3.41 million barrels of oil equivalent a day by 2021[17], which means a decrease by 30 per cent compared to previous planning. Petrobras's crisis – and Brazil's economic and political instability in general – certainly affects the way the country plugs into oil and gas GPNs. In this paper we however concentrate on the years prior to the crisis; first of all because of constraints of data and second because we think that analysing the impact of the present crisis on processes of plugging into GPNs would require a paper of its own.

Prior to 2014 the oil and gas sector in Brazil was a success story. The number of firms in the oil and gas sector increased considerably during the 2000s, in particular during the second half of this decade – that is, after the findings of major offshore resources. The 2010s conversely have been marked by stagnation. In the last year for which we could obtain data, the number of companies in the oil and gas sector even declined slightly (Figure 4). During the same period jobs in Brazil's oil and gas sector increased; especially in the mid-2000s. The more recent trend towards stagnation is less pronounced for jobs than it is for the number of firms (Figure 5).

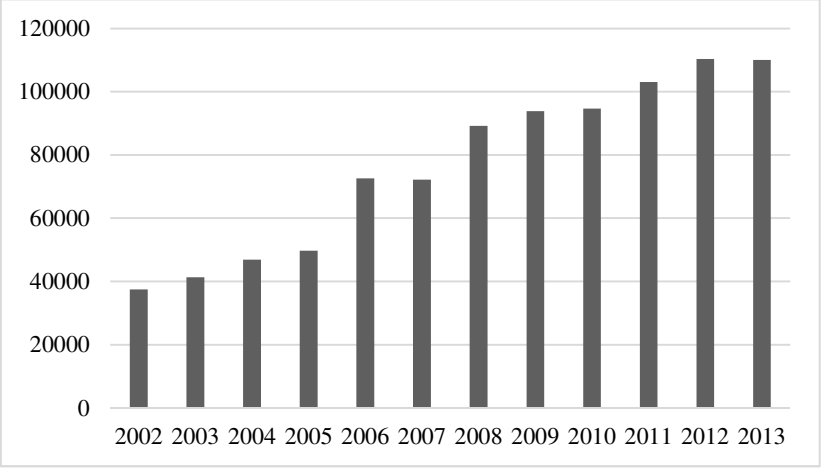
(17) The barrel of oil equivalent is a unit of energy based on the approximate energy released by burning one barrel of crude oil. It is used by oil and gas companies as a way of combining oil and natural gas production and reserves into a single measure.

Figure 4
Firms in Brazil's oil and gas sector



Source: RAIS database.
Note: National legislation stipulates that companies that want to operate in the Brazilian oil and gas sector be established in Brazil. The data therefore includes domestic firms and firms of foreign origin.

Figure 5
Jobs in Brazil's oil and gas sector



Source: RAIS database.

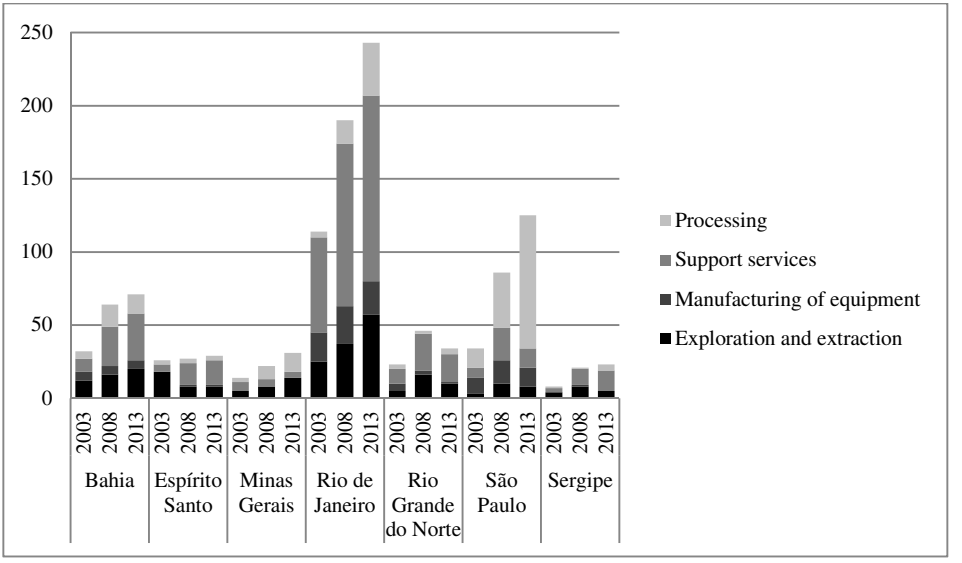
Oil and gas activities in Brazil are, from a spatial perspective, highly concentrated. The seven most important federal states – Bahia, Espírito Santo, Minas Gerais, Rio Grande do Norte, Rio de Janeiro, São Paulo and Sergipe –

accounted for 77.8 per cent of all firms in the sector in 2013. More than 30 per cent of them were based in Rio de Janeiro. The according share of São Paulo increased from 10.6 per cent in 2003 to 17.5 per cent in 2013. Bahia, Espírito Santo, Minas Gerais, Rio Grande do Norte and Sergipe played a secondary role. Data on employment reveals even more clearly that Rio de Janeiro is the hub of Brazil's oil and gas sector. It accounted for 57.6 per cent of all jobs in that sector in 2003, 53.2 per cent in 2008, and 58.0 per cent in 2013. São Paulo's shares for these years were 8.5, 10.4 and 11.0 per cent respectively. With regard to employment, Bahia is rather at a level with São Paulo than a member of the group of the secondary federal states.

The data shown by Figure 4 and 5 allows us to draw first conclusions on the dynamics of the oil and gas sector that set in when the pre-salt resources were found off the coast of Rio de Janeiro and São Paulo: the immediate boom turned into stagnation at the beginning of this decade; Rio de Janeiro and São Paulo increased their dominance relative to other federal states. Yet this data is highly aggregated. It does not tell anything precise on how Brazil has plugged into oil and gas GPNs. Hence a closer look at sub-sectors and their dynamics is necessary. The RAIS database classifies companies and employment according to the National Classification of Economic Activities (Classificação Nacional de Atividades Econômicas, CNAE). This classification allows us to divide the oil and gas sector into five branches: (1.) exploration and extraction, (2.) support services to exploration and extraction, (3.) processing of oil and natural gas and (4.) the production of equipment used for exploration and extraction.

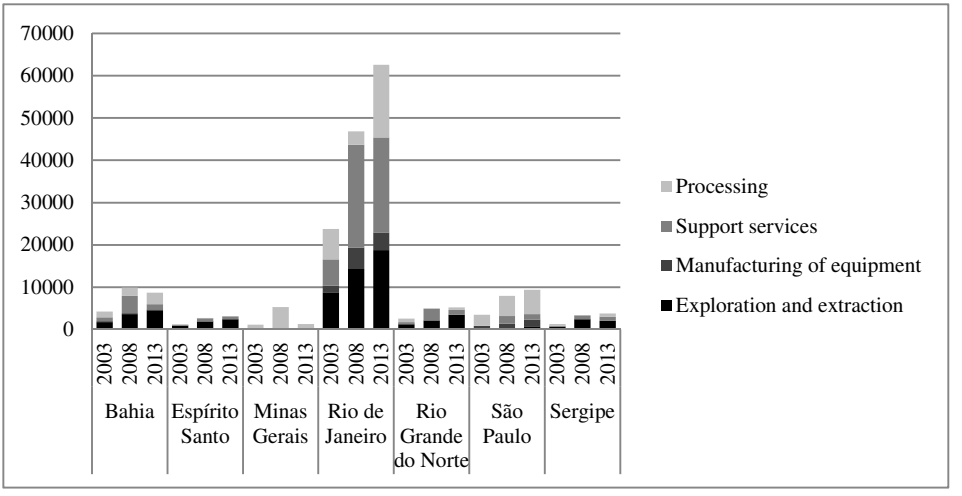
Comparing these sub-sectors across the aforementioned federal states reveals that exploration and extraction, support services and the production of equipment for these activities play a dominant role in Rio de Janeiro. Processing conversely dominates in São Paulo (Figure 6 and 7). The growth of the sector in São Paulo is due to the growth of the processing sub-sector. The number of firms involved in exploration and extraction as well as support services declined there from 2008 to 2013. These sub-sectors accounted for the overall growth of the sector in Rio de Janeiro. In other words, Brazil's two economically most important federal states play very different roles in oil and gas GPNs. The distribution of jobs per sub-sector confirms that the role of the seven federal states varies considerably: the downstream sector dominates in São Paulo, the upstream sector in Rio de Janeiro. Processing has been catching up in Rio de Janeiro, in particular from 2008 to 2013, not coming close to the upstream activities though.

Figure 6
Firms in the oil and gas sector by federal state and sub-sector



Source: RAIS Database.

Figure 7
Jobs in the oil and gas sector by federal state and sub-sector



Source: RAIS Database.
Note: There are jobs in sub-sectors other than processing in Minas Gerais. Because their number is very low, they are not visible in the figure.

The importance of Rio de Janeiro as the starting point of oil and gas GPNs is also confirmed by the office locations of the operators of Brazilian oil and gas fields (Table 1). Concerning service provision there appears to be some more diversity but Rio de Janeiro remains the hub, especially when thinking about its share of companies (Table 2).

Table 1
Office locations of operators in Brazil

Operator	Main office location	Number of oil and gas fields in Brazil
Petrobras	Rio de Janeiro	22
Shell	Rio de Janeiro	2
Chevron	Rio de Janeiro	2
BP	Rio de Janeiro	2
BG Group	Rio de Janeiro	2
ONGC	Rio de Janeiro	1
Repsol	Rio de Janeiro	1
Inpex/Sojitz	Rio de Janeiro	1
Maersk	São Paulo	1
Anadarko	Rio de Janeiro	1
Statoil	Rio de Janeiro	1
Sinochem	Rio de Janeiro	1
Ouro Preto	Rio de Janeiro	1
QGEP	Rio de Janeiro	1
Total oil and gas fields		27

Source: A Barrel Full database and firms' websites.
Note: We used the websites of the firms listed here so as to locate their headquarters in Brazil.

Although the data on service providers is not complete, it is interesting that, in addition to the city of Rio de Janeiro, only São Paulo and cities in the federal states of Espírito Santo (Aracruz) and Rio de Janeiro (Macaé and Niteroi) appear as locations. In other words, service provision to the oil and gas sector is spatially concentrated and potential frontier regions such as Brazil's North appear not to host service providers, at least not firms that reach a certain degree of specialisation and therefore appear in the database that we have used.

Table 2
Office locations of oil and gas service providers in Brazil

Contractor	Main office location	Number of oil and gas fields in Brazil
FMC Technologies	Rio de Janeiro	10
Modec	Rio de Janeiro	6
Technip	Rio de Janeiro	5
Saipem	Rio de Janeiro	5
Oceaneering	Rio de Janeiro	4
Keppel	Rio de Janeiro	4
SBM Offshore	Rio de Janeiro	3
Subsea	Rio de Janeiro	3
Jurong Shipyard	Aracruz (Espírito Santo)	3
Aker	Rio de Janeiro	3
Stolt Offshore	São Paulo	3
Intermoor	Rio de Janeiro	2
Manatee	*no office in Brazil*	2
Acergy	Rio de Janeiro	2
Fels Setal	Niteroi (Rio de Janeiro)	2
Mustang	*no office in Brazil*	2
McDermott	Rio de Janeiro	2
FoundOcean	*no office in Brazil*	2
Nexans	Rio de Janeiro	2
KBR	Rio de Janeiro	1
Wellstream International	Niteroi (Rio de Janeiro)	1
PGS	Rio de Janeiro	1
BrasFels	Rio de Janeiro	1
Inocean	*no office in Brazil*	1
Cosco	São Paulo	1
Nessco	Macaé (Rio de Janeiro)	1
VME Process	Rio de Janeiro	1
Dril-Quip	Macaé (Rio de Janeiro)	1
First Subsea	*no offices in Brazil*	1
IKM Ocean Design	Rio de Janeiro	1
Vallourec	Rio de Janeiro	1
Global Industries	*no office in Brazil*	1
Damen Shiprepair Rotterdam	*no office in Brazil*	1
Mitsui	São Paulo	1
Tecna	Rio de Janeiro	1
Sembcorp Marine	Aracruz (Espírito Santo)	1

Source: A Barrel Full database and firms' websites.
Note: The data on service providers is incomplete. It only shows a tendency.

The internationalisation of Petrobras and regional integration in South America

In addition to analysing the oil and gas sector in Brazil, it is helpful to assess it in regional comparison; first of all in order to get a better idea of how successful Brazil's plugging-in has been and second because in the 1990s and 2000s Petrobras expanded internationally, especially within South America, building a GPN of its own. Table 3 depicts the number of incoming projects of greenfield foreign direct investment (FDI) in South America, distinguishing different business activities. Brazil and Argentina attracted most FDI projects in the oil and gas sector during the period of 2003 to 2015. Chile, Colombia, Peru and Venezuela were also important for the sector, followed by Bolivia and Ecuador. Paraguay and Uruguay were of marginal relevance.

Table 3
FDI projects in the oil and gas sector in South America

	Extraction	Manufacturing	Electricity generation	Logistics, marketing and sales	Retail	Business services	Design, research and development	Headquarter
Argentina	35	8	5	23	2	0	0	0
Bolivia	12	6	0	3	0	0	0	0
Brazil	21	9	7	21	2	13	6	1
Chile	8	3	13	7	2	4	0	0
Colombia	31	7	1	12	0	1	2	0
Ecuador	6	2	0	3	1	0	0	0
Paraguay	1	1	0	0	1	0	0	0
Peru	24	8	8	5	2	0	0	0
Uruguay	0	1	0	3	0	0	0	0
Venezuela	30	6	2	3	0	1	0	0

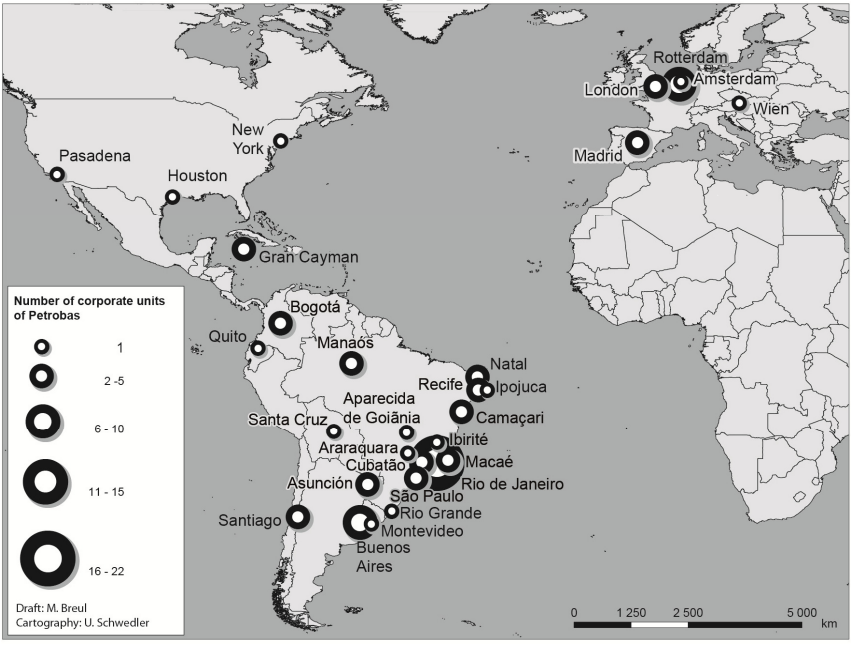
Source: fDi Markets database.
Note: Data is for 2003 to 2015. For the purpose of your analysis we have modified the categories of business activities used in the fDi markets database.

Bolivia, Ecuador and Venezuela appear to be mere resource providers, occupying segments at the lower end of the GPN. Argentina, Brazil, Chile and Peru conversely have also attracted FDI in segments from the middle of the network: electricity generation, logistics and sales. There is, of course, also electricity generation from oil and gas, related logistics and sales in Bolivia,

Ecuador and Venezuela. Yet the data we have analysed suggests that these countries are not attractive for greenfield FDI in segments other than exploration and extraction. Brazil is the only regional country that performs strongly on the upper end of the GPN, featuring several FDI projects in business services, design and research and development.

The strong performance of the Brazilian oil and gas sector is to a large extent based on one player: Petrobras. In 2015 the corporate network of Petrobras encompassed 91 subsidiaries in the oil and gas sector as well as related and supporting sub-sectors. About half of them were located in Brazil (Map 1). Rio de Janeiro served as the hub for Petrobras with 22 corporate units being located there. Besides the company's headquarters, corporate functions in Rio de Janeiro ranged from crude oil processing and electricity generation to logistics to supportive business services. Whereas Rio de Janeiro continues to play this role, Petrobras has significantly reduced its activities abroad (more on this later). Until 2015 Buenos Aires and Rotterdam hosted eight and ten corporate units respectively, being the second-most important hubs for Petrobras. Petrobras's subsidiaries in the Netherlands were mainly support activities. There were eight subsidiaries in Argentina, covering down-, mid- and upstream activities.

Map 1
Petrobras's corporate units worldwide



Source: Zephyr database.
Note: Data is for 2012 to 2015.

The now significantly diminished involvement of Petrobras beyond the national context indicates that the Brazilian oil and gas sector was not only plugged into GPNs through extra-regional firms. Whereas Petrobras's international activities in the 1980s were limited to trade agreements so as to meet Brazil's domestic oil demand, the company started investing abroad in the 1990s, using its capabilities in offshore drilling. Petrobras's activities abroad intensified from the early 1990s until the present economic crisis, especially during the last decade. The Brazilian company became involved in projects in Angola, the United States and several other countries all around the world. The Bolivia–Brazil Natural Gas Pipeline, or GASBOL is the outstanding project of the 1990s. The project officially began in 1991 and was completed ten years later, reaching a total length of 3,150 kilometres from Bolivia's gas fields near Santa Cruz to Porto Alegre in the South of Brazil. Petrobras became the largest company active in Bolivia and, about a decade ago, accounted for about 20 per cent of Bolivia's gross domestic product (Segabinazzi, 2007).

As Ribeiro Cahen (2015) summarises, market and strategic-asset seeking soon started to accompany Petrobras's resource-seeking foreign investment; at least in Argentina, where Petrobras participated in electricity generation and the petrochemical industry and owned two oil refineries and pipelines that connect Buenos Aires to natural gas fields in Patagonia (Segabinazzi, 2007). Petrobras withdrew from Argentina in 2016. Less successful were Petrobras's efforts to co-operate with Venezuela's state-owned oil company PDVSA on the development of ultra-heavy crude oil deposits in the Orinoco Basin and a refinery in the Brazilian federal state of Pernambuco. Still from 2003 until 2016 Petrobras made a significant number of brown- and Greenfield Investments Worldwide. South American countries – in particular Argentina and Venezuela – were key destinations for Petrobras's investment (Table 4). The data that we have assessed is based on a rather narrow definition of the oil and gas sector. Hence it does not capture the full variety of Petrobras's activities abroad. Nevertheless it clearly shows that the Brazilian giant invested not only in upstream but also in mid- and downstream projects.

In 2015, having already begun a major disinvestment strategy, Petrobras was still involved in the oil and gas sector in Argentina, Bolivia, Colombia and Venezuela. South America accounted for 45 per cent of the company's proven and developed oil resources abroad and 60 per cent of its proven and developed natural gas resources abroad in 2014. The according figures were 65 and 97 per cent respectively in 2013 and 49 and 87 per cent respectively in 2012 (Petrobras

2015). Beyond the region, the company participated in upstream activities in Gabon, Mexico, Nigeria and the United States. Many of the assets held by Petrobras abroad have now been sold, in particular in Argentina, Colombia and Peru (Petrobras 2016a). Yet even during the height of its internationalisation Petrobras had a clear focus on Brazil, especially on the Southeast where its headquarters and most corporate units are located (Map 2). The North and Northeast – or the cities of Manaus and Natal – appear to be secondary hubs.

Table 4
Petrobras's investment projects abroad

	Extraction	Manufacturing	Logistics	Marketing and sales	Retail	Total
Argentina	4	4	4			12
Venezuela	6					6
Cuba	1	1		1	1	4
United States	3	1				4
Uruguay			3		1	4
Chile					3	3
Japan		1	1		1	3
Peru	2	1				3
Bolivia	1	1				2
Colombia	2					2
Nigeria	1	1				2
Algeria	1					1
Angola	1					1
China				1		1
Ecuador	1					1
Iran	1					1
Libya	1					1
Netherlands				1		1
Pakistan	1					1
Paraguay					1	1
Portugal		1				1
Saudi Arabia		1				1
Turkey	1					1
Ukraine				1		1

Source: fDi Markets and Zephyr databases.
Note: Data is for 2003 to 2016.

Map 2
Petrobras's corporate units in South America

Source: Zephyr database.
Note: Data is for 2012 to 2015.

By investing abroad in the 1990s and 2000s, Petrobras apparently overcame distance and division. Following the 2009 *World Development Report*, regional integration is critical in this regard. Regional integration in South American began with the foundation of the Mercosul in 1991 – an organisation that aims at creating a common market for its members, based on the free movement of people, goods and services. The Mercosul initially consisted of Argentina, Brazil, Paraguay and Uruguay. Venezuela became a full member in 2012 but its membership has recently been suspended. In 2004 the Mercosul signed a co-operation agreement with the Andean Community of Nations (Comunidad Andina de Naciones, CAN), a customs union formed by Bolivia, Colombia, Ecuador and Peru. Both organisations declared their intent for future negotiations towards integrating all of South America.

The impact of the Mercosul on Petrobras's internationalisation was limited though. One of our interviewees argued that at least from the perspective of private firms the Mercosul and other regional organisations alike were 'inefficient, weak and not advancing'[18]. The organisation could have facilitated Petrobras's investment in the Southern Cone by an agreement on investment protection: the Colonia Protocol for the Reciprocal Promotion and Protection of Mercosul Investments (*Protocolo de Colonia para la Promoción y Protección Recíproca de Inversiones en el Mercosur*) from 1994, which specifies that investors domiciled or resident in the territory of any member state have to be entitled to a treatment that is not less favourable than that accorded to national investors. According to the protocol states receiving intra-Mercosul investment must not apply discriminatory means that would be capable of restricting the investor's freedom to use its investment. However only Argentina ratified the protocol.

Whilst the Mercosul appears to have come to a standstill (Doctor 2013; Malamud; Gardini 2012), regional integration is also pursued by the Union of South American Nations (União de Nações Sul-Americanas, Unasul). The Unasul consists of all South American countries and is not primarily a tool for trade integration. It concentrates on policies such as defence, energy, transport infrastructure and, since more recently, education, health and social development. The Unasul framework does not mention a customs union or free trade zone. The concepts it refers to are economic co-operation, industrial integration, poverty

(18) Personal interview with an executive of an international consulting company (São Paulo, Aug. 24, 2015).

reduction and the wellbeing of the South American people. What matters most for our analysis is that the Unasul serves as an umbrella for physical integration, which has been the core of integration in South America since Fernando Cardoso's presidency (Burges 2005; Malamud 2005).

According projects are planned within the framework of the Initiative for the Integration of the Regional Infrastructure of South America (Iniciativa para a Integração da Infraestrutura Regional Sul-Americana, IIRSA)[19]. IIRSA's first action plan, published in 2000, set ambitious goals: to develop a vision of an integrated South American infrastructure; to harmonise and modernise policies and regulations affecting transport; to strengthen environmental and social aspects of infrastructure projects; and to develop consultative processes and joint design, finance and execution of these projects. In 2004 IIRSA delivered a large portfolio of 335 projects – distributed along ten geographical axes – to be implemented in the following ten years. The number of projects increased to 524 in 2010, mostly dealing with transport infrastructure and, to a rather limited extent, energy infrastructure. IIRSA also promotes regulatory harmonisation of issues such as border crossing, energy transmission, financial flows, information technologies and air, maritime and multimodal transport.

Despite significant shortcomings in terms of implementation (IIRSA 2011, Perry 2014), IIRSA's focus on physical integration is of some relevance to the oil and gas sector because of pipeline projects. Several researchers have pointed out that energy shortage has become a bottleneck for economic growth in many South American countries. Regional integration in terms of energy would therefore contribute to development (e.g. Bodemer 2010; Sennes, Pedrotti 2007). The overly ambitious Great Pipeline of the South – initiated by Hugo Chávez and Nestor Kirchner in order to connect Argentina, Brazil and Venezuela – probably never had a chance of becoming a reality but smaller projects have been pursued. These include natural gas pipelines in northern Argentina, which is already linked to Bolivia, and cross-border pipelines connecting Brazil's South with Bolivia, Paraguay and Uruguay. A regasification plant is to be built in Uruguay (Cosiplan, 2016a). The pipelines in northern Argentina have been ascribed priority status (Cosiplan, 2016b). Co-operation on oil in the Southern Cone is, at least at the moment, not part of IIRSA's agenda.

Trade in natural gas in the Southern Cone has been questioned, however, by the exporting side on several occasions. Argentina stopped exporting natural gas to Chile, breaking bilateral contracts, in 2004 because of a domestic shortage. Chile has ever since concentrated on purchasing liquefied natural gas on global markets. In 2006 the Bolivian government decided to re-nationalise its natural

(19) Detailed information on IIRSA's initiatives and projects is available at http://www.iirsa.org/.

gas resources, leading to a re-negotiation of its contract with Petrobras, which eventually had to pay higher royalties. In addition to the doubtful reliability of Bolivia, Brazil developed, as noted, domestic alternatives: the pre-salt resources off the coast of Rio de Janeiro and São Paulo. This had an impact on regional co-operation far beyond Bolivia. When the pre-salt resources were found in Brazil, Petrobras abandoned the Mariscal Sucre Project with Venezuela, which constituted the final blow to the Great Pipeline of the South. Having vast resources at home, regional co-operation is hardly attractive for Brazil. The preference for energy autarky is boosted by the apparent risks that result from being dependent on neighbouring countries. At least for now the era of an oil and gas GPN being built by a Brazilian company appears to have come to an end.

The impact of density, distance and division

As we have explained above, Rio de Janeiro and São Paulo play very different roles in oil and gas GPNs. Whereas São Paulo is critical for the downstream sector, its relevance for the upstream sector is marginal. This is due to the fact that Petrobras's headquarters and the Petrobras Research Centre (Centro de Pesquisas da Petrobras, CENPES) are located in Rio de Janeiro. The lead firm ties all major companies from the upstream sector to itself and hence to Rio de Janeiro. One of our interviewees, who works as a private consultant and has in-depth knowledge of the practices of Petrobras, accordingly said: 'Everyone who works with Petrobras [in upstream activities], has to be in Rio de Janeiro'. He explained that Petrobras specifies in its contracts with foreign firms that these firms have to open an office in close proximity to Petrobras's headquarters[20].

As a consequence of this split of the sector between Brazil's two largest cities, some transnational companies such as Shell have two headquarters in Brazil: downstream activities are dealt with in São Paulo; upstream activities are managed from Rio de Janeiro. The just mentioned interviewee also emphasised that 60 per cent of the industrial inputs demanded by the oil and gas sector – for example engines and pipes – are produced in the federal states of São Paulo. Interviewees from public authorities stated the same figure[21], which results from the fact that São Paulo is the industrial heartland of Brazil. The figure is apparently based on a very broad understanding of industrial inputs. The RAIS data that we presented above suggests that Rio de Janeiro dominates manufacturing of equipment for the oil and gas sector but most inputs that the

(20) Personal interview with an oil and gas consultant (São Paulo, May 7, 2014).

(21) Personal interview with representatives of the Energy Secretariat of the Federal State of São Paulo (Apr. 30, 2014).

equipment manufacturers in Rio de Janeiro need come from São Paulo. The companies that are based in São Paulo and produce these inputs supply numerous sectors. Their products are not limited to applications related to oil and gas.

In spite of the concentration of the upstream sector in Rio de Janeiro, the government of the federal state of São Paulo has identified economic opportunities in maritime engineering, logistics and shipbuilding, meaning in sectors traditionally located in Rio de Janeiro. What appears realistic in this regard is the setting-up of supply bases, as envisaged for the coastal towns of Bertioga and São Sebastião. Industrial services to the offshore operations could also be provided from Caraguatatuba, Itanhaém and Peruíbe. Both domestic and foreign firms are expected to invest in these towns. Beyond that, the government of the federal state of São Paulo predicts that various non-industrial services – ranging from accommodation to car rental to expositions – will benefit from the offshore oil and gas sector[22]. Representatives of public organisations that promote economic development and investment in São Paulo expressed the hope that the shift of offshore exploration to the south – that is, from the Campos Basin to the Santos Basin – will trigger a relocation of some upstream activities, especially to the harbour of Santos. At the same time, it was recognised that Rio de Janeiro is the hub for oil and gas field operators and first-tier service providers[23].

In this regard it was pointed out that due to the Santos Basin being developed, transnational companies, whose headquarters are (and remain) in Rio de Janeiro, have opened 'small representative offices' in Santos. This locational shift is a consequence of a move made by Petrobras, which has opened a co-ordination office for the Santos Basin in Santos[24]. Although new supply bases offer prospects for massive investments, there appears to be a strong persistence of spatial patterns because Petrobras prefers, according to the aforementioned private consultant, to concentrate its activities in Rio de Janeiro as far as possible. Local politics and the traditional rivalry between Brazil's two largest cities boost this tendency. Only an enormous expansion of the activities in the Santos Basin could initiate a major relocation of the upstream sector, our interviewee suggested. Even it that case, Rio de Janeiro and its existing supply bases would still be relatively close to the Santos Basin, reducing the benefits of relocating[25]. Hence it appears that low distance and division between Rio de Janeiro and São Paulo complicates processes of plugging-in in São Paulo. If it were not so easy to manage and supply activities in the Santos Basin from existing headquarters

(22) Presentation drafted in December 2010 and used for internal discussions by the Government of São Paulo, provided to the authors.

(23) Personal interviews with an executive of INVESTE São Paulo (Apr. 28, 2014) and with an executive of SP Negócios (Apr. 30, 2014).

(24) Personal interview with an oil and gas consultant (São Paulo, May 7, 2014).

(25) Personal interview with an oil and gas consultant (São Paulo, May 7, 2014).

and supply bases in Rio de Janeiro, there would be more according investments in São Paulo.

Regardless of these questions on the territoriality of GPNs, the plugging-in of Brazilian companies is eased by Petrobras's dominant role. Local companies do not have to partner directly with foreign investors. By building ties with Petrobras, they can plug into GPNs. Petrobras uses an online system in order to certify and register suppliers. This register comprises suppliers of more than 4,000 types of equipment, ranging from boilers to heat exchangers to electric panels, and roughly 2,500 types of services such as drilling and maintenance. Companies that are certified and registered by Petrobras may enter a database that serves as an orientation for firms contracted by Petrobras, meaning that these contractors choose their sub-contractors from Petrobras's list. Being part of Petrobras's database does not mean, however, that a company will be invited to each and every tender process. Petrobras pre-selects bidders based on the tender in question. What is more, it is critical to bear in mind that the most sophisticated services in the upstream oil and gas sector are provided by transnational companies such as Baker Hughes, Halliburton and Schlumberger. The services that these firms provide are extremely knowhow-intensive and at the same time not required frequently. Hence it would be difficult and probably also irrational for local companies to seek to also provide these services.

Whereas Petrobras reduces division for Brazilian suppliers, it appears that the lead firm increases division for foreign operators. An interviewee from an international consulting company argued that Petrobras obtained the best blocs in past concession bids. Foreign firms obtained relatively poor blocs. From her experience these practices discouraged foreign investment even before the decline of the oil price. She added that investment opportunities do not so much result from the availability of resources but rather from political conditions affecting according investments, which is why, amongst other countries, Mexico with its recently liberalised energy sector is more attractive to foreign investors than Brazil[26].

The impact of density, distance and division can be shown by two science and technology parks in Brazil that focus, amongst other sectors, on oil and gas. Science and technology parks are meant to generate innovation by facilitating formal and especially formal networks that depend on proximity (e.g. Basile 2011, Feldman 1999). In other words, they bring firms involved in research and design together, creating density and overcoming distance and division. One of the science and technology parks that matter to the oil and gas sector in Brazil is located in Santos. The other is in the city of Rio de Janeiro, on the Ilha do

(26) Personal interview with an executive of an international consulting company (São Paulo, Aug. 24, 2015).

Fundão[27]. Petrobras is the anchor company in both parks. As we (2017) explain in a working paper published earlier in this series, at least the park in Rio de Janeiro serves as a gateway in terms of knowledge generation. It enables foreign companies to adapt existing technologies to local conditions – that is, to the specific requirements of ultra-deepwater, pre-salt exploration – and partner with Brazilian firms for this purpose. Science and technology parks as gateways may also constitute a platform for Brazilian firms to internationalise, globally marketing technologies initially developed for local application.

National legislation has given a certain push for research activities related to oil and gas. The regulatory framework for extraction in major fields requires all companies involved in these fields – first of all Petrobras (Table 5) – to invest at least 1 per cent of their gross receipts in research and development. Half of these funds must be used for contracting local research institutions, mostly public universities. The other half can be used in-house or through outsourcing (ANP Resolution n. 33 from 2005). This policy reflects the support of the Brazilian government for Petrobras's efforts to boost its role as a technology leader via co-operation with domestic and foreign partners in science and technology parks (Ministério da Ciência, Tecnologia e Inovação, 2016). Petrobras is the world leader in offshore, pre-salt exploration technology already today (Garcia Ribeiro; Tosi Furtado, 2014; Mauro de Morais, 2013). In 2015 it received the OTC Distinguished Achievement Award for Companies, Organisations and Institutions for the third time in a row. The award is granted every year by the Offshore Technology Conference, which brings together all major business associations and firms involved in the offshore oil and gas sector.

The science and technology park in Rio de Janeiro dates back to 1963, when the Graduate and Research Institute for Engineering (Instituto de Pós-Graduação e Pesquisa de Engenharia) was opened on the Ilha do Fundão by the Federal University of Rio de Janeiro (Universidade Federal do Rio de Janeiro, UFRJ). Ten years later Petrobras created a research centre of its own, focussed on the oil and gas sector, nearby: the aforementioned CENPES. Petrobras's centre was the first major industry–university partnership in Brazilian history. It has served as a kick-off for numerous research projects carried out by scholars from the UFRJ. The science and technology park itself was only approved by the council of the UFRJ in 1997 and three years later the municipal authorities of Rio de Janeiro launched an according urban infrastructure project.

(27) Information on these parks is available at http://www.fpts.org.br/ and http://www.parque.ufrj.br/.

Table 5
Investment in research and design

	Petrobras	Others
2003	323,299,906	-
2004	392,585,953	11,117,686
2005	506,529,318	2,279,136
2006	613,841,421	2,547,915
2007	610,244,146	6,259,121
2008	853,726,089	7,132,144
2009	633,024,264	5,858,020
2010	735,337,136	11,579,885
2011	990,480,683	41,416,212
2012	1,148,763,766	77,922,925
2013	1,161,786,262	98,080,695
2014	1,246,469,446	161,095,785
2015	894,001,057	136,955,340
2016	456,362,515	98,070,311

Source: Information provided by the ANP.

It took another three years until the first research laboratory, the so-called Tanque Oceânico, which deals with ocean technology, began its work. Other laboratories maintained by the Graduate and Research Institute for Engineering carry out research on technologies for the natural gas sector, develop numerical methods in computational mechanics, test various products used in the oil sector and work on the recovery of ecosystems. A representative of the park's administration stressed, however, that it was only after the discovery of the pre-salt resources and intensive lobbying by Petrobras amongst its foreign partners that the park became dynamic[28]. Interviews conducted by Rocha and Urraca-Ruiz (2012) confirm that the vast amount of offshore reserves has been a main reason for foreign companies to come to the UFRJ Science and Technology Park. Today a total of 57 enterprises, including 27 start-ups, have their offices in the park. Outstanding ones are list in Table 6:

(28) Personal interview with a representative of the UFRJ Science and Technology Park (Rio de Janeiro, Dec. 12, 2016).

Table 6
Firms in the UFRJ Science and Technology Park

	Origin	Activities in general	Objectives in the park related to oil and gas
Tenaris Confab	United States	leading producer of welded steel pipes in Latin America	pipe welding for offshore oil and gas operations
Baker Hughes	United States	major upstream service provider	drilling optimisation, reservoir evaluation; both for pre-salt, ultra-deepwater operations
Halliburton	United States	major upstream service provider	software specialised for pre-salt exploration and extraction
Schlumberger	France	major upstream service provider	acquisition of technologies for pre-salt, ultra-deepwater operations
FMC Technologies	United States	major upstream service provider	new technologies for pre-salt, ultra-deepwater operations (e.g. separation of oil from sand and water)
Siemens Chemtech	Germany	sub-sea technologies applicable in the oil and gas sector	new technologies for offshore and subsea use
Ambidados	Brazil	services in acquisition, processing and analysing data for offshore operations	developed a system to acquire real-time data from anywhere offshore
BG E&P Brazil[29]	Netherlands/United Kingdom	integrated oil and gas company	technologies for carbon dioxide reduction
EMC2	United States	services related to information analysis and storage	big data assessment related to the oil and gas sector
General Electric	United States	conglomerate with a particular strength in energy technology	equipment, software and integrated systems that can be used in offshore oil extraction
Georadar	Brazil	environmental diagnostics and geological surveys	acquisition and analysis of geo-physical data
Repsol	Spain	integrated oil and gas company	biodiversity preservation in exploration and extraction areas, life cycle assessments for petrochemical products
Vallourec	France	seamless steel tubes for the energy sector	adaptation to pre-salt, ultra-deepwater operations

Source: Authors' own compilation based on the websites of the respective companies.

(29) BG E&P Brazil is a subsidiary of Shell.

According to Rocha and Ucarra-Ruiz (2012) the UFRJ Science and Technology Park not only serves as a gateway to Brazil and its offshore resources for foreign companies. Baker Hughes and Schlumberger suggested in interviews that they seek to learn about pre- salt exploration and production conditions because they are aware that knowledge developed in Brazil can be used elsewhere. FMC Technologies meanwhile concentrates on adapting its technologies to the needs of Petrobras, which has contracted FMC Technologies for several operations. In other words, whereas FMC Technologies is exploiting its existing assets through adaptation, Baker Hughes and Schlumberger seek to augment their assets by absorbing Brazilian technologies and developing new technologies together with Brazilian partners.

The science and technology park in Santos is a much more recent project. It was officially launched in 2011 in the context of the exploration of newly found oil and gas fields off the coast of the city. Representatives of the public authorities expressed high hopes in the development of the park, in particular with regard to research activities carried out jointly by Petrobras and universities from the federal state of São Paulo[30]. The park is not limited to oil and gas though. It is also dedicated to communication and information technology, port logistics, renewable energy and urban development – apparently areas that are related to the oil and gas sector. The general objective is to strengthen the competitiveness of local companies and their innovative capacities by bringing them together with non-local partners, educational institutions and universities. Presently many local enterprises cannot, however, overcome division and thus fail to plug-into oil and gas GPNs. According to an official from the municipal authorities of Santos local firms often have the necessary technical skills to participate in the sector but are 'not very professional' in terms of management. Language barriers also complicate their collaboration with foreign companies[31].

Our interviewee pointed out that she and her colleagues support the sector by organising events at which foreign investors and local firms come together. The city moreover provides office space in the science and technology park for oil and gas companies, which also benefit from tax incentives. The interviewee stressed the need – and the efforts undertaken by herself and her colleagues – to upskill local entrepreneurs and local labour. Other public authorities such as the Special Commission for Oil and Gas (Comissão Especial de Petróleo e Gás,

(30) Personal interviews with representatives of the Energy Secretariat of the Federal State of São Paulo, 30 April 2014, and with a representative of the Municipality of Santos (Aug. 18, 2015).

(31) Personal interview with a representative of the Municipality of Santos (Aug. 18, 2015).

CESPEG) of the federal state of São Paulo however only ascribe medium relevance to this issue. They argue that much more has to be done to identify the technologies that independent suppliers need and stimulate according research. Before the domestic crisis the CESPEG (2010) identified sectors in which they would like local institutions to carry out research. These include carbon capture and storage, different forms of engineering, especially for sub-marine operations but also for using natural gas that is set free when exploiting offshore oil resources, geological surveys and specialised logistics.

Currently investment for the science and technology park in Santos stands at BRL 14 million. The area designated for the park is still under construction but several partnerships, driven by universities that plan to open laboratories in the park, have already been agreed upon. Large Brazilian companies such as the steel producer Usiminas will be in the park. So will local and national business organisations, most importantly the Business Association of Santos (Associação Comercial de Santos), the Federation of Industries of the State of São Paulo (Federação e Centro das Insdústrias do Estado de São Paulo, FIESP) and the Brazilian Support Service for Micro and Small Enterprises (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, SEBRAE).

It is important to mention that Petrobras alone has committed itself to invest another BRL 77 million for an oil and gas technology centre in Santos: the Technology Centre of the Santos Basin (Centro Tecnológico da Baixada Santista). The purpose of this centre is to further explore the nearby offshore resources. Universities from the federal state of São Paulo with a particular strength in research – the University of São Paulo (Universiade de São Paulo), the São Paulo State University (Universidade Estadual Paulista) and the Campinas State University (Universidade Estadual de Campinas) – will collaborate directly with this centre.

GPNs and the Brazilian oil and gas sector

In this section we bring the empirical information presented above together with the GPN approach, highlighting both findings of our research and issues that require more empirical analysis. It has become clear that the Brazilian oil and gas sector, especially its upstream components, is concentrated in Rio de Janeiro, where the lead firm of the sector is located: Petrobras. São Paulo is the second-most important federal state but this relevance results primarily from processing, meaning downstream activities, which are most likely related to the large local

market. In other words, the territorial embeddedness of oil and gas GPNs in Brazil varies considerably from one federal state to another. Rio de Janeiro moreover serves as a gateway city on the national scale. We have shown that not only Petrobras has its headquarters there. All other operators of oil fields have established offices in the city. Even though our data on service providers is not complete, it suggests that Rio de Janeiro also serves as a hub for these companies. At least in the case of the science and technology park on the Ilha do Fundão, the gateway role has been facilitated by institutions: the park has been established by public authorities so as to facilitate the co-operation of local and foreign enterprises; it is based on the long-term collaboration of Petrobras and the UFRJ.

Petrobras not only shapes the territorial embeddedness of the sector. It is also crucial for the creation, enhancement and capture of value. Petrobras creates value, being the most important oil and gas extractor in the country. Its value creation results from different forms of rent: its access to resources, its technological leadership and legislation on local content, which is a policy rent (Table 7).

Table 7
Value creation through rents

Rent	Examples
Resource	offshore oil and gas*
Technology	leadership in pre-salt, ultra-deepwater operations
Finance	*unclear*
Infrastructure	*unclear*
Organisation	science and technology parks
Brand	*unclear*
Policy	legislation on local content

Brazil possesses the second-largest oil and gas resources in South America. In 2014 it extracted 179.8 million barrels of pre-salt oil and 6.3 billion cubic metres of pre-salt gas (Energy Information Agency, 2015).
Source: Authors' own compilation.

Petrobras enhances value through refining crude oil and purifying raw natural gas and also captures a considerable share of the value generated in Brazilian oil and gas GPNs; most importantly because it plays a dominant role in the downstream sector, owning 15 refineries that account for everything but a marginal share of Brazil's refined oil production. Hence in comparison to other regions from the

Global South, which usually play a subordinate role in GPNs, Brazil plugs into oil and gas GPNs via a lead firm. This means that power is, to a large extent, concentrated in Brazil and not in the Global North. As Petrobras's internationalisation from the early 1990s until the end of the last decade showed, the company is able to set up a GPN of its own.

The creation, enhancement and capture of value are strongly influenced by legislation on local content. It would, of course, be plausible to argue that the Brazilian government was particularly powerful vis-à-vis transnational enterprises when Petrobras was performing well and when the oil price was high. With the serious crisis of Petrobras and the decline of the oil price, the bargaining position of the government then became weaker. Yet the recent shifts in Brazil's policy on local content, especially the end of Petrobras's 30-per cent minimum participation, can also be attributed to the new conservative government being convinced of liberal economic policies, differing in this regard fundamentally from the previous PT governments.

Regardless of the paradigms that shape Brazil's economic policy, the previous 30-per cent minimum participation and the right of first refusal that has now been granted to Petrobras make sure that the Brazilian giant plays a major role in GPNs that comprise Brazilian oil and gas fields. What is more, foreign investors are, as noted, obliged to invest in research activities in Brazil. Considering the tremendous offshore resources, the technical challenges of their exploitation and the fact that Petrobras is the leading company for according technologies, there would probably be significant investment in research on oil and gas in Brazil if the government had not passed legislation that makes this investment mandatory. From the perspective of plugging into GPNs, the outcome is more important than its causation: Brazilian firms not only participate in the extraction and processing segments of the oil and gas GPN; they also play a role – in the case of Petrobras, the lead role – in research activities. The activities of these firms are functionality complex. They produce for a specialised market, work with heightened product and processes technologies and require a qualified workforce. This boosts value creation and value enhancement in Rio de Janeiro and potentially also in Santos.

As far as our empirical research is concerned, functional coupling only applies to the Brazilian firms that have established themselves successfully in the UFRJ Science and Technology Park. Their products and services are not standardised. The firms are not necessarily limited to participating in activities

carried out in Brazil. The Brazilian functional couplers possess a reasonable potential to apply their abilities elsewhere, using the park as a stepping stone for the internationalisation of their respective businesses. Petrobras itself is also a functional coupler, as it is a critical partner for foreign investors and develops complete solutions for logistical, managerial and technical challenges. At least during the height of Petrobras's internationalisation, the company achieved indigenous coupling: using the experiences and skills that it had gained domestically, it expanded internationally, setting up a GPN of its own. Companies that benefit from local content legislation but are not involved in research activities are typical examples of structural coupling by generic suppliers, meaning that they provide standardised goods and services – for example engines and pipes – for activities carried out in their home region. The aforementioned resolution by the ANP guarantees that these firms participate in oil and gas GPNs.

Related to these different forms of coupling, the respective impacts on the Brazilian economy as a whole remain to be assessed. These impacts go beyond the creation of jobs and the sector's direct contribution to the gross domestic product. They include, most importantly, backward and forward linkages of all companies involved in the oil and gas sector but also the up-skilling of labour and local partner companies, in particular by the foreign operators and contractors that we have identified. Referring to the concept of 'related variety' (e.g. Boschma and Iammarino 2009, Frenken, van Ooort and Verburg 2007), one could argue that Brazilian firms that upgrade their capabilities through partnerships in oil and gas GPNs will have a positive effect on Brazil's economic progress in sectors that require similar capabilities, for instance civil engineering and electricity generation.

Given that we have shown considerable spatial disparities on the sub-national scale, it would also be worthwhile to study the dynamics in more peripheral parts of Brazil. Although consumption concentrates in São Paulo and most resources are located off the coast of Rio de Janeiro and São Paulo, there are other regions that matter to the oil and gas sector, in particular the North and Northeast. With regard to spatial disparities and the role of gateway cities, one should assess whether dynamics and the peripherial regions of Brazil lead to spread effects, with segments of GPNs being increasingly relocated to places other than Rio de Janeiro and São Paulo. Furthermore it could be studied what role different districts in the federal states of Rio de Janeiro and São Paulo play for the sector so as to learn about the small-scale functional fragmentations of

according GPNs. This way we would find out whether the incorporation of Brazil into oil and gas GPNs leads to what Hein (2000) describes as new islands of a global archipelago economy.

Conclusions and challenges

The oil and gas sector in Brazil experienced a boom in the second half of the 2000s because of newly found resources offshore. The number of firms and jobs in the sector increased considerably. Brazil participates in oil and gas GPNs in a way that is untypical for countries from the Global South. The emerging economy does not only possess tremendous resources. Petrobras is a major global player, especially because of its technology leadership for pre-salt, ultra-deepwater operations. Laws on local content – advanced by the PT governments and reflecting the concept of developmentalism – guarantee that value is captured locally, by Petrobras and numerous other Brazilian firms. Many of these firms are generic suppliers, involved in processes of structural coupling. Some, including Petrobras, also couple functionally, in particular in the knowledge-intensive parts of oil and gas GPNs. At the same time there are considerable territorial differences of oil and gas GPNs in Brazil: whilst Rio de Janeiro is the hub of the upstream sector, the downstream sector concentrates in São Paulo. Other federal states play a much less important role than Rio de Janeiro and São Paulo.

The information that we have gathered furthermore suggests that density makes Rio de Janeiro a gateway city. Rio de Janeiro is not only the hub for operators and contractors. The city also hosts the UFRJ Science and Technology Park, where firms are expected to benefit from density. It appears that in particular major foreign services providers use the park so as to gain access to Brazilian markets and technologies. The efforts to plug Santos into oil and gas GPNs reveal how division – between foreign investors, on the one side, and local firms, on the other – impedes processes of plugging-in. Counterintuitively, low distance and division on the national scale hamper the plugging-in of the federal state of São Paulo and boost the role of Rio de Janeiro as a hub, at least with regard to the upstream sector: the Santos Basin can be supplied from Rio de Janeiro; relocation to Santos and other towns remains limited.

This finding leads to a first shortcoming – or perhaps rather a challenge – of the analytical concept that we have developed and applied. The *World Development* euphemistically predicts that overcoming distance and division

eventually leads to economic development everywhere. Yet, as said, it appears that Rio de Janeiro will remain the hub with little impulses generated for coastal towns in the federal state of São Paulo. This disillusioning finding is related to a contradiction between Geographical Economics and the *World Development Report*: the former suggests that low transport costs tend to reinforce polarisation between hubs, on the one side, and their hinterlands, on the other (Krugman 1991a, 1991b, 1992). Related to this, the development of oil and gas resources in Brazil's North and Northeast is likely to trigger regional economic dynamics because these parts of the country are separated from Rio de Janeiro by high distance and division. Oil and gas companies whose Brazilian headquarters are in Rio de Janeiro thus have to open branches in cities such as Manaus and Recife, searching for partners located there[32].

A second conceptual challenge results from our application of the concept of density. We have shown the three Ds complement the GPN approach: they enable us to explain why regions do not plug into GPNs or only partly. Yet there are inconsistencies with regard to merging the GPN approach and the three Ds, in particular when focussing on the role of gateway cities. Density, as understood in the 2009 *World Development Report*, is based on economies of scale. Gateway cities do benefit from economies of scale, most apparently as hubs for industrial processing and logistics, two dimensions of gateway cities that we hardly addressed in this paper. Science and technologies parks conversely imply that gateway cities depend on social interaction and tacit knowledge. This understanding of density is characteristic of research on innovation and world cities (e.g. Parnreiter 2015, Storper 1995, 1997). It is, however, beyond the scope of the three Ds, at least if one elaborates on their conceptual background. Hence, in addition to the aforementioned empirical gaps, future research based on this paper would benefit from a more thorough elaboration on the background of the analytical concepts that we applied so as to better integrate them and overcome inconsistencies.

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