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Buying to Develop: The Experience of Brazil and China in Using Public Procurement to Drive Innovation*

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This paper sets out to understand the use of public procurement as a policy instrument for catching up. Brazil and China, who have explicitly linked procurement to innovation, are used as empirical cases. We review their respective institutional settings, policy approaches, and micro-level processes related to the public procurement of innovation (PPI). We have discovered that they share similarities concerning issues encountered during PPI implementation. Although both countries have made some achievements in promoting innovation through procurement, this paper highlights some of the obstacles they have experienced when implementing this policy, such as institutional problems, changes in the political landscape, and macroeconomic constraints. Such obstacles, more prominent in the case of Brazil, may have acted as an obstruction to achieving the pursued objectives, thereby restricting the full potential of PPI in driving technological catching up. The article then offers managerial and policy implications for the implementation of PPI, such as the importance of choosing relevant procurement procedures, critical roles played by policy champions, and demonstrating effects of leading firms and regions. While in China PPI was once an instrumental part of its technology development agenda, in Brazil it has been sporadic and unconnected to a given national strategy.

Keywords: Public procurement; innovation; development; policy; catch-up; Brazil; China.

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1. Introduction

Public procurement refers to the process whereby public bodies acquire from third parties various goods and services that they need for their activities [Arrowsmith *et al.* (2000)]. According to the OECD, expenditure on public procurement typically takes up around 12% of an OECD country's GDP.[a] This proportion may be even higher in developing countries where governments are making progressive investment to build public infrastructures and enhance public services [Anderson *et al.* (2012)].

Public procurement has historically facilitated the industrialization of advanced economies [Geroski (1990); Edquist *et al.* (2000)]. Since 2000, there has been an intense, renewed interest, especially within the EU, in using public procurement as a policy instrument to support innovation [Uyarra (2016)]. This interest has recently spread from developed countries to the context of developing countries [Yulek and Taylor (2011); UNOPS (2014)]. Two of the largest developing countries, China and Brazil, have both explicitly linked public procurement with the promotion of innovation, and in particular, to catch up [Ribeiro and Furtado (2015); Li and Georghiou (2016); Rauen (2017)]. Public procurement of innovation (PPI) in developing countries, while, under certain circumstances, sharing similar characteristics to those of developed countries, can be fundamentally distinct from PPI in developed countries, given the differing industrial and technological trajectory, strategic priorities, institutional settings, operational barriers and nature of innovation. Even among developing countries, such as Brazil and China, the prospects unveiled by PPI may vary significantly due to their economic, political, institutional and technological specificities.

Using public procurement as an instrument of innovation policy for developing countries is both promising and problematic. On the one hand, developing countries have more flexibility to leverage their purchasing power for development purposes because they are typically not signatories of the Agreement on Government Procurement — GPA [Frenkel *et al.* (2014)]. For example, as demonstrated in Srinivas [2006], public procurement has served as a useful demand-side instrument to induce industrial change and technological innovation in the vaccine sector, particularly through improved technical standards and regulations.

On the other hand, there are recurring problems among developing countries, such as the lack of necessary expertise, capabilities and institutional capacity. Such problems can create obstacles to exercise public procurement as a multi-functional policy instrument. Additionally, PPI in developing countries may be highly complex, due to a variety of reasons, including but not limited to: underdeveloped procurement systems, which often feature flawed institutions and more severe corruption, a limited institutional capacity, which restrains the space in which to exercise this sophisticated policy instrument, and the weak capabilities of practitioners (including procurers and suppliers), which undermines the effective design and implementation of policies [Lember *et al.* (2014)].

The purpose of this paper is to clarify the profile of public procurement as a policy instrument for technological catching-up in two developing countries, Brazil and China. The justification for choosing these countries is because they both have large domestic markets that, to a great extent, depend on government procurement and

[a]See https://www.oecd.org/gov/public-procurement/ for OECD official data.

that in different manners employ public procurement as a tool for technological development. So, we specifically use Brazil and China as the empirical cases and comparatively review their respective institutional settings, policy approaches, and micro-level processes related to PPI, aiming to derive implications for developing countries in pursuit of innovation.

This research is justified because there are currently few studies that have investigated PPI in developing countries as a phenomenon situated at the interfaces between innovation and development. On a conceptual level, Kattel and Lember [2010] explored the pitfalls and opportunities of PPI in developing countries and provided an analysis of the potential strategies that may be adopted. However, in terms of empirical research, little knowledge has been developed in order to understand what PPI entails for developing countries. This is one of the research gaps that this paper aims to address. One other gap that it also intends to fill is to provide an understanding on how public procurement may be employed in the technological development of countries with very different national strategies. In other words, we wish to analyze how public purchases are able to have different uses and weights, considering the specificities of each country.

We discovered that China and Brazil differ significantly in policy approaches, but share similarities regarding issues encountered during PPI processes. The results of this research indicate that, while both countries have achieved some degree of success in promoting innovation through procurement, macro circumstances, such as austerity and political change, can make it difficult to achieve the intended objectives through this policy. While it has proved to be unrealistic for developing countries with weak institutions to embark on PPI aggressively, a differentiated approach based on policy experimentation and capability building would seem to be the way forward.

Moreover, the paper also presents how public procurement can have different weights in national strategies. While in China public procurement is central to the technology development strategy, in Brazil, PCP and PPI are sporadic and unconnected with a given national strategy. In the literature, this is the only paper that has made evident with concrete examples, that the specificities (political, economic and institutional mainly) can vary significantly, even among countries classified as developing countries, creating favorable or unfavorable conditions for the exercise of the PPI. Section 2 reviews the strands of literature on procurement in the international political economy and the existing knowledge related to PPI to contextualize the subject. Section 3 presents the methodology employed by the study and how the cases of the two countries have been constructed. Section 4 illustrates the cases of Brazil and China, respectively, followed by Sec. 5 which provides a comparative analysis of the two cases. Section 6 provides further discussion and a conclusion, thereby drawing wider implications for PPI as a catching-up policy instrument.

2. Literature Review

2.1. *Public procurement in the international political economy*

In most domestic systems, public procurement is regulated by strict, formal rules, including legislation and other types of institutions [Thai (2001)]. Procurement

regulations commonly specify a range of features, including, but not limited to, the goals and organizational structure of procurement, the applicable processes and procedures, and codes of conduct [Thai (2001)]. In addition to the basic need to fight against corruption, public procurement is often used as leverage for domestic development. In the United States, for example, the government launched the Buy American Act as early as 1933 [Knapp (1961)], according to which, US public agencies were required to demonstrate a preference toward US goods and services (i.e. goods/services with the cost of foreign components not exceeding 50% of the total cost) in public procurement processes [Luckey (2009)]. Thereafter, this practice has become an archetype of preferential procurement policy.

Because of its importance, public procurement is also subject to supranational as well as national law, in relation to the procedures, scope, and values associated with international procurement practices. Domestic and international regulations are distinct from one another. While the former emphasizes anti-corruption and domestic socioeconomic development, the latter, notably the World Trade Organization (WTO) regime on procurement, is widely concerned with international free trade and non-discrimination [Anderson and Arrowsmith (2011)]. The cornerstone of the WTO regime on procurement is the Agreement on Government Procurement (GPA), initially signed in 1979, with expanding coverage of member countries globally. Most developed countries have become signatories of the GPA, selectively opening up their public markets to other signatories.

Despite WTO efforts to liberalize such markets, some countries have chosen not to join the agreement, such as Brazil and China (and most of the developing countries). Some of the reasons for certain developing countries to show reluctance in joining the supranational arrangements are: problems in communication, exchange rates and payment, customs rules, waiting times, foreign government regulations, and transportation [Thai (2001)]. Significantly, adherence to supranational agreements may derail or hinder the use of public purchasing power to achieve objectives such as economic, social, and technological development, since these agreements do not allow preferential treatment for domestic companies, although there are some exceptions. Understandably, there is an overall willingness for current GPA signatories to persuade non-signatories to open up their public markets and join the GPA, and similarly, there is an overall unwillingness for non-signatories to do so. This has led to inevitable tensions associated with GPA membership negotiations [Anderson *et al.* (2012)], which underpins the difficulty for acceding countries and existing signatories to reach an agreement on the exact scope and conditions of GPA membership.

It remains debatable as to whether or not international trade regulations have led to less space for developing countries to use procurement as an instrument of development policy [Wade (2003); Chang (2006); Muchhala (2007)]. There are two competing perspectives. The first is that free trade and openness are good for all parties, and developing countries still have plenty of opportunities to use procurement for development [Anderson and Arrowsmith (2011); Yukins and Anderson (2012)]. Some authors have argued that the GPA may be flexibly interpreted in order to suit the needs of member countries in achieving their socioeconomic

objectives [Arrowsmith (2003); McCrudden (2007)]. However, utilizing this flexibility requires solid capabilities of policymakers and practitioners, as well as sufficient institutional capacity, which most developing countries lack [Kattel and Lember (2010)]. The opposite perspective is that the freedom for developing countries to exercise public procurement to drive development would be fundamentally constrained once they join the GPA [Kattel and Lember (2010); Tayob (2010)].

2.2. *Leveraging public procurement for innovation and development*

The idea of leveraging public procurement for development, and more specifically, for innovation-driven development, is that by favoring innovative solutions in their procurement activities, the government may act as a leading user. Thus, government can accelerate the adoption and diffusion of new technologies and meanwhile provide better public infrastructures and services [Edler and Georghiou (2007)].

The strictest definition of PPI has been the procurement of as-yet-inexistent solutions with radically innovative features, which would stimulate suppliers to make a move and innovate while being reassured of a guaranteed customer. However, a broader definition of PPI has more frequently been adopted, since the previous description was biased toward radical innovation [Uyarra (2016)]. By PPI, this study means: any public procurement activities that stimulate the creation, improvement, adaptation, and diffusion of innovation. Therefore, PPI could encourage the dissemination of existing cutting-edge solutions as well as the creation of those as-yet-inexistent. "Innovation" could mean "new to the world," while in the context of developing countries, it is often "new to the country."

Existing studies have proposed a variety of taxonomies to capture the different modalities of PPI [see, e.g. Edler *et al.* (2005); Hommen and Rolfstam (2009); Uyarra and Flanagan (2010)]. For developing countries, there are at least two important differentiations of PPI that are worthy of particular attention:

– *Generic PPI* versus *strategic PPI*: in "generic PPI," innovation is considered as one of the essential criteria for routine procurement practices; while in "strategic PPI," the procurement of particular technologies/solutions is encouraged by the state out of strategic purposes;
– *Direct* versus *indirect PPI*: in "direct PPI," public agencies purchase innovative solutions for their use and are the end-users; in "indirect PPI," public agencies purchase innovative solutions in cooperation with private users (i.e. so-called cooperative PPI), or public agencies, which are in fact not the end-users of the purchased solutions, although private users are (i.e. so-called catalytic PPI).

There is an important distinction between PPI and PPI policies. By "PPI" we mean the actual public procurement activities (which might or might not have been triggered by policies) that stimulate innovation. By "PPI policies" we mean the policies employed to encourage and support PPI. Practitioners involved in PPI and PPI policies may be different from one another. PPI is mainly centered on procurement cycles, while PPI policies could affect a wide range of initiatives.

Georghiou *et al.* [2014, p. 4] provided an extremely comprehensive categorization of PPI policies. Policies used to support PPI activities are broadly grouped into four categories: (i) framework conditions; (ii) organization and capabilities; (iii) identification, specification, and signaling of needs; and (iv) incentivizing innovative solutions. The existing PPI policy practices in the international context have covered all four of the abovementioned categories. For instance, in the EU context, the EU commission has revised its framework conditions, e.g. procurement directives, to accommodate the needs of buying innovation, including the design of suitable Pre-Commercial Procurement (PCP) procedures [see Chapter 2 in Uyarra *et al.* (2016)]. In the US, federal agencies with high R&D budgets are expected to spend around 2% of their R&D funding on the Small Business Innovation Research (SBIR) program [see Chapter 1 in Uyarra *et al.* (2016)]. More broadly, many countries have adopted electronic platforms to carry out procurement practices, so that the organizational issues may be dealt with more efficiently, and the capabilities of procurers may be strengthened. Nevertheless, there is still a limited understanding as to how PPI policies in developing countries fall into this categorization. By unpacking the policy instruments employed in Brazil and China, this paper helps to further this understanding of the policies of developing countries.

3. Methodology

The methodology adopted for this study could be summarized as a comparative, embedded case study [Yin (2009)]. By "comparative" we mean that we examine Brazil and China comparatively so as to draw insights on PPI policy experience in large, catching-up economies. By "embedded" we mean that our analysis involves multiple levels and units, which cover both the levels of governance of PPI policies as well as significant PPI activities. A case study methodological approach is appropriate here because a case study is especially relevant for answering questions of "how," which requires no control over behavioral events, and is well suited for the qualitative, exploratory, and contextual characteristics of this topic. Case studies have been recognized as being particularly instrumental in understanding policy implementation processes [Yin (2009)].

We have chosen Brazil and China because these are the two major emerging economies which have explicitly linked public procurement to the agendas of innovation and development. As key players within BRICS, their sizeable public markets and policy aspirations offer important insights related to the developmental challenges that modern economies might have to face.

We first characterize the contexts of both countries regarding their institutional settings related to innovation as well as procurement. We then describe the policy approaches of both countries, primarily using the framework proposed by Georghiou *et al.* [2014], but complementing the framework with additional considerations regarding the development agenda. We then critically review the experience and draw lessons from both contexts.

Brazil first linked public procurement with innovation through Law No. 10.973/2004 (the "Innovation Law"), whereas China did so through its

National Medium- and Long-Term Program for Science and Technology Development (MLP) in 2006. Empirical material employed by this study includes both primary and secondary data collected during the period from the launch of PPI policies to the present. Primary data have been collected through semi-structured, in-depth interviews with stakeholders involved in PPI and related policies in China and Brazil. Stakeholders interviewed include national and lower-level policymakers, public procurers, suppliers/contractors, users, and researchers.

Two recent, representative cases have been selected to analyze the profile, potentialities, and obstacles to the practice of pre-commercial procurement (PCP) and PPI in Brazil: the P-51 oil platform and the KC-390 cargo aircraft. There are two sectors in which a strong presence of the Brazilian State may be perceived. One is the petroleum sector, through Petrobras. The other is the aerospace sector, through the Brazilian Air Force (FAB), and its defense equipment contracts, and through the remarkable presence of Embraer, a former state-owned company, which even after privatization, has continued to have an explicit connection with the Brazilian government.

The study has been based on information collected from face-to-face interviews using semi-structured questionnaires. The objective of the field research was to clarify the views of the main actors involved in these two orders (the P-51 and the KC-390), bringing to light information that enhances the findings provided by the bibliographic and documentary research. A central element that has permeated all the questionnaires (and hence the field research) was how these orders, in terms of technological capability, impacted local companies included in the suppliers' group. Also participated in the field research informants of the two actors linked to the Brazilian public sector, responsible for the analyzed orders; more precisely from Petrobras for the analysis of the P-51 and, in the case of the KC-390, from the Ministry of Defense, Coordinating Commission of the Combat Aircraft Program (COPAC) and Program and Industrial Promotion and Coordination Institute (in Portuguese, Industrial Development Institute — IFI).[b]

For the Chinese cases, 20 informants covering different levels of governance (seven national officials located in Beijing, four local officials in Shanghai, five business managers from supplier and user companies, and four researchers working in the fields of innovation and procurement) and different stakeholder groups (supplier, procurer/user, and government officials) were interviewed. The selection of informants was based on three key criteria: their knowledge of the subject, their willingness to participate (or data accessibility), and their objectivity in recollecting the case itself. Key criteria used to select the cases were threefold: first, the case needs to qualify as a PPI case (innovation was stimulated or enhanced in some way as a result of procurement). Secondly, the case needs to offer insights and learning points for a wider audience, and thirdly, sufficient and reliable data needed to be accessible in order to build the case. Due to the exploratory nature of this study and limited data sources concerning procurement in both countries, only a handful of cases were eventually built, as presented in this paper.

[b]See appendix for more details regarding the interviews.

Secondary data were collected from the documentation on legislations, policies, statistics, and sectoral and organizational strategies. A substantial amount of data was gathered in both countries during the timeframe of 2007–2017. Two levels, in general, underpin the data analysis. First, we look at the policy process, i.e. the design and implementation of PPI policies in both countries. Secondly, for the micro-level processes of PPI, we adopt perspectives from research on PPI activities, which examines the nature and rationales of PPI and associated issues, mostly on an organization level. After the two-level, descriptive analysis of each country's case, we then conduct a cross-case analysis to draw comparative observations.

4. Overview of Public Procurement

4.1. *Overview of public procurement in Brazil*

Government expenditure in Brazil takes up a significant proportion of its economy, accounting for approximately 40% of its GDP [OECD (2017)]. The precise size of the public procurement market has been difficult to estimate due to the lack of systematic monitoring and the high degree of fragmented public demand across sectors and levels of government. A close estimation is that in 2012, public procurement spending in Brazil was approximately 13.8% of its GDP [Ribeiro *et al.* (2017)].

The main legal reference governing public procurement in Brazil was provided by Law No. 8,666/1993. This law provides all the procedures that need to be adopted and followed by the Brazilian public sector at national and sub-national levels. Although Brazil is not a signatory to the WTO-GPA, the abovementioned law, in general, does not discriminate against foreign products. However, in tiebreaker cases, preference is given to goods and services produced in Brazil — produced or rendered by Brazilian companies or produced or provided by companies that invest in the country's R&D.

Concerning the legal framework that regulates the PCP and PPI in Brazil, the role of the Brazilian Innovation Act (Law No. 10,973/2004) Law No. 12,349/2010 and Law No. 9,283/2018 should be emphasized. In the first of these two laws, Article 20 stipulates that public bodies may outsource R&D activities to firms in order to address specific problems. In particular, this legal framework establishes the possibility of procuring R&D services in such a manner that the government can commission a single supplier (or group of suppliers) for a particular technology solution or an individual product or service:

> Public administration bodies and entities, in matters of public interest, may directly hire ICT, non-profit entities or companies, alone or in consortiums, that are focused on research activities and with the recognized technological capacity within the sector, conduct research, development and innovation activities that involve technological risk, to solve specific technical problems or obtain an innovative product, service or process [Brazil (2004)].

Further to this, the Brazilian Innovation Act states that this kind of procurement should not be included in the regular public bidding process and must be treated as an exception (direct hiring). In other words, the Innovation Act changed Law No. 8,666/93 and created its own "regime" of purchase outside the framework of Law No. 8,666/93. The Second Paragraph of Article 20 provides alternatives for a recurring problem in R&D projects, namely, concluding the contract without the full range or partial range of the intended result. In such cases:

> [...] the authority or contracting entity, at its sole discretion, may, through a technical and financial audit, extend the period of validity or draft final report closing such a contract [Brazil (2004)].

Moreover, the Act also permits the same supplier that was contracted for particular technology development to become the large-scale supplier for the results of this development. This is to promote the participation of providers in risky or uncertain projects. Therefore, it may be stated that this law introduced the perspective for the Brazilian public sector to practice PCP and PPI.

However, as demonstrated by [Rauen (2017)], Article 20 did not have the expected effect. According to Rauen, despite attempts to address issues of risk and uncertainty (which is not observed in Law No. 8,666/93), the Brazilian Innovation Act is incomplete, since it does not provide for contracts to reimburse costs of activities that precede the introduction of innovation (such as those associated with prototype development).

To deal with these problems, Law No. 9,283/2018 was therefore published and amended certain items of Law No. 8.666/1993 and the Brazilian Innovation Act. With particular regard to technological orders, Law No. 9,283/2018 establishes that contracts of a technological order may include the costs of activities that precede the introduction of the innovative solution, product, service, or process onto the market, such as: (i) prototype manufacturing; (ii) scheduling, as a pilot plant for proof of concept, testing, and demonstration; and (iii) the construction of the first plant on a commercial scale, when of interest to public administration [Brazil (2018)]. Given the recent publication of Law No. 9,283/2018, it is difficult to assess its actual impact on the practice of PCP and PPI in Brazil.

Within this scope of the legal framework that supports the placing of technological orders by the Brazilian public sector, Law No. 12,349/2010 also deserves to be mentioned. This Law stipulates that Brazilian public administration may grant, to some selected sectors — such as pharmaceutics, telecommunications equipment, and so on — a preference margin up to 25% against foreign suppliers if the products/services were developed in the country. Differently, from the general case of the Law No. 8,666/1993, this preference margin goes explicitly against WTO-GPA agreement. To qualify for the benefit, the product must also be a result of R&D process carried out in Brazil. Therefore, this is a policy instrument designed not only to protect specific sectors but also to pull national technology development through the demand side.

In conclusion, it can be stated that Brazil has legal mechanisms in which the public sector can support itself for placing technological orders. However, this kind of

order represents a very small set of the total purchases made by the country's public sector, according to mapping by Rauen and Barbosa [2019] for the period 2010–2019. In addition, Brazilian Public Agents have tried to squeeze the R&D project into the legal requirements of Law No. 8,666/1993, with the use of devices such as waiver and unenforceability, and avoid a complex (and risky) procurement process. Perhaps the new wording given to Article 20 of the Innovation Law by Law No 9,283/2018 may, in fact, allow more extensive use of PCP and PPI in the country.

Petrobras: The case of the P-51

Petrobras is the leading Brazilian state-owned company, with a large share of the country's GDP [Rauen and Barbosa (2019); Severich (2016)]. The procurement policy of this National Oil Company (NOC), throughout much of its six-decade history, has been guided by strategic goals in terms of the country's development, such as the development of local suppliers [Dantas and Bell (2009, 2011)]. Moreover, it is one of the world's leading oil companies and well situated within the cutting-edge technology of deep-water projects [Ribeiro *et al.* (2019)]. Thus, we have selected a company that possesses the necessary attributes for adopting a procurement policy that induces the technological development of its suppliers.

In addition to these factors mentioned earlier, the choice of Petrobras is justified because, until recently, Petrobras' procurement policy, following the guidelines established by the National Petroleum Agency (in Portuguese Agência Nacional do Petróleo — ANP), was based on local content requirements. So, during Workers' Party (in Portuguese, Partido dos Trabalhadores — PT) governments[c], there were high local content indexes (around 80%) incorporated into the bidding of its oil platforms, both in the stages of exploration and in the development stage of this Brazilian NOC's offshore projects [Limoeiro and Schneider (2017)].

Since the main objective of this study is to clarify PCP and PPI, it was decided to choose an order that was significant from the viewpoint of its technological challenge. Ordering an oil platform fits this profile since it involves a large volume of customized equipment and services. Hence, this is fertile ground for the practice of an innovative purchasing policy, and so this study is based on an analysis conducted by Petrobras, the Semi-Submersible P-51 Platform. P-51 was auctioned in 2003, during the Luiz Inácio Lula da Silva administration, and was delivered in 2009. The local content requirements, close to 70%, were reached [Silva (2009)].

This project was divided into three parts, and which evolved through three bidding processes: (1) construction and integration of the hull and the processing/utility plant; (2) electrical generation modules; and (3) gas compression modules. The three winning Engineering Procurement Construction (EPC) contractors from this project made up the field research sample.

The hull and topside construction, topside detail engineering, and deck mating[d] solutions were undertaken in the country, which demonstrates that the Brazilian

[c]PT governments permeated the administration of Luis Inácio Lula da Silva (2003–2010) and Dilma Rousseff (2011–2016).

[d]This method, also known as floatover, "is used for a deck installation when the weight of the deck exceeds the available crane capacity. The mating operation is executed using transporting vessel which may be a flat top cargo barge or a heavy lift ship"

industry was suitably prepared to build such large structures. However, it should be mentioned that EPC activities, referring to the main components of generation and compression modules, were undertaken abroad and were not considered in the calculation of local content. These two EPC contractors achieved the local content required by Petrobras, but it is important to note that key types of equipment used in these modules were developed and manufactured outside the country and excluded from the local content calculation [Silva (2009)].

In addition to the three EPC contractors who participated in this order, 14 local suppliers also participated in the field survey. The choice of the sample largely resulted from suggestions by EPC contractors and Petrobras' respondents, who were asked about local companies with prominent participation in the P-51 project. The suppliers studied were separated into three groups: (1) construction and assembly; (2) equipment and service suppliers; and (3) engineering companies.

Interviews indicated that interaction with Petrobras staff represented one of the main learning sources for the sample companies. By providing to a user, such as the Brazilian NOC, which inspects, supervises, and monitors the activities performed by suppliers, according to most interviewees, there was an interaction that provided the acquisition of informal learning. Local suppliers that were established or incorporated into Petrobras Corporate Register were required to meet strict quality criteria.

Therefore, it may be stated that the standard of quality required by the national operator for ordered items forced local suppliers to pay special attention to quality management. One example cited by an interviewee from one of the sampled companies, to illustrate the technological contribution provided by the P-51 platform order, concerning the need to develop a welding process for new materials, such as super duplex steel since the company had not yet acquired this kind of experience. So, according to information collected in the field research, local suppliers often incorporate technological learning resulting from the need to introduce changes and their processes, as well as the products and services provided.

Despite that, the predominance of multinational EPC contractors in the Petrobras platform projects also demonstrates, on the one hand, the almost complete lack of national builders and EPC contractors and, on the other, the technological and entrepreneurial fragility of the country's industrial system. The survey revealed that the technological capability of most of the subcontractors in the P-51 project was concentrated on an operational level. Thus, the activities conducted by the sample suppliers were more closely linked to production processes that they were already able to dominate, thereby reinforcing learning-by-doing, i.e. the cumulative development of skills and knowledge through routine activities. In licensing agreements between foreign technology holders and Brazilian companies, there is no provision for technology transfer.

In conclusion, it may be stated that this NOC directed its purchases toward the domestic market, greatly contributing to the recovery of important segments of the country's oilfield equipment and service enterprises, but did not advance toward reducing the technological dependence of this sector. To create conditions to change this framework, the Brazilian government launched The Inova Petro in 2012, a partnership between Funding Agency for Studies and Projects (FINEP) and the

National Bank for Economic and Social Development (BNDES) with a total budget of R$ 3 billion (U$ 1.9 billion ppp). In Inova Petro Program was created to foster projects that cover research, development, engineering and/or technological absorption, production and marketing of innovative products, processes and/or services, to leverage the competitiveness of the country's oilfield equipment and service industry and to support the goals regarding Local Content Policy [Limoeiro and Schneider (2017)].

In fact, Decree No. 2,745/1998, which regulates the acquisitions of goods and services of the Brazilian state-owned enterprises (SOEs), does not provide for the possibility of exemption or the unenforceability of bidding for the scale supply of innovative products or services developed by Brazilian companies promoting the company. Article 20 of the Brazilian Innovation Law and Law No. 9,283/2018 could be applied in case such as these. Despite this, as already highlighted, the legal instruments provided by Brazilian Innovation Law are not well understood or accepted by most Brazilian public entities because of the aversion to the risks underlying the public procurement for innovation. Concerning Law No. 9,283/2018, its approval is recent, so it has not yet been possible to assess the effective impact of this legal framework on the practice of PCP and PPI in Brazil [Rauen (2017)].

Another point that deserves attention concerning Petrobras' procurement policy is that the power alternation in the Brazilian government may generate profound changes in the country's development model, often bringing about discontinuities and abrupt changes in the route. An example of this is that after the impeachment of former President Dilma Rousseff, a neo-developmentalism[e] model was replaced by a development agenda, largely supported by reducing the size of the state. Thus, depending on the position of the political pendulum, Petrobras, the country's largest state-owned company, may assume a set of diametrically opposite behaviors. During the Workers' Party governments, there was a significant increase in its investment portfolio, and its purchasing power was used as an instrument for inducing the oilfield equipment and service industry development [Morais and Saad-Filho (2012); Mendonça and de Oliveira (2013)]. However, with the deposition of President Dilma Rousseff, the intervention of the Brazilian state in the economic domain through this NOC has been replaced by a new logic marked by divestments and the abandonment of the local content policy [Ribeiro and Inácio Júnior (2019); Ribeiro *et al.* (2019)].

Brazilian Air Force (FAB): The case of the KC-390

The Brazilian Ministry of Aeronautics created EMBRAER in 1969 as a mixed company (partially public, partially private). The company was privatized in 1994 and pursued a new path in its strategy focussing on the civilian (regional) market. Currently, the company is one of the major airplane manufacturers in the world with leadership in regional flights. Nevertheless, the defense market is still relevant and highly connected to the demands of FAB.

[e]Neo-developmentalism, also called new-developmentalism, represents a development agenda that combines the focus on economic stability with traces of developmentalism that characterized the strategy of import substitution industrialization (model adopted in the country during much of the twentieth century) as state interventionism, which justifies the use of the prefix "neo" or "new" [Morais and Saad-Filho (2012)].

Regardless of the legal constraints associated with non-traditional public procurement (not off-the-shelf products) in Brazil, FAB has been able to bypass these problems and execute a major, risky project, the KC-390. This project aims to develop a new aircraft, designed to replace the old Brazilian Hercules C-130 fleet. This is a flagship technology order for a few reasons. The risk involved in a PCP of sophisticated, high-tech equipment is not negligible. Besides, as noted above, it is the largest aircraft ever designed and manufactured by Embraer. In addition, it is part of the National Defense Strategy (in Portuguese, Estratégia Nacional de Defesa[f]). This document highlights the need for the re-alignment of the country's armed forces and, as such, to foster the technological development of the Brazilian defense industry. It should be noted that the acquisitions made by these institutions often involve not on-the-shelf-type equipment and items, just the case of KC-390.

When FAB decided to deactivate the Hercules, there was an option to purchase the new version of this Lockheed-Martin aircraft, the C-130J. To decide between internal development and international procurement, FAB considered elements such as the investment made in both alternatives, the cost of flying the aircraft and the possibility of promoting the Brazilian Aeronautical Supply Chain. The analysis carried out by FAB on the alternatives revealed that developing a new aircraft, with the requirements it stipulated, would be of better service than acquiring the C-130J. Hence, it was decided to contract the development stage, through which two prototypes were to be produced [Ribeiro (2017)].

The KC-390 project was commissioned using a particular kind of bidding process, prescribed by Law No. 8,666/1993: the enforceability. As stated in Article 25 of Law No. 8,666, bidding is unenforceable in special cases, such as: acquiring materials, equipment, or genres that may only be supplied by a producer, company, or exclusive commercial representative; for contracting technical services of a unique nature, with professionals or firms of well-known specialization.

By avoiding the regular bidding process, FAB was able to cooperate with EMBRAER in a more flexible and less bureaucratic manner. In the ordinary process of procurement, through the bidding mechanism, there was much less dialog, and the definitions of the procurement outcomes had little or no negotiation. The regular process of acquisition established by the Law No. 8,666/1993 works reasonably well for the purchase of paper and pens but not for a non-existent airplane. For instance, Pellegrini *et al.* [2012] demonstrated, with the example of a satellite, that the use of the bidding process is entirely unfit for the purchase of an R&D service and could bring too many adverse effects, particularly for the supplier.

As in many other situations, EMBRAER was commissioned to develop the airplane. Initially, in 2008, two prototypes were ordered. At that point, after a series of tests in which the technological maturity of the product was proved, in 2014, FAB ordered 28 units of this new airplane. The project is still running, and the two prototypes are known to be in the phase of flying tests.

The KC-390 represents the largest aircraft ever produced in Latin America and was developed to operate within a variety of conditions — from the wet climate of

[f]Available at http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2008/Decreto/D6703.htm.

the Amazon to the cold of Antarctica — and perform rescue missions, air-to-air refuelling (AAR) and troop/cargo transport. The KC-390 relies on state-of-the-art technology about electronic warfare. It will also have active and passive ability against infrared missiles and armor [Pereira and Jasper (1969)], boasting the very latest flight control system and reduced operating and maintenance costs. Besides this, according to Francelino *et al.* [2019, p. 2] "*The KC-390 is the only aircraft in its category that has electronic Fly-by-Wire system, which provides greater efficiency for pilotage and integration with other missions.*" Thus, there is high optimism concerning the export prospects of the KC-390.

Despite the elements that point to the success of the program — thus far — the existence of two major problems is already evident. The first concerns the unstable federal budget allocation. Indeed, this is a recurring problem in defense programs in Brazil and, in the case of the KC-390, this constraint has strongly affected the development schedule of the program, delaying the final certification of the prototype by 18 months.

The second problem is related to the lack of a local supplier throughout the development of the KC-390. Since the program also aims to foster national development (as many other procurement programs at FAB), a higher number of Brazilian companies would be expected among the leading suppliers. So, while the country's main legislation governing public-sector procurement gives the possibility of placing technology orders, it is extremely difficult to find companies that are technologically skilled, with a tradition in R&D and positioned at the technological forefront in their niches. Thus, it is symptomatic that the KC-390 program relied on a small number of Brazilian companies among its suppliers of key items. For some of the respondents, the KC-390 could have had more national items. However, there was a trade-off: local supply brings auspicious fruits to the country (such as the creation of jobs and the technological development of its industrial park) but embodies risks and high costs.

What, on the contrary, must be taken into account is the fact that there is a high degree of manufacturing fragmentation within the high technology sectors, a situation that per se leads to a reduced national integration for such projects. So, the evolutionary pattern of the world aviation industry has changed markedly by the unbundling and internationalization of activities and responsibilities. Following the privatization of Embraer, particularly from the ERJ 145 and Embraer 170/190 families, the company abandoned its concern regarding component nationalization, as well as the mastery of technologies that were not critical to its core business. Moreover, following the privatization of Embraer, particularly from the ERJ 145 and Embraer 170/190 families, the company abandoned its concern regarding component nationalization, as well as the mastery of technologies that were not critical to its core business. Given this scenario, it may be said that there was a reduction in the financial and technological risks of Embraer projects. However, the participation of foreign suppliers/risk partners in such projects was reinforced, making it difficult to expand the Brazilian aeronautical chain [Ribeiro (2017)].

Another point that deserves our attention concerns the impacts of the budget problems of the Brazilian government on the country's defense programs. This is a

recurring problem and, specifically in the case of the KC-390, has affected the development schedule, delaying the final certification of the new product by 18 months. In order to continue the development program, Embraer was obliged to use its resources. In a recent statement, Embraer's CEO even admitted that the delay of the KC-390 had affected the sale of this aircraft to potential customers [Ribeiro (2017)].

Finally, by examining the Brazilian Air Force public procurement, it is possible to identify some similar problems such as those faced by Petrobras, like disruptions, that the political pendulum can cause. Embraer, the company responsible for the development of the KC-390, is a former state-owned company. This company was created during the Brazilian military dictatorship (in 1969), within the state-led developmental logic. Therefore, the existence of this company is the result of Brazilian state leadership and a reflection of the technological ambitions that once moved the country's development model [Francelino *et al.* (2019)].

Even after its privatization (in 1994), the Brazilian government maintained special shares of the company called "golden share," "giving it veto power over strategic decisions involving military programs and any change in its controlling interest" [Dias *et al.* (2018)]. It should be noted that former President Dilma Rousseff and her political party, the Workers' Party (PT), were opposed to the sale of Embraer, as it is a strategic company for the country, in economic and military terms.[g] However, following the impeachment of the former president, the political pendulum moved thereby modifying the approach to issues crucial to the country. As in the case of Petrobras' procurement policy, the movement of the political pendulum alters the content of the Brazilian government's strategies for the country. Under the new logic, President Bolsonaro, at the beginning of this year, approved the sale [Dias *et al.* (2018)].

Those who opposed the sale use as argument the rich it brings in terms of: (i) loss of technological capacity and (ii) national security and sovereignty. Regarding the loss of technological capacity the professor Ph.D. Barbieri in an interview [Drummond (2019)] states that the sale will imply the division of the engineering and development structure, which operates in an integrated manner between the three areas, commercial, executive and defense a very high risk of losing Embraer's remaining technological capabilities, jeopardizing the development of future technologies and products, particularly aircraft, of military employment.

Regarding the risks to national security and sovereignty, it is important to emphasize that Embraer is a Brazilian company of great strategic value in its economic, political, and military dimensions [Francelino *et al.* (2019)]. In this regard, opponents of Boeing's acquisition of Embraer claim that the Brazilian government should not have allowed such an operation, as it will represent the delivery of technological capacity, a vulnerability in terms of national security and serious risks to national sovereignty [Drummond (2019)].

[g]Available at https://www.redebrasilatual.com.br/politica/2018/02/brasil-sendo-vendido-pedaco-por-pedaco-diz-dilma-sobre-embraer/ [accessed on 12 November 2019].

4.2. *Overview of public procurement in China*

Two primary laws form the legal framework underpinning public procurement activities in China, i.e. the Law on Tendering and Bidding (LTB) [LTB (1999)] and the Law on Government Procurement (LGP) [LGP (2002)]. Although both address the issue of government procurement, the functions and purposes of these two laws are different. The first covers bids in general, on the other hand, the second represents the legal framework for the purchase of entities that receive fiscal funding from the Chinese government. However, regulating public procurement under two primary laws and led by two ministerial-level agencies does not always work in practice. For example, the definitions of key concepts could be different through different laws, and monitoring has been a major challenge given the institutional fragmentation. As a result, in practice, the boundaries and functions of LTB and LGP frequently overlap.

One consequence of the institutional fragmentation is that the size of the Chinese public procurement market was difficult to determine. Transactions are hard to track and measure across all public organizations. The Chinese Ministry of Finance (MOF) claims that government procurement expenditure in China accounts for around 3% of the GDP, whereas the European Union Chamber of Commerce in China (EUCCC) has argued that public procurement in China represents "well over 20 percent of China's rapidly growing economy" [EUCCC, (2011, p. 2)]. Recognizing the problem of fragmentation, there have been recent advances to remedy the conflicts between legal frameworks, primarily through implementation measures to support LGP and LTB. It is still early to determine the effectiveness of these implementation measures.

Being a member of WTO since 2001, although as yet not a signatory of the WTO-GPA, China has been under pressure to open up its public market. Key trade partners, especially the US and the EU, have been urging China to make an acceptable offer. Since 2007, China has made several significantly improved offers regarding openness. Nevertheless, existing GPA signatories have still found the offer unacceptable given its fundamental incompatibility in relation to legislation. One problem is the exclusion of state-owned enterprises (SOEs) from government procurement in China, which implies that non-Chinese products might be subject to discrimination when trying to enter the Chinese public market.[h] Besides these disputes related to market coverage, the abovementioned Chinese regulatory framework remains inconsistent with international traditions because it is fragmented.

Initiatives to use procurement for catching up

The use of public procurement as an innovation policy instrument was initially called for in 2006 through the MLP (2006–2020) [State Council (2006a, p. 54)]. Specifically, Article VII-3 of MLP (2006–2020) makes explicit reference to the use of this policy instrument:

- Formulate implementing regulations of the PRC Government Procurement Law to encourage and protect indigenous innovation;

[h]For a 2019 update on China's GPA accession, see http://trade.djaghe.com/?tag=china-gpa-accession [accessed on 8 February 2019].

- Establish a coordination mechanism for government procurement of innovative indigenous products;
- Government practices the first-buy policy for major domestically made high-tech equipment and products that possess proprietary intellectual property rights;
- Provide policy support to enterprises in procuring domestic high-tech equipment;
- Develop relevant technology standards through government procurement.

Following this initiative from the State Council, the National Development and Reform Commission (NDRC), the MOF, the Ministry of Science and Technology (MOST), and the Ministry of Industry and Information Technology (MIIT) issued several implementation measures, which, coupled with other innovation policies targeting specific technological sectors, formed a portfolio of policies promoting PPI. We conducted a thorough policy analysis, which identified the following policy instruments within the portfolio: (i) a routinized mechanism to conduct PPI via accrediting catalogs; (ii) signaling catalogs of equipment and other strategic technologies; and (iii) support programs for key, strategic, and emerging areas.

The first policy instrument listed above features a strong tendency toward national protectionism. A product/technology has to fulfill a set of requirements to be included in the catalogs, such as: domestic ownership of intellectual property, innovativeness, the status of being internationally competitive, reliable quality, and a certain level of readiness in terms of commercialization. Innovation agencies supervised by MOST are responsible for producing those catalogs, while financial departments supervised by the MOF are responsible for procuring products from the catalogs.

The second instrument, i.e. signaling catalogs, serves multiple functions, including guiding the directions of R&D for suppliers, as well as providing a policy justification for government agencies as to which technologies to support. Signaling catalogs initially had the clear intention of promoting import substitution, which was a cause of concern for stakeholders, such as the US-China Business Council [USCBC (2015)].

The third instrument coincided with the international policy trend to promote the development of emerging and strategically important sectors from the demand side [OECD (2011)]. This type of instrument mainly targets new technologies that are promising in addressing large challenges [Edquist and Zabala-Iturriagagoitia (2012)], especially those that the private sector or the market mechanism itself would be unable or unwilling to address.

Experience of policy implementation

Little quantitative data are available to reflect the application and impacts of China's PPI policies, primarily owing to three reasons. First, as discussed earlier, China still lacks a consistent mechanism that monitors all of the public procurement activities conducted in the country, without which, it is hard to establish a baseline for policy evaluation. Secondly, various policies have been implemented to support PPI, which not only function independently, but also interact with other policies and regulations, and form part of a broader policy mix which is very complex to assess.

Lastly, PPI policies typically impact on the demand side rather than the supply side, which signifies that their longer-term and wider implications are hard to capture within the context of a diversity of stakeholders. For these reasons, this paper can only comment on the overall experience of PPI policy implementation.

The implementation of explicit PPI policies enjoyed a high-profile start in 2006, but ground to a standstill in 2011, and the following trajectory of these policies has become ambiguous ever since. The primary cause of this policy change was conflicts with key international stakeholders regarding China's tendency to protect domestic suppliers through public procurement [see USCBC (2015) for an idea of the conflicts].

After 2011, emphasis on PPI policies in China differentiated at different levels of government and across different regions. For example, although the routinized PPI mechanism based on innovation catalogs was terminated at a national level as a response to concerns raised by the US, some regions (e.g. Beijing) still adopted a variance of this policy approach as an instrument to drive local innovation.

Regional protectionism was an issue that arose during the policy implementation process. China is characterized with political centralization versus financial decentralization across regions, and to support the local economy regions often prefer local suppliers over those from elsewhere. In this case, although China's PPI policies were *national* policies, the implementation process essentially turned them into *regional* initiatives, which were restricted to local territories and frequently caused duplicate production.

Offshore wind energy example of PPI/PCP

This case involves the procurement of turbines for the first offshore wind farm in China, i.e. Shanghai Donghai Bridge Offshore Wind Farm. For China, where the majority of the population, as well as wind resources, is concentrated in coastal regions, offshore systems avoid the difficulties and high costs of long-distance power transmission. Nevertheless, developing offshore turbines is technologically challenging — offshore turbines need large capacities in order to achieve lower average generation costs and be sufficiently robust to cope with corrosion and typhoons; construction, installation, and maintenance are also demanding, due to the complex offshore work environment.

China announced a range of policies to promote wind energy, from R&D support to PPI policies. Domestically developed wind energy products were included in the innovation catalogs, and as-yet-inexistent wind energy equipment has been one of the key products required by equipment catalogs. The immediate political factor leading to this procurement case, however, was not the PPI policies, but a government decision driven by a failed open call for imported products. Failure to obtain satisfactory products on the international market led to a decision to buy domestically made wind turbines for Donghai Wind Farm.

A local government agency, Shanghai Development and Reform Commission, organized open tendering in 2007. A joint venture by four state-owned enterprises won the operational rights of the wind farm. An initial investment of 460 million Yuan took up 20% of the total, and the remaining 80% was mortgaged from the

World Bank. The planned generation capacity for the farm was 100 MW; the planned capacity for each turbine was at least 2 MW. According to one of our interviewees, Shanghai was determined to finish the project before EXPO 2010, as "green technology" was one of the themes of the event.

The decision to buy domestic was backed strongly by top-level officials in the Chinese central government, turning this procurement into an opportunity to accelerate the development of domestic technologies as well as to save money. The joint venture adopted a restricted tendering procedure under the guidance of the NDRC. Instead of defining technical specifications, the procedure provided the supplier candidates with the freedom to choose alternative designs. Evaluation criteria included: whether or not the product and services could be delivered before EXPO, whether the product could cope with offshore circumstances and other considerations, such as price and maintenance services.

Among the competitors, the Chinese company Sinovel was outstanding, because its design and R&D progress were considered the most satisfactory, and its solution for maintenance was the most convenient for users. Furthermore, one interview suggested that Sinovel's collaboration with the Austrian turbine supplier Windtec (now part of American Superconductor, AMSC) reassured the likelihood of delivering products on time. Installation work was contracted to a Chinese marine project construction company with more than 50 years of business experience. Besides the perceived competences of Sinovel, however, an interviewee suggested that the selection of Sinovel as the supplier was somehow a result of government intervention.

By July 2010, 34 Sinovel 3 MW turbines with a designed lifetime of 26 years had been delivered and connected to the East China grid. Since it was the first offshore wind farm with a demonstration effect, Sinovel was required to provide a 5-year warranty; a specialized services group was formed to settle in the wind farm to monitor the performance of the turbines. The deal was ultimately costly for Sinovel, and its symbolic meaning (i.e. being the first Chinese supplier to be able to produce offshore wind turbines) exceeded the actual profitability.

The main outcome of the case was that China eventually had domestically produced offshore wind turbines. Our interviewee commented that the success of the first offshore project afterwards encouraged NDRC to commission more offshore wind energy projects. The overall development of the Chinese offshore wind energy industry was accelerated. A visible reduction of turbine prices down to 6000 Yuan/kilowatt in the Chinese market was also achieved in early 2011.

The deal also led to an accelerated development for the suppliers. Besides Sinovel's improved ability to produce large-capacity turbines, the supplier for construction work obtained some patents owing to the installation experience. All parties involved gained valuable practical knowledge; an initial supply chain for offshore wind farms was established; suppliers for this project afterwards enjoyed extra points while bidding for public contracts.

Tunnel engineering example of PPI/PCP

In this case, the supplier Shanghai Tunnel Engineering Company (STEC) developed an advanced shield machine prototype with the R&D support from MOST but later

encountered severe commercialization challenges. With the mediation and consumer subsidies provided by the local government, several state-owned project operators purchased 22 "Forerunner" shield machines, which led to further commercialization of the technology, as well as a reduction in the price of shield machines on the Chinese market.

A shield machine is a type of tunnel boring machine, widely used in the construction of underground and water/electricity utilities. It is usually a tailored integration of various technologies including control, electronics, measurement, and hydraulics, requiring detailed investigation into local soil characteristics. Developing shield machines for urban construction environments presents a major challenge, since any disturbance to the ground surface is strictly forbidden.

In China, the largest boring machine market in the world, the market share of imported machines was higher than 95% back in the early 2000s. Some Chinese firms produced boring machines by collaborating with international suppliers, but they did not own the Intellectual Property Rights (IPRs) for core technologies. The price of shield machines in China was very high given the low bargaining power of domestic buyers.

The supplier, in this case, STEC, was well experienced in constructing tunnels (i.e. a boring machine user) and more recently as a manufacturer of boring machines. In 1997, STEC developed a wholly domestic shield machine prototype (i.e. the components were all produced by domestic suppliers). However, it failed to perform to the required standard. According to one of our interviewees, the failure was caused by a fragile bearing made of unqualified domestic steel. Realizing that the complete domestic production of all the components of its products was unrealistic, STEC then sought to strike a balance between "domestic production" and high performance by selectively deploying domestic as well as imported components. The central government was supportive of this and lowered custom tax to encourage STEC (and other equipment manufacturers faced with the same problem) to conduct global procurement of the required components.

In September 2004, a prototype of the ø6.34m earth pressure balance shield machine, "Forerunner," with core IPRs owned by Chinese firms was produced at STEC. STEC was eager to put the product on the market. However, the underground transport operating company considered it too risky to use a real tunnel project as a testing ground, since Shanghai needed to finish most of the projects before EXPO.

Having encountered this risk aversion from key stakeholders, STEC approached Shanghai S&T Commission (supervised by MOST) with regard to this difficulty. As the Commission had already supported STEC earlier with R&D funding, it was keen to give STEC the opportunity to commercialize its technology. An official performed as a key broker, helping STEC persuade the transport department and the operating company to approve an "as-yet-unimportant" project for prototype testing. Forerunner was tested in June 2005, achieving an average daily advance of 38.4 m, slightly better than its imported counterparts whose average daily increase was approximately 31 m.

After the pilot operation was successfully conducted, STEC again approached government officials trying to promote their products on the local market before EXPO. The local government warmly welcomed the idea of procuring domestic, innovative products to prepare for EXPO. They agreed to coordinate different construction companies in Shanghai to purchase 22 Forerunner No. 2 machines.

Encouraged and supported by the local government, STEC proposed to demonstrate the use of Forerunner for at least 100 m in a real project of one of its potential users. The product performance proved to be very stable and competitive. As a result, several state-owned construction companies agreed to place their orders with STEC, which were to be delivered by May 2007. The agreed price was 20 million Yuan each, i.e. around 30% cheaper than imported shield machines with similar technology. STEC sold 18 Forerunner machines to its construction competitors and kept four machines for itself. As an encouragement policy for equipment users, the local government allocated a 2 million Yuan subsidy (10% of the price) for each machine. Two of the companies using the machine, in this case, were awarded the title of "Meritorious User of the First (set of) Major Equipment in China," which led to a higher public awareness of indigenous equipment. According to one interviewee, these 22 machines finished one-third of Shanghai's newly developed underground lines in 2007.

As a result of this procurement, incremental improvement of Forerunner's performance was achieved, including improvement in the monitoring system with a database of more than 60 million instructions derived from STEC's construction experience, and the dynamic correction system, thereby preventing the driver from making operational errors. The share of STEC machines in the local market grew to 30% by May 2011, with 41 machines being sold. STEC also won contracts from other Chinese cities and foreign markets. The expansion of STEC's business accelerated the development of firms along its supply chain.

One interviewee noted that the commercialization of Forerunner led to a 20% price reduction in the Chinese shield machine market, which indicates considerable cost efficiency for similar infrastructure projects in China.

Despite its success in the Shanghai region, STEC encountered difficulties in promoting its products to other regions, with regional protectionism being the main barrier. To break into the markets of other Chinese regions, STEC was asked to move in as a local firm, which would have been unrealistic given the high cost of setting up tunnel equipment manufacturing lines. Ironically, the supplier found it easier to get into foreign markets, where it was able to achieve contracts, providing that its products were qualified.

5. Comparative Analysis and Discussion

Brazil and China differ greatly from one another in relation to the PPI policy approaches they have selected. While Brazil set about adapting articles in relevant laws, attempting to link procurement with innovation, China, instead of seeking legislation, launched a series of policies attempting to set up systematic mechanisms of PPI implementation. In terms of policy implementation, central policymakers in

Brazil gave overall directions to PPI, leaving ample space for practitioners to interpret; China, in contrast, introduced concrete measures for practitioners to follow, although practitioners have their own way to conduct PPI flexibly. Table 1 summarizes the PPI policy initiatives taken in Brazil and China, analyzed using the framework developed by Georghiou *et al.* [2014].

From Table 1, we observe that notionally at least, Brazil and China's PPI policies covered most of the instrument types categorized in Georghiou *et al.* [2014]. There have been attempts to improve the framework conditions in which PPI operates, to set up communication channels linking supply and demand, as well as incentives to motivate public agencies against risk aversion.

However, we also observe gaps in the policy portfolio of both countries. This is in sharp contrast to the policy approaches adopted in developed countries. In European countries, major efforts have been placed into building capabilities through training schemes and good practice networks, such as the Dutch PIANOo and the European-level Procurement of Innovation Platform [Uyarra *et al.* (2016)]. This neglect of capability building proved to have severe consequences on policy implementation in developing countries such as Brazil and China because capability failures frequently undermine policy effectiveness in these contexts.

Both countries featured the explicit intention of "buying domestic" through the power of the public purse, and while this is not a new policy trick, it raised concerns from other countries, as demonstrated in the China experience. China's ambitious attempt to adopt a generic, protectionist PPI policy approach has arguably failed, marked by its termination in 2011. In the Chinese context, domestic suppliers appeared to be stronger regarding capabilities. PPI performed a role to find an outlet for new technologies developed already by suppliers, rather than stimulating the development of new technologies from the demand side. Although the Chinese tunnel boring machine supplier succeeded in developing the equipment, selling it to user companies was challenging due to the lack of trust in domestic products.

As shown in the Chinese tunnel engineering case, 100% domestic production might not be realistic or even desirable. A balance between domestic and imported components is often needed, and the key for catching-up countries is to master the core technologies to obtain bargaining power. In the Chinese cases, to an extent, PPI managed to generate the desired outcomes, such as further commercialization of new technologies, and a reduction in the price of the product. These effects, however, were largely limited to the localities rather than spilling over to elsewhere. It was found that PPI in China appeared to be mostly "adaptive procurement," which facilitated the diffusion of incremental innovation rather than "developmental procurement," which stimulates radical innovation. PPI policies have been positioned as an instrument to follow supply-side policies and support the commercialization of existing R&D outcomes, rather than a tool to trigger the creation of as-yet-inexistent solutions.

The leadership role played by key individuals as technology champions contributed to both Chinese cases. The NDRC officials in the case of wind energy and the S&T officials in the tunnel engineering were both strong advocates of domestic technologies and addressed the risk aversion of first-time users. In China, regions

Table 1. Rationales of PPI policy instruments in Brazil versus China.

PPI policy category	Instrument types	Instruments — Brazil	Instruments — China
Framework conditions	i) Introduction of innovation-friendly regulations ii) Simplification & easier access for tender procedures	i) Article 20 of the Brazilian Innovation Act, Law No. 12,349/2010 and Law No. 9,283/2018 can be considered friendly-innovation regulations ii) Missing	i) No specific regulations focusesd on innovativeness but regulations on environment and industry could serve as a complementary instrument to implement PPI. ii) Adopting e-procurement platforms; although the use of this has been restricted by the fragmentation of legal frameworks regulating public procurement in China
Organization and capabilities	i) High level strategies with which to embed innovation procurement ii) Training schemes, guidelines, good practice networks iii) Subsidy for additional costs of innovation procurement	i) Petrobras' procurement policy and the refitting of the Brazilian Armed Forces have achieved strategic policy status and, to a greater or lesser extent and with many obstacles, contemplate the importance of innovation. ii) Missing; iii) missing	i) Inclusion of PPI policy as one of the new instruments of the indigenous innovation strategy, backed with a set of high-level policy measures ii) and iii) Missing
Identification, specification, and signaling of needs	i) Pre-commercial procurement of R&D to develop & demonstrate solutions ii) Innovation platforms to bring suppliers & users together; foresight and market study processes; use of standards and certification of innovations	i) InovaPetro e Estratégia Nacional de Defesa (National Defense Strategy) ii) Missing	i) National and regional signaling catalogs which specify the technologies/solutions in great demand. ii) Demonstration/support programs for new technologies such as new energy vehicles
Incentivizing innovative solutions	i) Calls for tender requiring innovation; guaranteed purchase or certification of innovation; guaranteed price/tariff or price premium for innovation ii) Insurance guarantees	i) Preferential price margin as high as 25% for innovative solutions ii) Missing	i) Larger government procurement budget for forthcoming financial year if agencies purchase innovative products ii) Accredit innovative solutions into catalogs which then forms a reference for procurers to support innovation

Source: Authors' compilation of instrument rationales according to Georghiou *et al.* [2014] framework.

became more motivated as they saw the potential to use procurement to drive local GDP growth. Nevertheless, unintended consequences such as protectionism and duplicate production were very harmful to the country as a whole. The Chinese PPI policy approaches have arguably failed to address this problem.

The PPI cases offer important managerial and policy implications. At the managerial level, to balance the different functions of procurement as well as the different needs of all parties, the selection of appropriate tendering procedures is crucial. For example, in the wind energy case, a restricted tendering procedure was adopted to enhance dialogs between buyers and suppliers, and functional specifications instead of technical specifications were used to select offerings. This procedure left considerable room for innovation, although it might also have posed more risks of corruption. Another implication is that the role played by individuals — or innovation champions — could be game-changing. For example, in the tunnel engineering case, an official from the Shanghai S&T Commission essentially reduced the barrier for the supplier to at least showcase its products.

Concerning Brazil, based on the study presented in this paper, it is possible to say that the country's framework of laws and rules is innovation-friendly for the practice of PCP and PPI. Despite this finding, technological orders are still underused by the Brazilian public sector.

In this sense, it is worth mentioning some obstacles to the practice of PCP and PPI in Brazil. First, the striking feature of the Brazilian industry is the reduced investment in R&D. In this context, it is extremely difficult to find technologically skilled companies, and positioned at the technological forefront in their niches, to participate in PCP and PPI. It is symptomatic that in the Brazilian PCP and PPI cases, most of the technology-intensive components were manufactured outside the country.

Another obstacle to the practice of PCP and PPI identified in the Brazilian case concerns the fact that for more than a decade, the country's macroeconomic policy has been based on instruments such as primary surplus and an inflation targeting regime [Morais and Saad-Filho (2012)]. Eminently orthodox fiscal and inflationary objectives are positioned ahead of other objectives, such as the country's industrial and technological development. Moreover, and according to some authors, due to this policy, the economic crisis facing the country since 2014 has compromised the public sector accounts and, consequently, it is budget availability. This problem often affects Brazilian defense programs. In the case of the KC-390, federal government budget constraints caused a delay in the development schedule and final certification. This situation forced Embraer to disburse its resources and affected the sales campaign of this aircraft to potential customers [Ribeiro (2017)].

Also, concerning Brazil, as highlighted in this paper, the alternation of power in government can lead to profound changes in the country's development model and discontinuities in programs and strategies. Recently, the neo-developmentalist model, which had as its characteristic a stronger presence of the Brazilian state in the direction of the development of the country, was replaced by a model whose main foundation is the reduction of the size of the public sector. The movement on the Brazilian political pendulum after the impeachment of former President Dilma

Rousseff provoked the following situations: (i) Petrobras' local content policy was replaced by a new logic marked by divestments and the abandonment of local content policy [Ribeiro *et al.* (2019)] and (ii) the Brazilian armed forces' refitting process with an emphasis on local technological development no longer has the same priority status and the sale of Embraer, once ruled out by the Brazilian government, was implemented during the Bolsonaro government [Dias *et al.* (2018)]. Thus, the movement of the country's political pendulum can significantly change the importance that the Brazilian government gives to technological orders.

6. Conclusions

This paper sets out to address the research gap regarding PPI policy practices in developing countries. While there has been a much-heated debate in the developed world concerning PPI, knowledge has been very limited, especially empirical, about the use of this policy by developing countries. Another important lesson from this study is that it is mandatory that public procurement — mainly in developing world — recognizes the need for better and stronger institutions (such as the rule of law and public ethics) and also for empowered and trained organizations to avoid corruption while not blocking the use of procurement as an industrial policy.

Considering the two countries analyzed in this manuscript, China presents certain attributes, which are absent in the Brazilian case, such as the solidity of its state policy and long-term planning. On the contrary, Brazil faces several obstacles (structural and cyclical) that make it difficult to extract the full potential of technological orders. China and Brazil also have many distinctions in the way they seek to achieve technological convergence. If, on the one hand, China uses a much more systematic and articulated approach, Brazil still has to face a chronic lack of articulation. For example, in Brazil, there is still a big difference between explicit and official actions and implicit politics. From the analysis around the experiences of Brazil and China, it is concluded that economic, political, institutional, industrial, and technological conditions may vary significantly even among emerging countries, favoring or disadvantaging the adoption of technological orders.

The main implication of the research findings is associated with the need to have a scale in the use of public procurement. In other words, for technological convergence strategies, it only makes sense to employ this policy in a coordinated manner designed to solve major national problems. The Brazilian case shows that public procurement was relevant to important economic sectors, especially oil and aviation. But without a large scale and coordination, the effects will only be sectoral. The maximum effects of public procurement as a technology development strategy are only achieved when major national problems are to be solved. That is precisely what China has been doing. This is because use public procurement as a tool for technological development is expensive, complex, and risky. Its use must be associated with other instruments (i.e. grants, credit) and a larger strategy that does not end with the development of a timely solution.

As an exploratory study, this research is subject to some limitations. Our research findings are based on limited number of interviews in two large developing countries

which feature uneven development of different regions, which means that the generalizability is limited. Future research might want to continue unveiling the policy dynamics in other regional and national settings, so more generalizable findings can be derived.

Appendix A. List of Companies of Petrobras Case

Group	Firm	Year of enaction	Supplied to P-51
Oil company	Petrobras	2008 and 2009	Managing Director Exploration & Production
			General Manager of Project Management
			Project Implementation Manager for Marlim Sul
			General Manager of Exploration & Production Business Unit
			Engineering Manager
			Investment Program Executive Manager
EPC contractors	Fels Setal Technip (FSTP) Consortium	2009	Platform P-51 Project Manager
	Nuovo Pignone	2009	Platform P-51 Project Manager
	Rolls-Royce	2009	Platform P-51 Project Manager
Construction and assembly	Nuclep	2009	Manager
	Usiminas	2009	Manager
Equipments suppliers	Iesa	2009	Manager
	Ebse	2009	Manager
	Weg	2009	Manager
	Cliner	2009	Manager
	Sulzer	2009	Manager
	Siemens	2009	Manager
	Unicontrol	2009	Manager
	Elco	2009	Manager
Engineering services	Projemar	2009	Manager
	Aibel	2009	Manager

Appendix B. List of Interviews Conducted of KC-390 Case

Companies/institution	Year of enaction	Job title
Ministry of Defense	2015	Director of the Department of Defense Products (Deprod)
Coordinating Commission of the Combat Aircraft Program (COPAC)	2015	KC-390 Program Executive Management
Industrial Promotion and Coordination Institute (IFI)	2015	Technical advisor
	2015	Technical advisor
	2015	Aeronautical Product Certification Specialist

(*Continued*)

Companies/institution	Year of enaction	Job title
Embraer	2015	KC-390 Program Director
	2015	KC-390 Program Engineering Director
Eleb	2015	Manager
LHColus	2015	CEO
Ael Sistemas	2016	KC-390 Program Manager
Aerotron	2015	Director and founding partner

Appendix C. List of Interviews Conducted of China Case

Date	Interviewees' working roles	Stakeholder roles
Dec. 2010	Vice head of a department in the MOST	STI official
Dec. 2010	Director of an office in the High-tech Department in the MOST	STI official
May 2011	One of the officials serving as key coordinator of PPI in MOF	MOF official
May 2011	One of the vice directors of the NDRC promoting PPI agenda	NDRC official
May 2011	Head of strategic planning office in MIIT	STI official
May 2011	Deputy director of key projects office, MOST	STI official
May 2011	Vice head of the central planning department, MOF	MOF oficial
Dec. 2010	Head of one office in Shanghai S&T Commission	STI official
Dec. 2010	Head of one office in Shanghai Commission of Economy and Informatization	STI official
May 2011	Vice head of one office in Shanghai S&T Commission	STI official
May 2011	Vice head of one office in Shanghai Commission of Economy and Informatization	STI official
May 2011	Chief engineer of an underground construction company	Procurer
May 2011	Chief engineer of Shanghai Tunnel Engineering Co. Ltd.	Supplier
Dec. 2011	A researcher on the topic of PPI in a university in Shanghai	Researcher
Dec. 2011	A researcher from China Academy of S&T for Development (CASTED)	Researcher
May 2012	A researcher/project manager in the area of PPI	Researcher
June 2012	A researcher in the area of PPI	Researcher
May 2011	One manager from Shanghai Donghai Wind Power Co. Ltd.	Procurer/user
June 2011	One manager from Sinovel Co. Ltd.	Supplier
May 2011	An engineer at Shanghai Donghai Wind Power Co. Ltd.	User

Appendix D. List of National Laws and Regulations Governing PPI in China

Title	Year of enaction	Key role
Law on Tendering and Bidding (LTB)	1999	Defines key issues related to bidding and contracting in China, regardless of the nature of purchasing body
Law on Government Procurement (LGP)	2002	Regulates the procurement activities of entities that receive fiscal funding from the Chinese government

(*Continued*)

Title	Year of enaction	Key role
National Medium- and Long-Term Program for Science and Technology Development (MLP) 2006–2020	2006	Article VII-3 makes explicit linkage between procurement and indigenous innovation for the first time
Implementation Measures of the MLP 2006–2020	2007	Formed a comprehensive portfolio of detailed measures promoting PPI, concerning bids evaluation, budgeting, contracting and special cases, etc.

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