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The effect of local content requirement on oil and gas exploration in Brazil

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1. Introduction

Natural resources normally give rise to huge economic rents as the gross sales income surpasses investment and production costs. Such gift from nature, and OPEC cartel pricing, can be either a blessing or a curse for the country that discovers oil. The windfall gains give the population an opportunity to consume and invest more than they their labor and capital normally produce. On the other hand, different groups in the population might divert their effort from productive to unproductive and even violent destructive competition in order to acquire this resource rent. Furthermore, the country might choose less productive policies both in the short and long run as a result of the inflow of resource rents.

Nigeria is riddled with corruption from oil or the many violent conflicts over diamonds and minerals tearing Congo apart are typical examples. However, also developed economies with strong institutions risk making policy choices that lead to suboptimal development paths in the future. Income from natural gas in the Netherlands in the 1960s led to wage increase and the demise of the former industry that could not compete. When the gas fields were empty, unemployment rose sharply as there were no industry left in Holland to employ them. Even Norway is criticized for using the large petroleum income to maintain an unproductive structure of society and government services, e.g. keep large rural population rather than centralize and urbanize, with low competitiveness if petroleum income runs out.

Natural resources is the major source of income in the Latin America economy. The rent from oil, gas, minerals, agricultural land and other natural gifts constitutes a large share of the GDP. In some countries like Venezuela it has led to high level of corruption, conflict and mismanagement that impede other sectors of the economy to grow and employ people. In others like Peru, the mineral sectors has led to considerable investments and secondary employment, but more importantly redistribution through efficient taxation spend on social programs, infrastructure investment and public services.

What about Brazil? How do the huge discoveries of oil and gas offshore benefit the population. The corruption scandals in Petrobras, a New York Stock Exchange (NYSE) listed oil company with the Brazilian state as majority shareholder, made illicit contributions to individual politicians and parties and hence distorted the political equilibrium. However, more important than the

possible diversion of income is how state regulations influences the structure of the industry, costs and extraction volumes that decide private as well as government income from oil and gas.

The local content requirement is probably one of the most relevant regulations in Brazil for that matter. The oil company consortiums with the right to explore and produce on specific oil and gas fields must demonstrate that a certain share of services and equipment is delivered by companies registered and producing in the country. This share differs between fields as the minimum requirement has differed over time and the oil companies can furthermore offer bids higher than the minimum mandatory requirement in order to obtain exclusive rights to explore and develop oil and gas fields. The main idea is to force the development of a national petroleum supplier industry that otherwise would not take place or be outcompeted. Such policy could lead to higher economic efficiency if it cancels market inefficiencies, e.g. positive externalities for the society. However, the local content requirement could also create negative externalities like withdrawing skilled workers from other sectors that must hence reduce their activity. Resulting inefficiencies could come from a mismatch between the capacity of local industry and the demand from companies willing to explore available resources, leading a slower exploration pace and, consequently, reduced annual oil and gas production volumes. Reduced total income might be more serious than the effects of redistributing the resource rent from oil companies and the state to equipment and service providers.

In our econometric analysis, we take advantage of this variation of the local content requirement between fields, resulting from differences in the tender rules over the years and the actual offer of the winning bid in each field. The oil and gas consultancy Geopost has compiled information at block, field and well level both on- and offshore in Brazil from state institutions, oil companies, newspaper articles and all other sorts of information sources. The information is shared interactively with paying customers in a graphical interface. With their permission, this team of researchers have compiled the statistics into a dataset for analysis in Stata program. It is hence possible to link all three levels of analytical interest into one common econometric model. The database does not hold any information on actual production costs or profitability for each field, the production structure of the suppliers or competing industries that might lose out to the oil service providers. We hence choose a more narrow approach of estimating the effect of local content on exploration phase as is it not possible to measure the optimal time path for the production

itself. The shorter time between signing the contract with the state on a given field and an economically viable discovery of oil, the more efficient we assume the company has been in the exploration phase. The company have to train personnel who are mostly Brazilians and apply infrastructure that has often to be built. Many things can go wrong in the operation, as they also often do. The big question is hence, does errors and delay happen more easily when a large share have to be supplied by the local industry rather than brought in from operators abroad with a long experience in the petroleum sector. However, we have to be aware that LCR is less stringent in the exploration phase compared to the production phase. We have no relevant indicator for efficiency for this phase and can hence not analyze efficiency here.

2. Local content regime in Brazil

The local content regulations in the Brazilian oil and gas sector (hereafter LCR) It is a classic protectionist strategy to promote infant supply industries, and a way to strengthen backward linkages in sectors based in the exploration of natural resources.[1] Due to the distorting market effects they produce, LCR instruments are strongly condemned by advocates of free trade.[2] Nonetheless, LCR were paradoxically implemented in 1999 during Cardoso's government – the same government that had promoted a dramatic liberalization of the Brazilian oil and gas sector.

Brazil, although a WTO member, did not sign the separate Agreement on Government Procurement (GPA) and is hence not restricted in the grey area of international trade since LCR is implemented as a clause in the concession agreements signed between the federal government and oil companies. Brazilian authorities argue that concessions given to oil companies are a type of government procurement and are not subject to restrictions from the WTO general agreement.[3]

There are two opposing views about industrial policy in general and the role of LCR in particular. On one side we have an *inward-looking* perspective that sees LCR mostly as a tool to generate jobs and contribute to the industrial diversification of the country. According to this perspective,

[1] Helge Ryggvik, "A Short History of the Norwegian Oil Industry: From Protected National Champions to Internationally Competitive Multinationals", *Business History Review*, 89 (Spring 2015), 3–41.
[2] Gary C. Hufbauer and Jeffrey Scott, *Local Content Requirements: A Global Problem* (Washington, DC: Peterson Institute for International Economics, 2013).
[3] Another part of the argument is that the LCR clauses in Brazil do not discriminate between national and foreign-owned companies. Under Brazilian law, a company is considered local if it is registered in the country, no matter the origin of its controllers.

LCR will maximize domestic output through securing demand as "everything that can be produced in Brazil must be produced in Brazil."[4] This perspective finds support in the long tradition of Brazilian developmentalism and its emphasis on self-sufficiency (e.g., with oil and its byproducts) and nationalization of manufactured goods (e.g., automobiles) that was evident during the ISI period.[5]

The more *outward-looking* perspective sees LCR as a temporary strategy to help domestic firms overcome initial hindrances in the international competition, e.g. make foreign oil companies chose new domestic suppliers over traditional suppliers which whom they have interacted earlier. This outward perspective was dominant among policymakers of Cardoso's government, particularly at the National Agency of Petroleum, Natural Gas and Biofuels (ANP). For them, LCR was a tool to create incentives for foreign oil companies to include competitive domestic companies in their supply chains, particularly in activities deemed as strategic (i.e., engineering activities).[6]

The LCR is part of the auction system for the public auction of blocks both off- and onshore in Brazil. The system has evolved and differs over time since the introduction since the first round 0 in 1998 that was actually formalization of current rights in the new system and is not included in our analysis.

Figure 1 - Evolution of Local Content Rules

Rounds 1-4 (1999-2002)	Round 5-6 (2003-04)	Round 7-13 (2005-present)
• No minimum offers required • Incentives for specific activities • self-declaration by suppliers	• Minimum offers exploration/development • No incentives for specific activities • Self-declaration by suppliers	• Minimum and maximum offers in each phase • Minimum required in specific equipment/services by phase • Third-party certification

[4] This is the motto of the Program of Mobilization of the National Industry for the Oil and Gas Sector (Prominp) established by President Lula in 2003.
[5] Kathryn Sikkink, *Ideas and Institutions: Developmentalism in Argentina and Brazil* (Ithaca: Cornell University Press, 1991).
[6] James Barlow. "Innovation and Learning in Complex Offshore Construction Projects", *Research Policy*, 29 (August 2000), 973-89.

In round 1-4 there were no minimum level of local content required. However, the companies still made bids in the auction by offering both local content and signature bonus. LC was a share of the total expenditures by the company, and these could choose where to use national citizens and products. As the LC level was rather low, the policy did not necessarily lead to more Brazilian than what would have been the result of a non-regulated market. The companies would probably have employ national citizens as back office, seamen and services in general anyway.

The LC offer increases sharply in round 5 and 6 as minimum requirement are introduced. These are still only shares of total value added, and the companies controls whether they comply with the contracted obligations or not as in round 1-4. The ANP request an quarterly investment and expenditure report by the companies in which they report the local content of their own efforts and input suppliers. The incentives for specific activities as given in round 1-4 are cancelled.

The fierce competition in the auctions led many companies to bid more LC than they could actually realize. The government hence introduces also a maximum offer for each phase of the operation. Furthermore, the minimum requirements now differs between different activities rather than to leave the decision to the companies. And most importantly, self-reporting by the companies on the LC use is now substituted with independent third party certification. However, the external audit applies only investment and expenditures used on fields from round 7. The self-reporting system was part of the previous contract and can hence not be changed retroactively if the government induces new regulations. This applies also at the supplier level, e.g. the shipyard will self-report if they sell a drilling platform that will operate in a field from round 1-6 and acquire third party certification if it will operate in a field from round 7-13. The same applies in theory to the sub-suppliers, e.g. steel plate producers, but it is unknown how they can differentiate in practice.

LCR policy in Brazil has its roots in the broader Import Substitution Industry (ISI) model adopted by the country during the second half of the twentieth century. In particular, the Tariff Law of 1957 known as "National Similar Law," that establish tariffs on all imported goods that was produced in the country and furthermore introduced tax exemptions for capital goods that were necessary to industrial sectors.[7] Petrobrás has since its inception in the 1950s been considered a key agent for the development of national industry and has strived to build suppliers of goods, services, and labor in Brazil, following the backward linkages model successfully adopted during the country's

[7] Sikkink, 142–3.

development of an auto industry. Even though it had a monopoly over oil exploration and production in the country until the late 1990s, Petrobrás was more interested in downstream activities through developing refineries and the petrochemical industry than upstream deliveries into it's production.[8]

The perspective changed after discovery of offshore fields in the Campos Basin during the mid-1970s, but Petrobrás was allowed to freely import equipment to develop offshore fields during the 1980s as local suppliers did not have drilling or offshore technology and the country preferred a rapid expansion of the offshore activity.[9] Neither did potential suppliers at the time develop their capacity to supply the offshore market as for example the shipyards had sufficient orders from the merchants fleet and did only show interest for the new sector when the traditional demand dried out in the 1990s.[10] At the same time Petrobras started to purchase from local suppliers due to lack of hard currency resulting from the foreign debt default in 1987. However, this was rather simple technology on blocks on shallow waters. The new fields located around 1,000 meters underwater imposed considerable technological and operational challenges and Petrobras rather contacted international oil service companies. As one director of Petrobrás said: "Traditionally, when we have a technological or operational challenge we look for the best companies in the world to help us find a solution."[11] During the 1990s local content in the acquisition of floating production units (FPUs) ranged from 35 to 52 percent when built in the country, and from 1 to 19 percent when made abroad.[12] However, due to the increased importance of the

With the consolidation of Petrobrás as an important global offshore oil producer beginning in the mid-1990s, and the steady growth of confirmed oil reserves along the Brazilian coast, the upstream segment began to acquire a renewed importance. Both business sectors and policy-

[8] Laura Randall, *The Political Economy of Brazilian Oil* (Santa Barbara, CA: Praeger Publishers, 1993).
[9] Presidência da República, "Decreto-lei no. 1703" (October 18, 1979). Accessed June 6, 2015. http://www.planalto.gov.br/CCiViL_03/Decreto-Lei/1965-1988/del1703.htm. For the prioritization of oil production by the Brazilian government, see República Federativa do Brasil, *III Plano Nacional de Desenvolvimento 1980–85* (Brasília: Secretaria de Planejamento, 1980).
[10] Alcides Goularti Filho, "Presença e Ausência do Estado na Trajetória da Indústria da Construção Naval Brasileira: 1959–1989 [Presence and Absence of the State in the Trajectory of the Brazilian Shipbuilding Industry: 1959-1989]", *Nova Economia*, 24 (May 2014): 445–470.
[11] Interview with the authors, Rio de Janeiro, November 14, 2014.
[12] Eloi Fernández y Fernández and Oswaldo Pedrosa, "A Petrobras e o Conteúdo Nacional [Petrobrás and the National Content]", *Brasil Energia* (October 1, 2003).

makers agreed that offshore activities represented a key sector for the future industrial development of Brazil, giving rise to a renewed interest in introducing an LCR.

3. Experience with the local content regime

The activity within the oil and gas has increased considerably, but it is difficult to establish the exact number of jobs created by the local content requirement. Local supply and job hires would probably have taken place as the oil exploitation and production increased in the 2000s. Furthermore, the Brazilian Institute of Geography and Statistics (IBGE) does not split the production by destination in their statistics and hence we do not know which sector demands a given type of capital good or service. However, the shipyard industry is now mostly delivering to the oil and gas sector in Brazil and the number of employees reflect the surge of jobs partly duetot the local content requirement, see table XX below

Figure 1: Shipyard employees by federal state, end of year with exception of 2016 in June. Source: http://sinaval.org.br/empregos/

The shipyard employment peaked in 2014 with 82.000 employees, but decreased sharply afterward due to falling oil prices and the current unsolved corruption investigation of Petrobras and their connection to politics which hinders new investment decisions. For 2015 the number of employees dropped to 57,000 employees end of year 2015 and further to 43,000 in June 2016, implying every second employee has lost his job.

LCR has some deficiencies as a regulation tool. First of all, our sources indicate it is possible to manipulate the balance sheets to satisfy the requirements to some degree. Secondly, although hypothetical, it creates a possible temptation for the certification agencies to request bribes from non-complying companies. Thirdly, although many companies actually did not fulfill the contracted local content obligations the sanctions imposed were not severe. Our dataset indicate a very low pay of fines, only 22 incidences paying on average 2 million Reais or 620.000 USD at currency rate of today. The pending fines that might, or might not, be requested in the future. The resulting insecurity is negative in itself, and furthermore create an opportunity to claim bribes for not issuing the fine.

The increase in demand from the oil and gas sectors is not just regulated by the local content for the oil sector. Transport ships require that the majority of the officers to be national citizens even institutional bottlenecks prevent the training of the needed number. The hard competition for sea officers has inflated their wages well above the Norwegian level. It is known that companies also hire sea officers from other Latin American countries and it is unknown whether these actually enters as local content or not.

4. Geopost database of ANP figures

Information is vital for all actors in the oil industry. When interested oil companies want to give a bid on state auctions for fields they will estimate the probability of finding oil based on geological information. Companies like GeoPost does not only offer existing seismological information on the field to their customers, but also compile all types of historical data relevant on costs, operators and the operation of current exploitations. Most of the information in this dataset comes from the National Petroleum Agency (ANP) of Brazil that publishes their numbers in a more decentralized manner. However, GeoPost normally share this information with paying customers through a graphical interface. By transferring the information by variables in a spreadsheet, we are able to conduct quantitative econometric analysis which is hence a novel way to present the data.

As we are interested in measuring the effects of LCR policy, we included only fields discovered from the first bidding round of concessions in 1998 – excluding fields from the so-called "round 0". The summary of all field variables are found in Table 1 in appendix. The main dates for the different part of the operation are given and we were able to calculate the time it takes from the

company and the state sign the contract (T0) to discovery (T1), commercialization (T2) and production (T3). The mean average numbers of days are, respectively, 1329, 2012 and 2224 days or 3.7, 5.6 and 6.2 years. However, only 85 of our 133 field operations are producing while 132 fields were actually declared commercial viable by the operating company. This implies that production does not necessarily start on a commercially viable field. One reason might be that the company does not have the capacity or interest in exploiting all commercially viable fields and put some on the waiting list for production later.

Of the 133 fields registered, 38 are offshore and 95 onshore. Most of the offshore fields originated from concessions awarded during the second bidding round in 2002 and the special handout without auction from the state to Petrobras in "Cessão Onerosa" that took place in 2010. The only pre-salt field in the dataset is the Libra field in the specific "Partilha" auction. Later auctions of pre-salt fields are not included the dataset as round 11 and 12 in 2013 were on rather small fields and the last round 13 in 2015 had not resulted yet in major discovery.

Not complying with the local content requirement should induce a fine for breaching the contract. Such happened in 22 of the 133 fields, but the average payment of 200,000 Reais (80,000 US dollars) in these cases was rather small. Even the absolute maximum fine given is only 8 million Reais (less than 3 million USD) is minimal compared to the heavy investment in the oil industry. The treat of implicit punishment through the loss of state confidence and prospects of winning future bids is probably a more disciplining.

The local content offer by the winning bid in the auctions for each block is partly influenced by the minimum requirement set by the state in each round and what each bidder expect others to offer. As competition is expected to be harder, companies must bid higher local content offers in both exploration and production to win the auction. However, the companies must also offer sign-on bonuses to the state. Only in the pre-salt field in the Partilha round does the company similarly have to offer a percentage of net profits from the field in a sharing agreement with the state. None of these two other dimensions are included in the analysis. We can observe that what the companies offered of local content. However, the rules and requirements change between the rounds. From round 1 to 4, companies only had to give a flat offer for each of the two main categories, while in subsequent rounds they had to give offers for different parts of the operation. In round 5 and 6 the companies had to specify for data acquisition, data interpretation, drilling, detailed engineering and

development, although the figures are about 20 percent local content for all of them (variables lco_* in table 1)

The local content offer for both the exploration phase and the production phase differs over time. The local content rises sharply in round 5 and 6, before it somewhat drops a bit later probably due to demonstrated difficulties in being able to actually implement the high local content offered (see table 2). The level differs furthermore considerably between fields onshore/land and offshore/sea as the average over all rounds and types is 84 percent for the former and 53 percent for the latter. The two modes of natural resource exploitation are very different. Transport, pipelines and simple drilling equipment is the major need onshore which can be supplied competitively by Brazilian firms, while large technological sophisticated drilling platforms, seabed installations and seagoing vessels are needed offshore. The former shipbuilding industry was in decay and the Brazilian industry was not very innovative and hence not in the forefront of technological development. The idea was hence to learn and adapt know-how of the oil industry through forcing the international oil industry to produce the equipment in Brazil and employ Brazilian labor.

Petrobras is definitely the most important oil company in Brazil. Although listed on NYSE, the Brazilian state as the majority owner implies that the regulating authorities give the company a special treatment. It is the operator on nearly 60 percent of all fields, and even higher with nearly 70 percent of the fields offshore (table 5 in appendix).

5. Econometric analysis

The Brazilian authorities were well aware that the Brazilian industry would have difficulties in supplying the infrastructure that especially the offshore petroleum sector would need when they introduced local content offers as part of the auction. However, initial delays and higher costs would be compensated by the development of a national oil and gas industry which would give high income and employment in the country and furthermore secondary effects as the know-how would pass to other national industries over time.

We hence expect that higher local content would lead to inefficiency in the short and medium term. One effect would be to delay exploration and production as it would take longer time to provide the equipment and infrastructure building as well as train labor and service providers in Brazil rather than buy them from leading international producers. The willingness to forego income and

endure problems in the short run is expected to be compensated by higher inland production and income as the Brazilian supply industry become more efficient over time. This improvement in efficiency should furthermore give fewer delays in the exploration and production phase over time. We approximate such learning and supply marked development effect by a variable of years since round zero in 1998. We also expect that local content requirement should have less negative effect as suppliers become more efficient, and we hence include an interaction effect between local content requirement and years since round zero.

The level of local content is negatively correlated with drilling at sea, -0.69 for exploration and -0.75 for production. Whether offshore or onshore should furthermore have a direct effect on the time spent in exploration and production, and is hence included as a control variable in the econometric model. Control variables included for technical difficulties that should furthermore delay the process is furthermore *Depth to seabed*, e.g. shallow waters should be easier to explore and drill and hence take less time, and the economic importance of the field approximated by the quality of the oil found in the *API index* with a higher value for lighter and more valuable crude oils. Finally, we also control for whether Petrobras is the operator of the field or not. We expect they would use more time as the company is the operator in several fields and must often prioritize which ones to explore and produce first. However, time might also reflect the efficiency of the company as an operator compared to other oil companies whether private Brazilian or international.

The winner of the auction starts their activity on the block after signing the contract with the government (*signature*). After exploring, they hopefully find oil and gas (*discovery*) and then later declare the official start of the commercial production (*production*). The local content requirement for exploration should affect the efficiency all the way to declaration, and both the number of days between discovery and signature (*daydissig*) and production and signature (*dayprosig*) are relevant indicators to use as dependent variable measuring efficiency in the operation. We do not possess any relevant indicator for the efficiency in the production phase, e.g. units of production per year, days of standstill, etc. or costs in the production phase and we can hence not conduct an analysis using the information on local content requirement in the production phase.

Exploration days	Coeff.	S.Err.	t	P>t	95% Conf.	Interval
LC exploration	-26	8	-3,52	0,001	-41	-12
Years	-325	60	-5,44	0,000	-444	-207
LC - years interaction	3,4	1,1	3,11	0,002	1,2	5,5
Depth	0,4	0,1	3,96	0,003	0,1	0,7
Sea	-11	214	-0,05	0,958	-436	413
API	14	5	2,75	0,007	4	25
Petrobras	242	113	2,14	0,034	18	465
Constant	2948	478	6,17	0,000	2002	3894

Table 1 Full sample: Days between block signature and discovery of oil/gas (#days) as dependent variable explained by local content in exploration, years and the interaction of the two, depth to seabed, oil quality API indicator and a dummy for Petrobras as operator. Data set of 119 on- and offshore fields, F(6,22) 22.3397, Prob>F 0.0000, R2 value 0.5847, R2-adjusted value 0.5585 and Roots MSE 552.7

The OLS model in table 1 above has a remarkable high explanatory power with R^2 value 0,58. The learning effect is clearly negative as expected since projects in later rounds takes less time between signature and finding oil/gas. However, the effect of the local content requirement is contrary to expected as it is significantly negative. However, the coefficient for the interaction effect between local content and years is significantly positive and the effect is hence reduced over time. A similar model without the interaction effect reduces the LC exploration coefficient from a significant -26 to an insignificant -6 (see table 6 in appendix). The joint effect of LC exploration and interaction effect turns positive after 8 years and increases to 22 in the final year of the dataset. The deeper sea, the significantly longer time and the more heavy crude oil with high API make the companies use more time in the exploration phase. The coefficient for the Petrobras dummy as operator is positive and significant and will retard the process by about 8 months.

Exploration days	Coeff.	S.Err.	t	P>t	95% Conf.	Interval
LC exploration	-14	24	-0,58	0,57	-63	35
Years	-435	167	-2,61	0,02	-782	-89
LC - years interaction	5,46	4,23	1,29	0,21	-3,31	14,22
Depth	0,44	0,30	1,50	0,15	-0,17	1,06
API	6	24	0,24	0,81	-44	56

Petrobras	550	666	0,83	0,42	-832	1932
Constant	2544	1109	2,29	0,03	244	4845

Table 2 Sea sample: Days between block signature and discovery of oil/gas (#days) as dependent variable explained by local content in exploration, years and the interaction of the two, depth to seabed, oil quality API indicator and a dummy for Petrobras as operator. Data set of 29 of offshore fields, R2, F(6,22) 7.97, Prob>F 0.0001, R2 0.6848, R2-adjusted 0.5988 and Roots MSE 717.66

There is a large difference between exploration on land and sea. The more sophisticated technologies and investments requirements are at sea, especially deep waters, in which the local content requirement is expected to boost technological progress the most. The estimated coefficients from OLS model for only offshore fields are given in table 2 above. The number of observations is reduced to 29 and the dummy for offshore operation become redundant. Few degrees of freedom increases the 95% confidence interval for coefficients and now only the learning effect is significant through the negative coefficient for *Years*. The estimated coefficients are more or less in the same range as for the full model, although the joint LC exploration effects turns positive only after as soon as 3 years and in a model without interaction effect the coefficient for local content is positive, although not significant.

The simple OLS regression give biased estimates of the coefficient if there is an reverse causation between our dependent variable *Exploration days* and the explanatory variable *LC Exploration*. If the companies can foresee difficulties in exploration, for example from geological data, and hence a more expensive and time consuming exploration phase, they might reduce the local content offer accordingly if such represents higher costs in order to compensate for lower profitability of the block. Then Exploration days and *LC Exploration* are negative correlated by inverse causation. We can correct for this bias if we instrument *LC Exploration*, e.g. "substitute" with a variable that is (i) correlated and (ii) has no independent effect on the dependent variable Exploration days.

There dummies for the four different institutional regimes for local content by round 1-4 (*d1*), 5-6 (*d2*), 7-13 (*d3*) and others Partilha and Cessa Onerosa (*d4*) as explained above in which amongst other the minimum required local content differs as explained above. The main difference between these round categories is the importance put on local content, not the signature bonus offered. It the latter fluctuates proportional to local content, the independent effect would be appropriated by that variable and these dummy variable for local content round regimes a valid instrument for the winning local content bid. However, different instruments has to be applied if we want to include more than one instrument in the regression model. Such several valid instruments does not exist,

we cannot interact interacted with *Years* as in table 1 and 2. We hence first runs a simple OLS without interaction (table 6) and then use a 2SLS instrument approach in which a OLS model first estimates *LC Exploration* (table 10 in appendix) as dependent of the round dummies and other controls, and these estimated *LC Exploration* values enters as an explanatory variable to estimate Exploration days (table 11). When valid instrument, there are no reverse causation effect bias on the estimated coefficient for *LC Exploration.*

We find that the estimated coefficient is increases from a nearly significant -6 (table 6) to an very insignificant -4 (table 10) when applying the instrumental variable the method. Similarly in the sample of only fields at sea, the effect increases from 12 (table 7) to 17 (table 13) although none of them significant due to the low number of observations.

The alternative way of measuring exploration days would be from signature to declaration of commercialization, hence more days than to discovery. To compare with instrumentalization, we run the regressions without interaction variable. The coefficient for *LC Exploration* is then a just significant -9 for the full sample, which is reduced to an insignificant -5 with instrument variable. Similarly applies to the sea sample where the coefficient increases from 18 to 28, both significant values.

6. Conclusions

Learning effect is significantly positive as later rounds uses less time to explore before discovery and declaration of commercial viability by the company.

Local content actually speeds up the process the first years, then retards the exploration effect afterward. Possible explanations is that the higher local content requirements came in round 5 and 6, not early in round 1-4 in which such was only a voluntary commitment by the companies.

Petrobras uses more time than Brazilian and international companies in the exploration phase until discovering oil and declaring such commercially viable.

7. References

8. Appendix

Table 3: Descriptive of field variables

Variable	Description	Obs	Mean	St. dev	Min	Max
namefield	Name do the oil field					
shortname	Short name of the field					
stage	Stage of the field					
product	Primary type of product					
depth	Depth to sea bed, #meter	133	337	740	0	2266
bassin	Geological Bassin					
block	Exploration concession code block					
block2	Exploration concession code block					
block3	Exploration concession code block					
block4	Exploration concession code block					
block5	Exploration concession code block					
block6	Exploration concession code block					
block7	Exploration concession code block					
block8	Exploration concession code block					
block9	Exploration concession code block					
block10	Exploration concession code block					
block11	Exploration concession code block					
block12	Exploration concession code block					
block13	Exploration concession code block					
block14	Exploration concession code block					
block15	Exploration concession code block					
block16	Exploration concession code block					
block17	Exploration concession code block					
block18	Exploration concession code block					
block19	Exploration concession code block					
location	Location of the field					
tobereturned	Total number of wells in the field	133	2,51	5,91	0	46
weltot	Number of wells in field, #	124	6,23	9,79	1	63
api	Quality of oil indicator API, inverse	120	31	10	11	56
date_com	Commercial viability, date	132				
area	Area of field, #km2	133	60	163	0	1523
d_pro	Field producing , dummy	133	0,64	0,48	0	1
date_pro	Date for the official production	85				
date_sig	Concession contract signature, date	133				
date_dis	Date of the discovery of the field	133				
date_dev	Date of field returned to ANP	2				
consortium	Consortium who owns the field					
operator	Company who operated the field					
lco_expl1_4	LC offered exploration (1-4)	133	0,92	5,20	0	35
lco_dev1_4	LC offered development (1-4)	133	0,85	4,45	0	30

lco_dacq5_6	LC offered data acquisition (5-6)	133	0,17	0,37	0	1
lco_int5_6	LC offered data interpretation (5-6)	133	0,19	0,39	0	1
lco_dri5_6	LC offered drilling (s 5-6)	133	0,18	0,36	0	1
lco_dete5_6	LC offered detailed engineering (s 5-6)	133	0,20	0,40	0	1
lco_dev5_6	LC offered for development (s 5-6)	133	0,19	0,38	0	1
min_explo7_11	Minimum Exploratory offered (s 7-11)	133	1069	1947	0	9980
lco_exp7_11	LC offered exploratory phase (s 7-11)	133	1,50	9,74	0	80
lco_dev7_11	LC offered development phase (s 7-11)	133	1,60	10,35	0	85
fine	Fine paid, dummy	133	0,17	0,37	0	1
value_fine	Value of fine, all	133	203964	897973	0	8E+06
value_fine	Value of fine, if fined	22	1E+06	2E+06	3063	8E+06
roucon	Round of concession of the main block	133	8,79	10,63	1	44
roucod	Field acquire, round	133	2,27	1,01	1	5
lcexp	LC offer in exploration, %	133	66	22	5	100
lcpro	LC offer production, %	133	75	19	20	100
d0	Round 0, dummy	133	0,00	0,00	0	0
d1	Round 1-4, dummy	133	0,31	0,46	0	1
d2	Round 5-6, dummy	133	0,20	0,40	0	1
d3	Round 7-11, dummy	133	0,41	0,49	0	1
d4	Round cessao onerosa, dummy	133	0,08	0,26	0	1
mar	Sea, dummy	133	0,29	0,45	0	1
petrobras	Petrobras operator, dummy	133	0,59	0,49	0	1
resource	Resource in field, type	133	2,03	0,46	1	3
oil	Main product is oil, dummy	133	0,79	0,41	0	1
gas	Main product is gas, dummy	133	0,09	0,29	0	1
other	Not oil/gas, dummy	133	0,12	0,33	0	1
date0	Start, year	133	14097	0	14097	14097
date1	Start LC, year	133	16071	0	16071	16071
dayexp	Time from contract to first oil, #days	132	1342	809	148	5176
daypro	First oil to production, #days	83	1024	616	41	3000
daytot	Contract to production, #days	85	2224	1005	464	4598
yea	From round zero to contract, #years	133	6,50	3,10	1,13	15,33
d	Before LC requirement, dummy	133	0,62	0,49	0	1
d_yea	After LC requirement, # years	133	5,22	4,44	0	15,334
d_lcexp	After LC exploration start, dummy	132	619	591	0	2757
d_lcpro	After LC production start, dummy	83	492	575	0	1981
lcexp_yea	LC exploration and year interaction	133	442	236	6	859
lcpro_yea	LC production and year interaction	133	504	246	23	913
dayprosig	Production and signature, #days	85	2224	1005	464	4598
daydissig	Discovery and signature, #days	133	1329	820	-405	5176
dayprodis	Production and discovery, #days	85	998	631	-95	3000
dayprocom	Production and com, #days	85	332	438	-373	2188

daycomsig	Com. and signature, #days	132	2012	988	434	5218
daycomdis	Com. and signature, #days	132	675	549	-766	2832

Source: GeoPost data set compiled from ANP

Table 4: Round of concessions of the main block

Round	Year	Land			Sea			Total		
		Fields#	LCexp%	LCpro%	Fields#	LCexp%	LCpro%	Fields#	LCexp%	LCpro%
1	1999				1	5	20	1	5	20
2	2000	11	50	70	11	38	35	22	44	52
3	2001	3	50	70	2	20	30	5	38	54
4	2002	15	54	72	0			13	54	72
5	2003	7	92	92	3	43	78	10	77	88
6	2004	16	98	100	1	70	85	17	96	99
7	2006	29	80	85	2	55	65	31	78	83
9	2008	10	80	85	7	55	65	17	70	77
10	2009	4	80	85				4	80	85
Cessa Onerosa	2010				10	37	59	10	37	55
Partilha	2013				1	37	55	1	37	55
Total		95	75	84	38	41	53	133	65	75

Table 2: The number of fields (Fields#), average local content in exploration (LCexp%) and production (LCpro%) measured in percent, by fields on Land, Sea and Total, for each round and according year. The Cessa Onerosa and Partilha are special rounds. We do not include Round 0 which formalized existing fields, and round 11-13 which were small and furthermore not sufficient time to actually explore and find oil and gas. Source: Authors calculations on GeoPost dataset compiled from ANP.

Table 5: Operators on Brazilian fields

	Land		Sea		Total	
	#	%	#	%	#	%
OP Energia			2	5,3	2	1,5
central	2	2,1			2	1,5
grantierra	1	1,1			1	0,8
hrt			1	2,6	1	0,8
nord	2	2,1			2	1,5
nova	1	1,1			1	0,8
ogx			6	15,8	6	4,5
parnaiba gas natural	3	3,2			3	2,3
partex	2	2,1			2	1,5
petrobras	53	55,8	26	68,4	79	59,4
petrogal	6	6,3			6	4,5
petroreconcavo	3	3,2			3	2,3
petrosynergy	8	8,4			8	6,0
shb	2	2,1			2	1,5
sonangol	1	1,1			1	0,8
statoil			2	5,3	2	1,5
total			1	2,6	1	0,8
utc	9	9,5			9	6,8
vipetro	2	2,1			2	1,5
Total	95	100,0	38	100,0	133	100,0

Table 6: Days between discovery and signature, no interaction, full sample

```
      Source |       SS       df       MS              Number of obs =     119
-------------+------------------------------           F(  6,   112) =   22.68
       Model |  44790125.4     6   7465020.9           Prob > F      =  0.0000
    Residual |    36857068   112  329080.964           R-squared     =  0.5486
-------------+------------------------------           Adj R-squared =  0.5244
       Total |  81647193.4   118  691925.368           Root MSE      =  573.66

------------------------------------------------------------------------------
      dayexp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lcexp |  -6.053557   3.788128    -1.60   0.113    -13.55925    1.452133
         yea |   -150.853   21.44462    -7.03   0.000    -193.3427   -108.3632
       depth |   .2694969   .1288701     2.09   0.039     .0141573    .5248366
         mar |   79.98916   220.1989     0.36   0.717    -356.3068    516.2851
         api |    17.8656   5.336136     3.35   0.001     7.292729    28.43847
          pb |   267.2734   116.7864     2.29   0.024     35.87622    498.6706
       _cons |   1866.406   339.3731     5.50   0.000     1193.982     2538.83
------------------------------------------------------------------------------
```

Table 7: Days between discovery and signature, no interaction, sea sample

Source	SS	df	MS		
Model	23758335.5	5	4751667.11	Number of obs	29
Residual	12190046.3	23	530002.014	F(5, 23)	8.97
Total	35948381.9	28	1283870.78	Prob > F	0.0001
				R-squared	0.6609
				Adj R-squared	0.5872
				Root MSE	728.01

dayexp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lcexp	12.02762	12.81753	0.94	0.358	-14.48745	38.5427
yea	-224.9416	36.79808	-6.11	0.000	-301.0643	-148.819
depth	.2869091	.2741051	1.05	0.306	-.2801205	.8539387
api	1.721909	24.19004	0.07	0.944	-48.319	51.76282
pb	754.0621	656.7392	1.15	0.263	-604.5064	2112.631
_cons	1794.776	958.7594	1.87	0.074	-188.5692	3778.121

Table 8: Days between commercialization and signature, full sample

Source	SS	df	MS		
Model	76228303.4	7	10889757.6	Number of obs	120
Residual	47784501	112	426647.33	F(7, 112)	25.52
Total	124012804	119	1042124.41	Prob > F	0.0000
				R-squared	0.6147
				Adj R-squared	0.5906
				Root MSE	653.18

dayexp2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lcexp	-37.68961	8.827265	-4.27	0.000	-55.1797	-20.19951
lcexp_yea	4.774844	1.257047	3.80	0.000	2.284166	7.265523
yea	-445.1307	68.84187	-6.47	0.000	-581.5321	-308.7294
depth	.7067417	.1549385	4.56	0.000	.3997509	1.013733
mar	-232.4806	253.0609	-0.92	0.360	-733.8883	268.9271
api	10.0695	6.213134	1.62	0.108	-2.241024	22.38003
pb	6.409934	133.3045	0.05	0.962	-257.7157	270.5356
_cons	4752.226	561.201	8.47	0.000	3640.278	5864.174

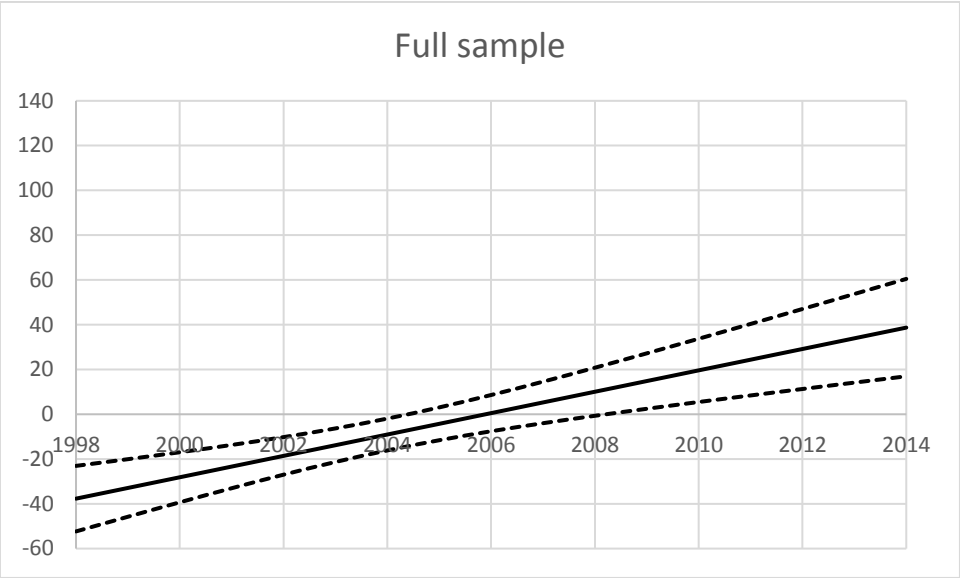

Figure 2: Total LC and LC-year interaction effect, with 95% confidence interval

Table 9: Days between commercialization and signature, sea sample

```
      Source |       SS       df       MS              Number of obs =      30
-------------+------------------------------           F(  6,    23) =   38.73
       Model |  44454385.7     6  7409064.28           Prob > F      =  0.0000
    Residual |  4399792.64    23  191295.332           R-squared     =  0.9099
-------------+------------------------------           Adj R-squared =  0.8864
       Total |  48854178.3    29  1684626.84           Root MSE      =  437.37

------------------------------------------------------------------------------
     dayexp2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lcexp |  -6.187872   14.37746    -0.43   0.671    -35.92992    23.55418
         yea |  -503.1906    100.357    -5.01   0.000    -710.7948   -295.5863
   lcexp_yea |   5.092687    2.56013     1.99   0.059    -.2033457    10.38872
       depth |   .5090297   .1798783     2.83   0.009      .136923    .8811364
         api |  -21.68913   14.64474    -1.48   0.152    -51.98409    8.605833
          pb |   1103.386   405.4963     2.72   0.012     264.5531    1942.219
       _cons |    3931.25    675.722     5.82   0.000     2533.412    5329.087
------------------------------------------------------------------------------
```

Figure 3: Total LC and LC-year interaction effect, with 95% confidence interval

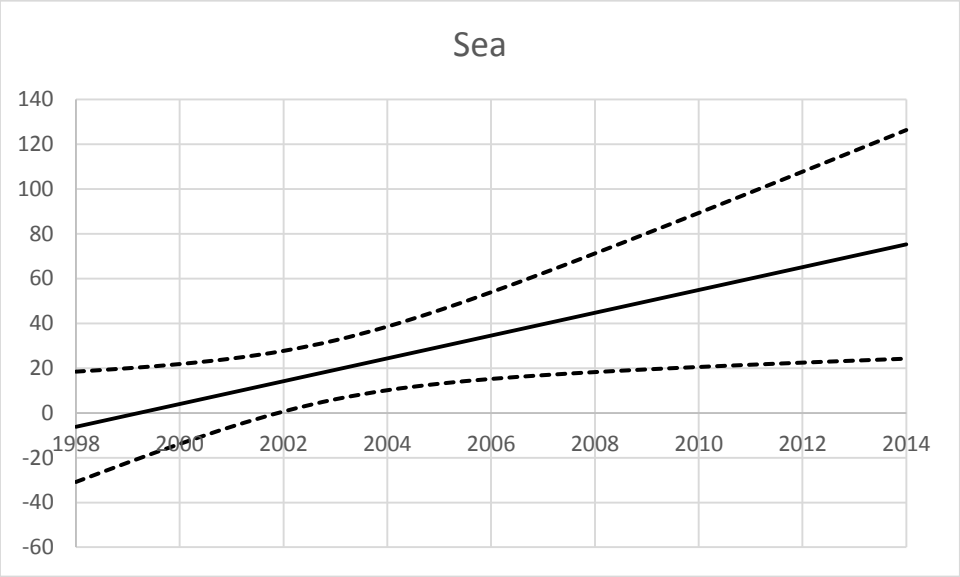

Table 10: First-stage stage instrument variable model, full sample

```
      Source |       SS       df       MS              Number of obs =     119
-------------+------------------------------           F(  8,   110) =  203.80
       Model |  55451.1622     8  6931.39527           Prob > F      =  0.0000
    Residual |  3741.16305   110  34.0105732           R-squared     =  0.9368
-------------+------------------------------           Adj R-squared =  0.9322
       Total |  59192.3252   118  501.629875           Root MSE      =  5.8319

------------------------------------------------------------------------------
       lcexp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         yea |   .2781479   .6011726     0.46   0.645     -.913235    1.469531
       depth |   .0038088   .0015354     2.48   0.015      .000766    .0068516
         mar |  -25.73369   2.033748   -12.65   0.000     -29.7641   -21.70328
         api |  -.0805163   .0569219    -1.41   0.160    -.1933223    .0322896
          pb |  -3.044229   1.205418    -2.53   0.013    -5.433085   -.6553729
          d2 |   41.07064   2.402787    17.09   0.000     36.30888    45.8324
          d3 |   26.41936   3.480498     7.59   0.000     19.52183    33.31689
          d4 |   .9686816    6.67669     0.15   0.885    -12.26295    14.20031
       _cons |   55.48519   2.651529    20.93   0.000     50.23048    60.7399
------------------------------------------------------------------------------
```

Table 11: Second stage instrument variable (2SLS) regression, full sample

```
      Source |       SS       df       MS              Number of obs =     119
-------------+------------------------------           F(  6,   112) =   22.43
       Model |  44739697.5     6  7456616.24           Prob > F      =  0.0000
    Residual |  36907495.9   112  329531.214           R-squared     =  0.5480
-------------+------------------------------           Adj R-squared =  0.5237
       Total |  81647193.4   118  691925.368           Root MSE      =  574.05

------------------------------------------------------------------------------
      dayexp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lcexp |  -4.570668   4.143758    -1.10   0.272    -12.78099    3.639658
         yea |   -155.061   21.97858    -7.06   0.000    -198.6087   -111.5133
       depth |   .2819102   .1297171     2.17   0.032     .0248924    .5389279
         mar |   116.8786   224.2486     0.52   0.603    -327.4413    561.1984
         api |   18.22247   5.354956     3.40   0.001     7.612317    28.83263
          pb |   268.6843   116.8771     2.30   0.023     37.10734    500.2612
       _cons |   1769.293    356.855     4.96   0.000      1062.23    2476.355
------------------------------------------------------------------------------
Instrumented:  lcexp
Instruments:   yea depth mar api pb d2 d3 d4
```

Table 12: First-stage stage instrument variable model, sea sample

```
First-stage regressions
-----------------------

      Source |       SS       df       MS              Number of obs =      29
-------------+------------------------------           F(  7,    21) =   12.66
       Model |    3336.803     7  476.686144           Prob > F      =  0.0000
    Residual |  790.438511    21  37.6399291           R-squared     =  0.8085
-------------+------------------------------           Adj R-squared =  0.7446
       Total |  4127.24152    28  147.401483           Root MSE      =  6.1351

------------------------------------------------------------------------------
       lcexp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         yea |  -2.923605   2.734679    -1.07   0.297    -8.610682    2.763472
       depth |   .0167125    .003561     4.69   0.000     .0093069    .0241181
         api |   .7394542   .2431085     3.04   0.006     .2338824    1.245026
          pb |   -41.2655   8.215144    -5.02   0.000    -58.34983   -24.18118
          d2 |   47.74676    12.5933     3.79   0.001     21.55756    73.93596
          d3 |   46.98018   18.42641     2.55   0.019     8.660378    85.29999
          d4 |   30.95057   27.55378     1.12   0.274    -26.35064    88.25178
       _cons |   25.72862   8.372519     3.07   0.006     8.317015    43.14023
------------------------------------------------------------------------------
```

Table 13: Second stage instrument variable (2SLS) regression, sea sample

```
Instrumental variables (2SLS) regression

      Source |       SS       df       MS              Number of obs =      29
-------------+------------------------------           F(  5,    23) =    9.00
       Model |  23671725.6     5  4734345.12           Prob > F      =  0.0001
    Residual |  12276656.3    23  533767.664           R-squared     =  0.6585
-------------+------------------------------           Adj R-squared =  0.5843
       Total |  35948381.9    28  1283870.78           Root MSE      =  730.59

------------------------------------------------------------------------------
      dayexp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lcexp |   17.20905   14.80381     1.16   0.257    -13.41496    47.83306
         yea |  -229.4756   37.48112    -6.12   0.000    -307.0112     -151.94
       depth |   .3043061   .2761752     1.10   0.282    -.2670059    .8756181
         api |   2.828507   24.32622     0.12   0.908    -47.49411    53.15112
          pb |   779.2226   660.0279     1.18   0.250    -586.1493    2144.594
       _cons |   1540.893   1026.971     1.50   0.147    -583.5585    3665.344
Instrumented:  lcexp
Instruments:   yea depth api pb d2 d3 d4
------------------------------------------------------------------------------
```