Procurement as Innovation Policy and its Distinguishing Effects According to Firm Size: the case of Brazilian oil and gas sector

Rocha, Frederico

Instituto de Economia - Universidade Federal do Rio de Janeiro, Brazil

Abstract

Using microdata from labor social indicators database (RAIS), the paper elaborates an indicator of innovative intensity represented by the ratio of personnel in scientific and technological occupation to total personnel. The paper then tests the hypothesis that procurement policy increases suppliers' innovative effort. After identifying treated firms, the paper creates a control sample through propensity score matching. Using treated and control samples, the paper tests the hypothesis that treated firms have higher innovative effort, concluding that, on average, the impact of procurement policy would be an increase of 2.6 percentage points. The paper then uses a two parts model to decompose the effect of procurement into (i) the incentive to begin the performance of innovative effort; and (ii) the increase in the intensity of the innovative effort. The paper finds that, in SMEs, the first effect on treated companies tended to be substantial, but the second effect seemed to be inexistent, while in larger firms the opposite has happened. The paper then concludes that one important cause for defending procurement policy may be a greater participation of SMEs in innovative activities.

1. Introduction

For many years, scholars and policymakers have downplayed the role of demand in innovative settings. As a consequence, innovation policy has mostly been directed towards correcting market imperfections on the supply side. Policy instruments such as public subsidies to innovation, tax credits and public financing have prevailed over the use of demand side instruments such as procurement policies (Edquist and Hommen 2000, Edler and Georghiou 2007 and Guerzoni and Raiteri 2015). Whenever applied, demand side policies have remained hidden and their results have very rarely been put under the spotlights. However, in these cases, governmental agencies and state companies have acted as coordinators of a network of suppliers, obtaining very inspiring results (Block 2008 and Mazzucato 2011).

Petrobras, the Brazilian state-owned oil company (SOC), has since its birth been a state instrument for the development of downstream and upstream firms. Cardoso's administration (1995-2002) reduced Petrobras' focus on supplier development and the importance of Petrobras' demand to domestic industrial companies. In fact, during Cardoso's two terms, no Petrobras oil and gas platform was produced internally and production chain effects were almost null. During Lula's two terms, Brazil saw the resurgence of local content policy and oil and gas procurement became an important issue. This policy has been largely criticized due to the establishment of very rigid local content requirements and has been accused of provoking huge profits loss to Petrobras and other oil and gas operators due to production delays (Guimarães 2012) and, as a consequence, the new Brazilian government has been threatening to discontinue it. However, some still believe in the potential of local content to develop local capabilities. Previous works on this thematic have focused on the impact over suppliers' growth and exports (IPEA 2011) with positive results and on the sources of innovative behavior (De Oliveira and Rocha 2008 and Rocha 2015). Nonetheless, little light has been thrown on the impact local content policy has had on innovative effort.

This paper aims at assessing the effect of demand oriented policy performed by Petrobras under the local content goals established by Agência Nacional do Petróleo (ANP). The paper uses microdata from Relação Anual de Informações Sociais (RAIS). It then creates a quasi-experimental setting building a counterfactual sample through propensity score matching. After forming the control sample, we run Schumpeterian based models to assess the impact of procurement policy on innovation efforts with emphasis on the differential effect of procurement on firms according to firm size.

The paper is organized in six sections, including this introduction. Section two presents an analytical framework based on previous literature on the subject and defines the contribution of this paper. Section three describes the local content policy in the oil and gas sector and the instruments Petrobras has designed to cope with the task of domestic acquisition of materials and services. Section four describes the database and presents the methodology used in the paper. Section five presents the results and section six discusses the results extracting the main conclusions from the carried out exercises.

2. Analytical Framework

Two different views usually motivate innovative policies. On the one hand, there are those who understand policies should be designed to **correct for market imperfections**; on the other hand, there are those that seek governmental intervention as **builders of networks**. The first perception is generally focused on correcting market imperfections, such as uncertainty or lack of appropriablity. Proposed mechanisms are typically the structuring of property rights instruments and the correction of market prices under the effect of externalities. In this case, resources may be channeled through the financing of R&D activities, the building of financial mechanisms and institutions, such as venture capital funds, the supply of non-reimbursable funds or the implementation of subsidies and tax exemptions for innovative activities.

The second perception emphasizes the interactive character of innovative activities and stresses the importance of structuring innovative networks. Emphasis is directed towards the interaction between different set of actors such as universities, research institutions, small and large firms. Supply and demand tend to be linked.

One should thus distinguish between direct and indirect innovation policies (Edquist, Hommen and Tsipouri 2000). In the first case, policy instruments pursue the enhancement of innovative activities through general changes in institutional framework, in the second case, instruments aim to cultivate interaction. In the latter setting, public organizations are directly involved in pursuing and building interaction.

Three factors have however been responsible for overshadowing government procurement. First, the demand-pull-technology-push debate of the 80's downplayed the importance of demand and emphasized the protagonism of supply factors in innovative settings (Dosi 1982, Scherer 1982). Second, demand policies suffered resistance from those opposed to *picking the winner* policies. Third, WTO agreements imposed restrictions to such policies, leading governments either to cease them (European Union) or to build a hidden agenda (USA) (Edler and Georghiou 2007, Mazzucato 2011).

Empirical evidence has however favored government procurement policies. Litchenberg (1987) tested the effect of federally financed R&D on R&D expenditures. However, whenever he introduced controls for sales derived from government procurement, the sign of the effect of federal finance to R&D variable on R&D expenditures became insignificant and the real effect on company R&D expenditures was found to be on the sales to government procurement. This conclusion is clearly associated with increases in future revenues and therefore with the potential of public procurement to positively affect R&D expenditures. Lichtenberg (1988) used a sample of 165 companies, controlling for industry characteristics and time variables, to test whether competitive or non-competitive government procurement affect company R&D expenditures. He concludes for a positive effect of government procurement, much larger than other policy instruments. Geroski (1990) also finds evidence for the good performance of public procurement. Guerzoni and Raiteri (2015) control for possible interaction between a diversity of supply policy and demand policy instruments, arriving to a similar conclusion as Litchenberg that whenever controlled for demand policy instruments, supply policy tend to reduce its effectiveness and that demand policy instruments remains relevant.

There have been a number of recent studies that have renewed the interest in procurement policy due to the possibility of interaction between agents that procurement may provide (Mazzucato 2011, Block 2008 and Edler and Georghiou 2007). More specifically, Block (2008) argues that the US has kept hidden a developmental State that has implemented a series of successful interventions. According to his research, the results are unchallenged and a large number of the main innovations in the US have followed projects that were funded by governmental agencies.

Guerzoni and Raitieri (2015) define public procurement innovation policy as the one where a public agency places and order products that do not exist at the time, but could be delivered if interaction with the public agency takes place. In the Brazilian context, nonetheless, one should consider that it not necessarily involves novelty to the international market, but in the domestic market context where these firms carry out their activities. More adequately, Edquist and Hommen (2000) list a set of instruments that may be present in these settings and that enhance innovative efforts. First, innovation procurement policies may provide early sophisticated demand for domestic firms. This means that new services and products that would not be otherwise demanded or that would only be demanded through exports may find a new demand in the public sector. Second, procurement may set stringent patterns and benchmarking for domestic firms. Quality control may be implemented. Third, procurement policy may encourage domestic firms "to act as 'lead users' in setting leading-edge standards for domestic producers" (Edquist and Hommen p. 62) and therefore contribute to international competitiveness of domestic industry. Fourth, and maybe most importantly, procurement policy should facilitate innovation and should emphasize the complementary strengths of firms in different positions of the product chain and seek the coordination of their actions, stimulating the establishment of linkages and flows of knowledge amongst firms and other organizations. Fifth, it should stimulate competition. Competitive dynamics is important to offer the tensions needed for innovation inducement and for a health network of innovative actors.

3. Local content policy in the oil and gas sector in Brazil

The employment of oil and gas sector local content policy under Lula's government represented a major step towards the establishing of a public procurement policy. Local content clauses were present in oil and gas exploration and production contracts since the first bidding round that took place in 1999 (president Cardoso's second term). The main purpose of local content requirements was "to allow locally established goods and service providers to participate in the oil and gas supply chain and increase their market share in a competitive basis" (ANP 2012).[1] However, until the fourth round, the clause expressed preference to domestic suppliers, but did not include any particular local content target, neither did it establish any discriminatory criterion. Rounds five and six bidding, that took place in 2003 and 2004, first established minimum percentages based on whether blocks were located onshore, offshore shallow water or offshore deep water. In 2005, authorities increased requirements and established a methodology to measure local content. In 2007, minimum and maximum local content levels were imposed per equipment. This regulation still holds up to today. Regulation became stricter as time went by. Moreover, monitoring became tighter and ANP played an increasing role in monitoring.[2] More importantly, local content began to play a central role in oil and gas policy in Brazil and the fulfillment of these requirements became a central concern for policy makers, oil companies and major suppliers.

---

[1] Procurement policy does not distinguish locally established multinational affiliates from domestic capital firms.

[2] Regulation ANP no. 9/2007 establishes the frequency, the format and the content of local investments reports made with exploration and production development activities

In order to measure local content, authorities developed a rule book to be followed by oil and gas suppliers from the 7th round on. This rule book submits to certification every item and sub item acquired by oil and gas companies and their EPCs in exploration and production activities. This trend towards stricter local content requirements has been highly criticized and accused of producing large delays in production and rules have been going through changes aiming to provide a more business friendly environment.

Petrobras, the Brazilian NOC, is the main oil operator in Brazil, producing around 90% of total oil. Up to 2013, it held the third largest R&D budget amongst the world's oil and gas operators and had the largest R&D to sales ratio (Rocha 2015). Petrobras acts in almost every stage of the oil and gas production chain, such as exploration, production, refining, transportation and even thermos-electric plants. Most importantly, Petrobras' activities in exploration and production involve the development of new technology to achieve deep water and ultra-deep water oil production, being also the only company that operates in pre-salt conditions. These features are important to settle that Petrobras operates in challenging and innovative conditions.

One important issue about the general use of local content policies in Brazil is whether Petrobras has been able to positively influence suppliers' learning and knowledge accumulation process. IPEA (2011) tried to provide an answer to this question. They show that, on average, Petrobras's suppliers are larger, have a larger percentage of scientific personnel, engineers, greater wages and better education. Therefore, Petrobras' suppliers are amongst the most qualified firms in the Brazilian economy. So, one important question would be whether Petrobras adds value to its suppliers. De Negri et al. (2011) use propensity score matching techniques to define a control group with respect to a set of characteristics. Analyzing the treated sample (Petrobras suppliers) against the control sample, they find that Petrobras' procurement has positive and continued effect on firm growth, labor force education level and wages (which may be an indicator for productivity). They however find a negative impact on exports. Though there is no test run by De Negri et al. (2011), one may speculate that this negative effect may be result of the redirecting of resources towards the greater opportunities provided by Petrobras.

It is true that Petrobras chooses better firms. A supplier certificate (CRCC) that authorizes departments to acquire goods or services has to be issued. Apart from formalities associated with the legal status of firms, Petrobras requires social responsibility, environmental and health certifications (respectively, ETHOS, ISO 14001 and ISO 18001). If the supplier provides critical products, product quality certification (ISO 9001) is required. It is well known that very often firms enhance their market value when they obtain CRCC from Petrobras.[3] Nonetheless, firms that become Petrobras' suppliers have their overall costs increased in order to cope with the requirements of the certifications. This has been stressed by some of the suppliers. They tell that they leave one type of market that takes price as the most important variable and enter another market where quality has an important role (also Oliveira and Rocha 2008).

However, Petrobras also acts to improve suppliers' product quality. Quality control may be divided into two main procedures: the technical audits for suppliers (ATF) and the Quality Guarantee Program for Services and Materials (PGMQSA). The ATF is composed of inspections that may be more or less intensive during production and delivery of the product, according to the supplier qualification as classified by the Procurement Department. Usually the intensity of audit is associated with the product line. Suppliers complain a lot about audit procedures saying that they increase their costs. However, they agree that some of the required procedures make their products better.

The PGQMSA has long run targets. The program consists of inspection visits to investigate the application of the state of art techniques of production. The planning of the program requires a complete investigation of the state of the art of technology in all covered product lines. After the inspection, each firm receives a grade and this is used by project managers in the choice of companies that will participate of their vendor list. Though some suppliers have lost their certification after implementation, the main objective of the program is to increase the compliance of state of the art norms and procedures in order to reduce the number of unconformities in product delivery.

The program has achieved its goal and the number of unconformities has radically decreased with the number of unconformities of PGQMSA covered products per US$ billion of investment approaching zero (see Rocha 2015). Moreover, the inspections at

[3] Oliveira and Rocha (2008) tell an anecdote that illustrates this case. One firm had its property structure changed. There were two partners. One of them left the partnership to open one company in the same line of business. The certificate was negotiated as the main part of the deal. Another case was related to an affiliate of a multinational enterprise

the PGQMSA served as a consultancy for the companies. Most of them improved their processes during the program. This has been detected by Petrobras' officials in their yearly inspections. One example of the type of impact is the introduction of engineering departments in valve producers in order to be able to calculate and store the signature of produced valves (Oliveira and Rocha 2008).

Petrobras has also a program for the development of new suppliers or the development of new products by existing suppliers. This program is undertaken by the procurement department of Petrobras but may have explicit involvement of internal R&D personnel and its intention is transference of knowledge required to have to product produced under the adequate conditions. The development of new products together with suppliers is at the center of Petrobras' success in deep waters. One striking case is the subsea equipment that made it possible for Petrobras to achieve its level of production.

There is however one important shortcoming in the relationship of Petrobras with most suppliers located in Brazil. Very rarely knowledge flows go in both ways in a purposeful manner. Mostly Petrobras is directing knowledge to its domestic suppliers. This characteristic makes evident the problems associated with innovative capabilities in the domestic supplying industry. Though suppliers were very likely to acknowledge the importance of Petrobras as source of knowledge, they very rarely pointed out situations where they contributed to innovative gains by Petrobras. Some exceptions occurred in some independent engineering companies and in subsea equipment.

In recent years, multinational oil and gas service and equipment supplies companies have established R&D labs in the Technological Park of the Universidade Federal do Rio de Janeiro, where the main Petrobras R&D lab, CENPES, is also located: Schlumberger, Baker-Hughes, Halliburton, FMC, Tenaris-Confab, Siemens, General Electrics, Vallourec and Georadar.[4]

Rocha and Urraca Ruiz (2011) analyze the R&D internationalization strategies of three of these MNC, Schlumberger, Baker-Hughes, and FMC, using patent data and interviews to their CEOs in Brazil and to the CENPES CEO. They argue that three main features have attracted these companies' R&D investments to Brazil:

[4] Apart from BG.

(i) the size of the pre-salt oil and gas province,
(ii) Petrobras' accumulated capabilities and
(iii) the existence of qualified personnel.

Furthermore, the Petrobras network has also impact on cooperation. Fioravante and Aguirre (2013) show that Petrobras' suppliers are more likely to cooperate with universities and public research labs than a control sample. Rocha and Bueno (2008) show, using Brazilian Innovation Survey for 2003, that oil and gas suppliers have strong innovative behavior when compared to other Manufacturing and Mining companies in Brazil. Nonetheless, they have lower R&D expenditures. They then explain this behavior due to the larger cooperative relations oil and gas suppliers establish with their clients (Petrobras) and outside industry agents, such as universities.

This narrative shows that Petrobras has a procurement policy that follows most of the instruments or directions proposed by Edquist and Hommen (2000). They provide market for new products, allow firms to supply products in international technological frontier, improve quality patterns and networking across different actors. The main shortcoming seems to be its relation with competitive environments. As De Negri et al. (2011) have shown, firms that supply to Petrobras become less likely to export. This is confirmed by Rocha (2011) in the examination of the quality control program participants. Petrobras seems to absorb their suppliers in their own operations.

4. Database and Method

4.1. The Database

The paper uses microdata from Relação Anual de Informações Sociais[5] (RAIS) for the years 2009, 2010 and 2011. RAIS is an administrative register that very employer has to file every year in the Ministry of Labor. It contains social information on employees, such as number of months in workplace, schooling, occupation, date of birth, gender, wage, among other variables. Aggregating this information per firm provides accurate information on the firm level. After aggregating, the whole database contains 2.2 million firms, in 2009, 2.4, in 2010, and 2.5, in 2011.

[5] Social Information Administrative Register.

In order to capture innovative effort, the paper creates a variable represented by the number of employees dedicated to scientific and technical activities (PoTec), using information of the Brazilian Occupation Classification. The variable gathers the following occupations in different levels of aggregation: (i) researchers; (ii) engineers; (ii) R&D managers; and (iv) scientific personnel, such as biologists, mathematicians, etc. A detailed exposition of the methodology used is presented in Araújo, Cavalcante and Alves (2009). They find that PoTec has a very high correlation to R&D expenditures by firms presented in the Brazilian Innovation Survey[6] (from 0.8 to 0.9 depending on the year tested) and may therefore be used as a proxy for technological activities.

In 2011, RAIS registered 573902 scientific and technical employees or 1.2% of total employees. These are distributed across firm size as presented in Figure 1Figure 1. Most R&D personnel are located in large firms. Firms with 1000 or more employees hire a little more than half of total R&D employees and 1.7% of its employees are in R&D related occupations.

(Figure 1 here)

After building the database, a subsequent task is to identify the treated sample, that is, those firms that are oil and gas suppliers. Previous experience indicates that the attempt to obtain the vendor list of oil and gas supplies companies may conduct to frustration. Therefore, we will use a list of suppliers through the Organização Nacional da Indústria do Petróleo (ONIP), which is an independent non-profit private organization that gathers companies that supply to oil and gas industry. It has cadastral information of the main players in the industry for the year 2007.

In order to control for heterogeneity across sectors, we excluded from the analysis non-mining and non-manufacturing firms and inside mining and manufacturing, we kept only those companies that supply critical equipment or inputs, that is, that belong to the

[6] The Brazilian Innovation Survey's (PINTEC) methodology is based on the European Union's Community Innovation Survey (CIS).

following ISIC3 divisions: 11 - Extraction of crude petroleum and natural gas, 27 - Manufacture of basic metals, 28 - Manufacture of fabricated metal products, except machinery and equipment, 29 - Manufacture of machinery and equipment n.e.c., 30 - Manufacture of office, accounting and computing machinery, 31 - Manufacture of electrical machinery and apparatus n.e.c., 32 - Manufacture of radio, television and communication equipment and apparatus, 33 - Manufacture of medical, precision and optical instruments, watches and clocks, 34 - Manufacture of motor vehicles, trailers, 35 - Manufacture of other transport equipment, 36 - Manufacture of furniture; manufacturing n.e.c. These procedures left 446 companies for 2009, 434 for 2010 and 441 for 2011.[7] Their size and sectoral distribution for each year is shown Figure 2 and Figure 3, respectively. Table 1 describes the variables used in the paper.

(Table 1 here)

(Figures 2 and 3 here)

4.2. *The Method*

Selection biases are a main concern for those who evaluate governmental innovation policies. The aim of governmental support is to increase innovative activities. Therefore, governmental programs should not fund activities that would happen anyway, but focus on activities that would not occur if governmental support was not available (Wallsten 2000). In the former case, governmental support would be substitute for private initiatives, while in the latter case it would be complementary.

Selection biases occur first because governmental officials would be inclined to choose firms that they are sure would present results, and therefore focus would be directed to firms that are more likely to carry out innovative activities. A second type of selection

[7] There are many reasons for the change in the number of firms reported by RAIS: (i) error in reporting data; (ii) changes in sector; (iii) exit from market, are amongst them.

bias would emerge from the behavior of innovative firms. In this case, firms would look for the cheapest way to perform innovative activities.

In the case of oil and gas suppliers, the requirements to obtain a Petrobras supplier certificate induce firms to upgrade or to have developed production methods previously to becoming a supplier. This is conducive of selection biases, that is, oil and gas suppliers may be better firms because Petrobras selects the best firms in the market and not because Petrobras has influence in their performance.

Table 2 shows that oil and gas suppliers have different characteristics when compared to firms in the same two-digit critical supplies sectors. Oil and gas suppliers are bigger firms, have higher number of R&D personnel, are more R&D intensive and their employees are more qualified and receive higher wages, indicating the presence of the type of selection bias that has been stressed above.

(Table 2 here)

Different authors have given different answers to the problem of selection bias. Wallsten (2000) uses a three stages least square model with instrumental variable to tackle the endogeneity problem. Gelabert, Fosfuri and Tribó (2009) follows Wallsten (2000) in the use of instrumental variables and adds fixed effects panel as an instrument for controlling for firm specific characteristics. Almus and Czarnitzki (2002) uses propensity score matching. Following Almus and Czarnitzki, a number of studies have introduced propensity score matching to control for selection biases (González and Pazó 2008, Goerg and Strobl 2007, Czarnitzki, Hanel and Rosa 2011).

This paper will adopt propensity score matching in order to compose a control sample and to deal with for selection biases. After composing the control sample, we will run two different models, in a pooled data sample: (i) ordinary least squares and (ii) a tobit model. In this case, we expect to deal with the question whether oil and gas suppliers, submitted to procurement policy, outperform their counterpart.

In order to build a control sample, we run a propensity score model that takes into account a number of firm characteristics. The probit pooled data model has petro as dependent variable, a dummy variable that assumes value 1 (one) if the firm is an oil and gas supplier and 0 (zero), otherwise, and as independent variables, the concentration level of the three digit sector where the firm is classified, represented by the Hirschman-Herfindhal index (hhi), the firm's wage level (wage), the proportion of employees with complete secondary education (capacity), the average number of years of the employees in the firm (experience), seven size dummies that account for the size level[8], and sectoral dummies for the two digit secotrs (see equation 1). The results are reported in Table 30. Table 4 shows that differences between treated and untreated samples with respect to size, sector and the other variables are insignificant and, thus, the following analysis will deal with firms that had similar probabilities of being treated.

$$petro = constant + \alpha_i sizedummies_i + \beta_1 HHI + \beta_2 wage + \beta_3 capacity + \beta_4 experience + \gamma_j sectoraldummies \qquad (equation\ 1)$$

(Table 3 and 4 here)

[8] The use of size dummies is justified by the avoidance of testing a quadratic relation between the dependent variable (intec=potec/nemp) and the independent variable that would represent size (nemp).

5. Results

After having defined the control sample, we shall run a model. The dependent variable, inttec, is however censored on the left at 0 and on the right at 1. Therefore, we should use a tobit model, where:

$$inttec = \max(0\,; constant + \alpha_i sizedummies_i + \beta_1 petro + \beta_2 HHI + \beta_3 capacity + \beta_4 experience + \gamma_j sectoraldummies) \quad \text{(Equation 2)}$$

We'll report the results for the OLS model in pooled data for the tobit model, also in pooled data, and a tobit model panel data with random effects. On the explanatory variables, equation (2) departs from the basic Schumpeterian model, relating innovation efforts to firm size and market concentration. The model uses sectoral dummies to control for opportunity and appropriability characteristics. Firm characteristics are also accounted for in experience and capacity variables. Petro is the policy intervention variable to be tested.

Table 5 shows the results for the three regressions. In all three equations, the respective F and Wald tests present adequate values. The results of all three equations confirm both Schumpeterian hypotheses. Size dummies are positive and significant. With the sole exception of size5 and size6 dummies, respectively, 100 to 249 and 250 to 499 employees, in the OLS equation, all size dummies coefficients are increasing in size, suggesting larger firms carry out greater efforts in technological activities. On the other hand, concentration has a positive and significant effect on technology intensity. The higher the three-digit market concentration, the higher the technological efforts are. Experience and capacity have the expected sign and improve technological efforts.

The petro dummy has the expected sign. Relation with oil and gas procurement policy has positive effect on technological effort, always significant at the 1% level. The dimension of the effect varies from 1 percentage point, in the OLS model, 2.6 p.p. in the tobit model, up to 2.7 percentage points in the random effects tobit panel data model. In the case of both tobit models the effect is substantial, suggesting that oil and gas procurement policy has been quite effective. The analysis of the four models and the adequacy of the tobit model to the situation, suggests that the impact should be closer to

2%. This impact is far from small. It more than doubles the technological efforts in relation to similar firms in size, capacity, experience, markets and sectors.

Equations (2) and (3) also show that a large number of firms (1,076) in the sample don't perform any R&D at all. Table 6 shows that most non-R&D performers are non-suppliers and that mostly they are concentrated in micro and small firms (less than 100 employees). Thus, one important effect of oil and gas procurement could be to motivate firms to become R&D performers.

In order to isolate the effect on the decision to carry out R&D from the effect on intensity, we'll run a two steps regression. First, we run a probit model to measure the effect of oil and gas procurement on suppliers' decision to carry out R&D or technology related activities. Then, excluding those firms that do not have technology related activities, we run an ordinary least square model (OLS) to capture the effect on R&D or technology related activities intensity.

(Tables 5 and 6 here)

The results of the two-part model may be found in Table 7. The probit model shows that being an oil and gas supplier substantially increases the probability of the firm getting engaged in technology related activities. Marginal effects say that the probability of performing technology related activities increases in around 19%. All other variables maintain the sign and significance as established in the tobit models run before. The OLS model shows however that separating the two effects decreases the size of the effect of oil and gas procurement on suppliers' technology related activities. Instead of a 2.6 percentage points increase presented in the tobit models, the OLS model presents an impact of 0.9 percentage point. The effect of firm size changes signs, showing that firms of less than 10 employees once they become engaged in technology activities are more technology intensive than firms of larger size. It seems that oil and gas procurement plays a greater part in the 'getting started' in technology activities than in increasing R&D intensity, although it positively affects both.

Table 8 uncovers another detail. Being an oil and gas supplier increases the probability of performing technology related activities in around 19%, if the firm is a small and medium size enterprise (SME). However, if the firm is large, there seems to be very little effect on becoming an R&D performer. Furthermore, once SMEs have decided to perform technology related activities, oil and gas procurement does not affect R&D intensity, whereas if the firm is large, the main impact of oil and gas procurement is on R&D intensity and the whole impact found in the two part model is much closer to the impact found in the tobit regressions, around 1.7 percentage point.

(Tables 7 and 8 here)

6. Discussion and Conclusions

This paper aimed at assessing the impact of Petrobras' procurement policy on firms' innovative efforts. The paper intended to argue in favor of a more systemic view of innovative processes and its consequence for innovation policy, which would require a greater interaction between participants of the system of innovation. Procurement policy involves this type of interaction between agents that participate in the same sectoral system.

The analysis indicates that:

(i) oil and gas procurement has had a positive impact on firms' innovative efforts. Petrobras' procurement policy would result in the treated sample outperforming the control sample on around 2.6 percentage points in the scientific and technological personnel to total personnel ratio;

(ii) high proportions of firms in the control (47%) and treated (36%) samples were on the censored side of the distribution, that is, those firms did not perform any technology related activity. As a consequence, it seemed wise to separate two distinguishing effects of treatment on firms. On the one hand, the effect on the incentive to begin technology related activities, that is, the increase in the probability of carrying out any innovative effort at all. On the other hand, the impact on efforts' intensity;

(iii) when separating these two effects, the analysis found that, whenever dealing with SMEs, the first effect on treated companies tended to be substantial, but the second effect seemed to be feeble, that is, Petrobras' procurement would affect positively the probability of SMEs carrying out innovative activities, but once firms had decided to carry out those activities, procurement would not affect its intensity. The opposite effect would happen to large firms. Procurement did not affect the probability of performing R&D but would substantially affect the intensity of R&D.

The first result adds little to what had already been emphasized by literature. However, this paper suggests that, at least in the case of the Brazilian oil and gas sector, procurement has played different roles according to firm size. It is arguable that this role shows greater importance in the case of SMEs. First, there are important statistical characteristics that allow this conclusion. As shown in the OLS model in Table 7, once a small firm becomes an R&D performer in this sample, its R&D intensity tends to be higher than larger firms, even when controlled by treatment. In the sample, firms under 10 employees that are R&D performers have, on average, 36% of their personnel in scientific and technological occupations. This percentage is decreasing on firm size up to firms over 500 employees. However, in no case, firms in the cohorts over 500 employees have on average larger percentage of scientific personnel than the average of firms' in the cohorts under 100 employees (see Table 6). The second reason is related to the opportunities of connection with lead users. The presence of strategic relationship, established through procurement oriented innovation policies, should be of more importance to smaller firms due to the lower probability of participating in many production chain systems. The gains from knowledge spillovers from users should be greater in these cases. Third, the probability of performing R&D is much lower in smaller firms and policy designs to include small firms are very challenging. One of the main features of Brazilian supply side innovation policy has been its inefficacy to increase the proportion of innovative firms. Most studies conclude for feeble differences between treated and non-treated SMEs (Carrijo and Botelho 2013, Rapini, Oliveira e Silva Neto 2014).

Thus, one important conclusion of the paper is the different role played by procurement policy across firm size. In the case of large firms, it has an intensive role, that is, it does not increase the number of firms involve in innovative activities, but it increases the intensity of innovative firms' technological efforts. In the case of SMEs, it has mainly an extensive effect, increasing the number of firms carrying out innovative efforts. This dichotomy may render this type of policy an additional role in national system of innovation due to its capacity to include new firms into the system.

References

1. Almus, M., Czarnitzki, D., 2003. The effects of public R&D subsidies on firms' innovation activities? Journal of Business and Economic Statistics 21 (2), 226–236.
2. ANP (2012) *Local content in Brazilian oil & gas industry*. http://www.anp.gov.br/?id=554.
3. Araújo, B. C.; Cavalcante, L. R.; Alves, P. (2009) "Variáveis proxy para os gastos empresariais em inovação com base no pessoal ocupado técnico-científico disponível na Relação Anual de Informações Sociais (RAIS)", *Radar: Tecnologia, Produção e Comércio Exterior*, Brasília, n. 5, p. 16-21.
4. Aschoff, B and Sofka, W. (2009) Innovation on demand—Can public procurement drive market success of innovations? Research Policy 38, 1235–1247.
5. Block F, (2008) Swimming against the current: the rise of a hidden developmental state in the US. *Politics and Society* 3(2).
6. BNDES (2014) Perspectivas do Investimento. http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes_pt/Galerias/Arquivos/conhecimento/perspectivas_investimentos/boletim_perspectivas_maio2014.pdf.
7. Carrijo, M.; Botelho, M. (2013) Cooperação e inovação: uma análise dos resultados do Programa de Apoio à Pesquisa em Empresas (Pappe). *Revista Brasileira de Inovação*, v. 12, n. 2, p. 417-447.
8. Cassiolato, J., Lastres, H., and Maciel, M. (eds.) (2003) Systems of Innovation and Development. Cheltenham, Edward Elgar.
9. Czarnitzki, D., Hanel, P., Rosa, J.M., 2011. Evaluating the impact of R&D tax credits on innovation: amicroeconometric study on Canadian firms. Research Policy 40 (2), 217–229.
10. De Negri, J.; Silva, A. Correia, L. Aguirre, L. Alves, P. (2011) O Impacto da Petrobras nos seus fornecedores. Em IPEA Poder de Compra da Petrobras: Impactos Econômicos nos seus Fornecedores. IPEA, Brasília.

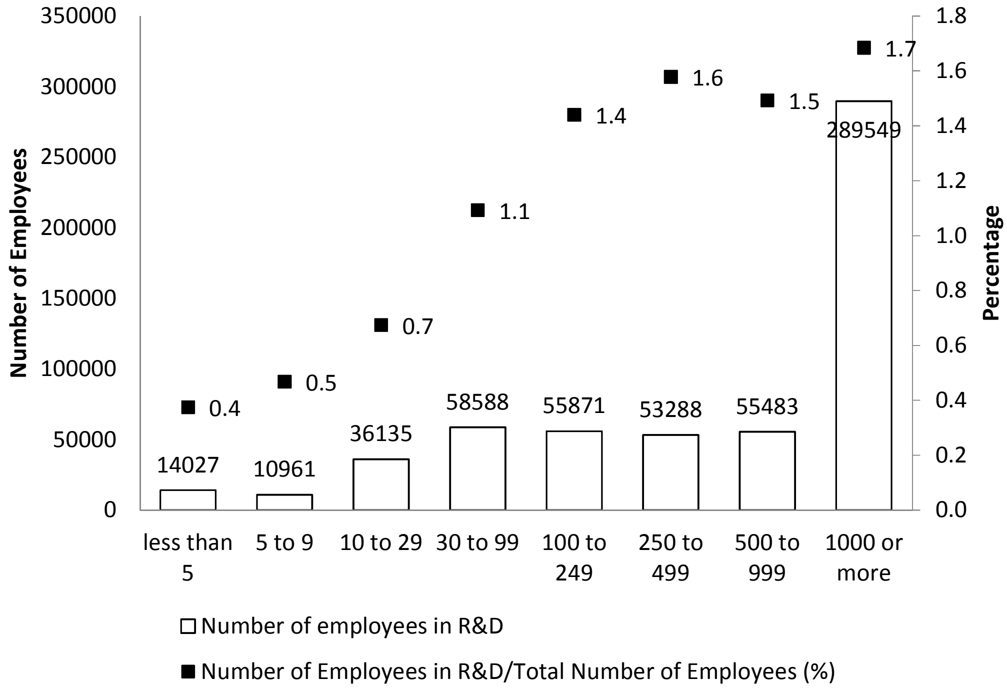
http://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=6477.

11. De Oliveira, A. and Rocha, F. (2008) Conclusões e Políticas. Final Report to the study Competitividade dos Fornecedores da Indústria Nacional do Petróleo e Gás, INDP&G 28. http://www.prominp.com.br/prominp/pt_br/projetos/projetos.htm.
12. Edler, J.,Georghiou,L. (2007) Public procurement and innovation? Resurrecting the demand side. Research Policy 36 (7), 949–963.
13. Edquist, C., Hommen, L., 2000. Public technology procurement and innovation theory. Public Technology Procurement and Innovation 16, 5–70.
14. Edquist, C., Hommen, L., Tsipouri, L., 2000. Introduction. Public Technology Procurement and Innovation, vol. 16. Springer.
15. Edquist, C. and Zabala-Iturriagagoitia, J. (2012) Public Procurement for Innovation as mission-oriented innovation policy. Research Policy 41, 1757–1769.
16. Fioravante, D. G. and Aguirre, L. (2013) A cooperação entre universidades e empresas e os fornecedores da Petrobras. Turchi, L.; De Negri, J. and De Negri, F. (2013) Impactos Tecnológicos das Parcerias da PETROBRAS com Universidades, Centros de Pesquisa e Firmas Brasileiras, Ipea, Brasília, http://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/livro_impactos_tecnologicos_parcerias.pdf.
17. Gelabert, l., Fosfuri, a. and Tribó, J. (2009) Does the effect of public support for R&D depend on the degree of appropriability? *The Journal of Industrial Economics*, LVII (4), 736-767.
18. Geroski, P., 1990. Procurement policy as a tool of industrial policy? International Review of Applied Economics 4 (2), 182–198.
19. Guimarães, E. A. (2012) Cadeia Produtiva de Petróleo e Gás. CNI, http://arquivos.portaldaindustria.com.br/app/conteudo_13/2012/08/20/44/20120906112614214901e.pdf.
20. Goerg, H., Strobl, E., 2007. The effect of R&D subsidies on private R&D? Economica 74 (294), 215–234.
21. González, X., Pazó, C., 2008. Do public subsidies stimulate private R&D spending? Research Policy 37 (3), 371–389.

22. Guerzoni and Raiteri (2015) Demand-side vs. supply-side technology policies:Hidden treatment and new empirical evidence on the policy mix. Research Policy 44, 726–747.
23. IPEA (2011) Poder de Compra da Petrobras: Impactos Econômicos nos seus Fornecedores. IPEA, Brasília. http://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=6477.
24. Lichtenberg, F.R., (1987). The effect of government funding on private industrial research and development: a re-assessment. The Journal of Industrial Economics 36, 97–104.
25. Lichtenberg, F.R., (1988). The private R&D investment response to federal design and technical competitions. American Economic Review 78, 550–559.
26. Lichtenberg, F.R., Siegel, D. (1991). The impact of R&D investment on productivity — new evidence using linked R&D-LRD data. Economic Inquiry 29, 203–228.
27. Lundvall, B. (1992) National Systems of Innovation Towards a Theory of Innovation and Intractive Learning. London, Pinter.
28.
29. Malerba, F. and Nelson, R. (2011) Learning and catching up in different sectoral systems: evidence from six industries. Industrial and Corporate Change, Volume 20, Number 6, pp. 1645–1675.
30. Mazzucato, M. (2011) The Entrepreneurial State. http://www.demos.co.uk/files/Entrepreneurial_State_-_web.pdf.
31. Peilei, F. (2006) Promoting Indigenous Capability: The Chinese Government and the Catching-Up of Domestic Telecom-Equipment Firms. China Review, Spring 2006, v. 6, iss. 1, pp. 9-35.
32. Porto, G.; Turchi, L; and Rezende,P. (2013) Radiografia das parcerias entre PETROBRAS e as ICTs Brasileiras: uma análise a partir da ótica dos coordenadores de projetos tecnológicos. Em Turchi, L.; De Negri, J. and De Negri, F. (2013) Impactos Tecnológicos das Parcerias da PETROBRAS com Universidades, Centros de Pesquisa e Firmas Brasileiras, Ipea, Brasília, http://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/livro_impactos_tecnologicos_parcerias.pdf.

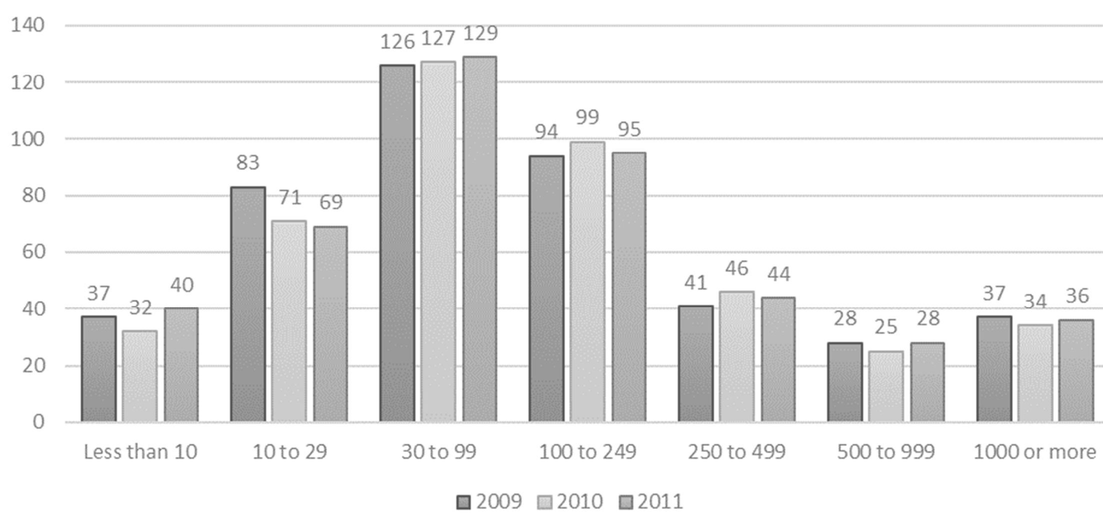
33. Rapini, M.; Oliveira, V.; Silva Neto, F. (2014) A natureza do financiamento influencia na interação universidade-empresa no Brasil? *Revista Brasileira de Inovação*, v. 13, n. 1, p. 77-108.
34. Rocha, F. (2011) O Desempenho dos Participantes no Programa de Garantia de Qualidade de Materiais e Serviços Associados. IPEA (2011) Poder de Compra da Petrobras: Impactos Econômicos nos seus Fornecedores. IPEA, Brasília. http://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=6477.
35. Rocha, F. (2015). Recursos naturales como alternativa para la innovación tecnológica: petróleo y gas en Brasil. http://www19.iadb.org/intal/intalcdi/PE/2015/15676.pdf.
36. Rocha, F. e Urraca Ruiz (2011) The role of the network coordinator in the attraction of foreign investments in R&D: The case of the Brazilian oil and gas industry. Transnational corporations, 20, 33-60.
37. Turchi, L.; De Negri, J. and De Negri, F. (2013) Impactos Tecnológicos das Parcerias da PETROBRAS com Universidades, Centros de Pesquisa e Firmas Brasileiras, Ipea, Brasília, http://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/livro_impactos_tecnologicos_parcerias.pdf.
38. WALLSTEN, S. (2000) The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research program. RAND Journal of Economics Vol. 31, No. 1, Spring.

Figure 1. Number of Employees in R&D (PoTec) and Number of Employees in R&D per Total Number of Employees, by Firm Size, 2011



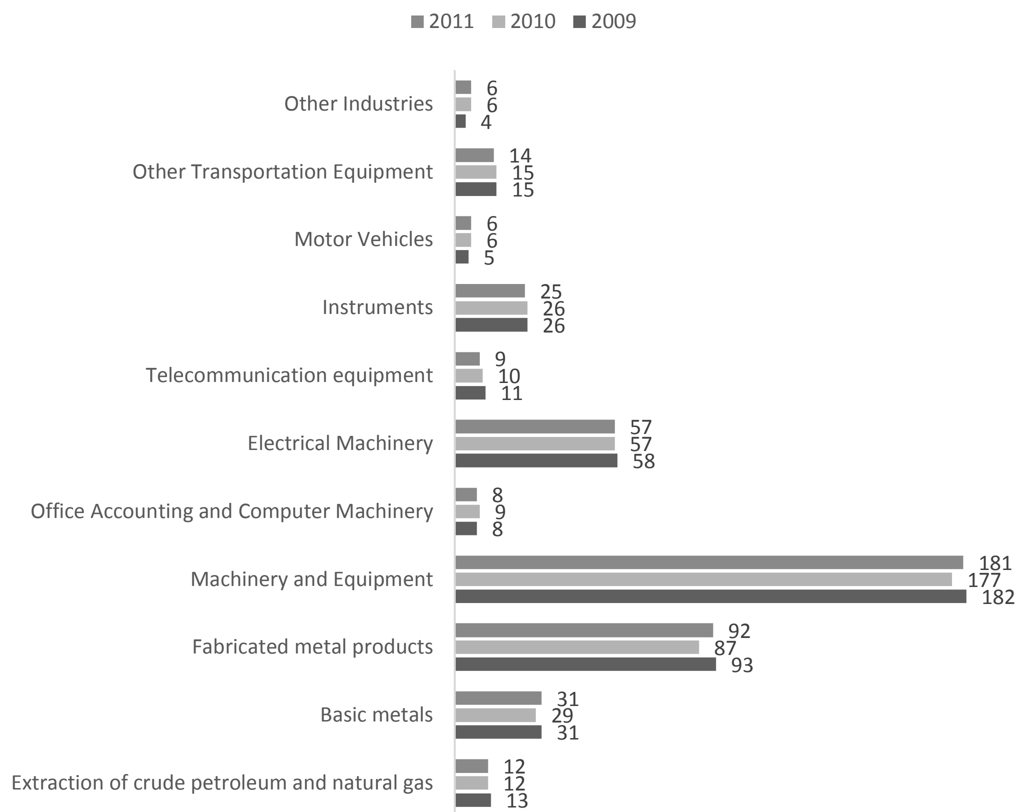
Source: Own elaboration from RAIS (2011).

Figure 2. Size distribution of the number of oil and gas suppliers, 2009, 2010 2011



Source: Own elaboration using RAIS.

Figure 3. Sectoral distribution of oil and gas suppliers, 2009,2010 and 2011



Source: Own elaboration using RAIS.

Table 1. Variables Description

Variable	Description
nemp	Number of employees
PoTec	Number of employees in R&D activities
inttec	PoTec/nemp
experience	Average number of months labor force is in the company
capacity	Number of employees with at least 12 years of schooling/total number of employees
sup	Number of employees with at least 16 years of schooling/total number of employees
wage	Average wage in terms of number of minimum wage
petro	dummy variable that assumes value 1 whenever company has been listed as an oil and gas supplier, 0 otherwise
size1	dummy variable for companies with 5 or less employees
size2	dummy variable for companies with 6 to 9 employees
size3	dummy variable for companies with 10 to 29 employees
size4	dummy variable for companies with 30 to 99 employees
size5	dummy variable for companies with 100 to 249 employees
size6	dummy variable for companies with 250 to 499 employees
size7	dummy variable for companies with 500 to 999 employees
size8	dummy variable for companies with more than 1000 employees

Table 2. Descriptive Statistics, Oil and Gas Suppliers and Non-Oil and Gas Suppliers, 2009-2011

		inttec	nemp	HHI	wage	experience	capacity
Non-suppliers	Count	276274	276274	276274	276274	276274	276274
	Mean	0.006	27.266	0.015	2.228	35.857	0.524
	Std. Dev.	0.043	290.238	0.033	1.657	37.092	0.367
	Min	0	1	0.001	0	0	0
	Max.	1	57459	0.725	114.39	513.2	1
Suppliers	Count	1321	1321	1321	1321	1321	1321
	Mean	0.037	421.545	0.031	5.114	60.131	0.672
	Std. Dev.	0.067	1766.690	0.067	3.026	34.259	0.222
	Min	0	1	0.001	0	0.52	0
	Max.	0.759	38979	0.725	18.572	274.708	1
Total	Count	277595	277595	277595	277595	277595	277595
	Mean	0.006	29.142	0.015	2.241	35.973	0.525
	Std. Dev.	0.043	315.302	0.033	1.678	37.117	0.366
	Min	0	1	0.001	0	0	0
	Max.	1	57459	0.725	114.39	513.2	1

Source: Own elaboration using RAIS.

Table 3. Probit regression

	Coef.	Std. Err.	z
size2	0.291	0.062	4.71
size3	0.675	0.046	14.76
size4	1.137	0.045	25.43
size5	1.549	0.049	31.57
size6	1.639	0.060	27.37
size7	1.802	0.074	24.31
size8	1.961	0.071	27.73
hhi	-0.631	0.256	-2.47
remmediadez	0.037	0.003	10.9
experience	0.005	0.000	18.65
capacity	0.339	0.049	6.93
sector27	-0.269	0.118	-2.27
sector28	-0.343	0.116	-2.96
sector29	-0.034	0.114	-0.3
sector30	-0.173	0.141	-1.22
sector31	-0.071	0.116	-0.61
sector32	-0.399	0.132	-3.02
sector33	-0.130	0.122	-1.06
sector34	-1.134	0.141	-8.02
sector35	-0.073	0.122	-0.6
sector36	-1.086	0.138	-7.87
_cons	-3.585	0.128	-28.05
N	277595		
LR chi	4779		
Pseudo R2	0.2851		

Table 4. Mean differences between treated and untreated samples

	Mean			t-test	
Variable	Treated	Control	%bias	t	p>|t|
size2	0.03272	0.03729	-1.6	-0.64	0.524
size3	0.16971	0.16058	2.3	0.63	0.529
size4	0.29072	0.28615	1.2	0.26	0.796
size5	0.21918	0.22983	-3.4	-0.65	0.513
size6	0.0997	0.10578	-2.8	-0.51	0.607
size7	0.05784	0.05327	2.6	0.51	0.61
size8	0.07991	0.07686	1.5	0.29	0.772
hhi	0.03056	0.03088	-0.6	-0.12	0.904
experience	59.879	60.304	-1.2	-0.26	0.793
capacity	0.6713	0.67733	-2	-0.66	0.509
remmediadez	5.0697	5.0154	2.2	0.34	0.733
hhi	0.03056	0.03088	-0.6	-0.12	0.904
sector27	0.06849	0.06393	2	0.47	0.638
sector28	0.20548	0.21689	-2.6	-0.72	0.474
sector29	0.40944	0.40183	1.7	0.4	0.691
sector30	0.01903	0.02588	-6.1	-1.18	0.236
sector31	0.1309	0.11872	4.3	0.94	0.345
sector32	0.02283	0.02588	-2.2	-0.51	0.613
sector33	0.0586	0.06545	-3.2	-0.73	0.467
sector34	0.01294	0.00989	1.8	0.73	0.463
sector35	0.03349	0.03729	-2.5	-0.53	0.598
sector36	0.01218	0.01446	-0.7	-0.51	0.61

Table 5. Regressions – Paired Sample, Dependent Variable inttec

inttec	OLS Pooled Data+ (1)	Tobit++ (2)	Tobit with Random Effects Panel (3)
petro	0.010*	0.026*	0.027*
	(4.27)	(6.89)	(5.3)
size3	0.014*	0.075*	0.067*
	(2.73)	(6.66)	(6.41)
size4	0.015*	0.109*	0.088*
	(3.25)	(10.11)	(8.66)
size5	0.019*	0.137*	0.105*
	(3.94)	(12.5)	(10.2)
size6	0.011**	0.138*	0.117*
	(2.02)	(11.89)	(10.82)
size7	0.018*	0.145*	0.126*
	(2.82)	(11.69)	(10.98)
size8	0.023*	0.149*	0.132*
	(3.74)	(12.2)	(10.99)
HHI	0.092*	0.110*	0.115*
	(4.22)	(3.57)	(3.37)
experience	0.0001*	0.000*	0.000*
	(4.72)	(6.23)	(6.56)
capacity	0.080*	0.165*	0.134*
	(14.54)	(16.85)	(13.3)
sigma_u		0.084	0.083
sigma_e			0.026
rho			0.910
Number of obs	2624	2624	2624
left-cens		1076	1076
uncens		1547	1547
right-cens		1	1
F(20, 2603)	27.66		
Wald			574.52
LR chi2(20)		918.34	
Adj R-squared	0.1689		

+ t statistics in parenthesis.
++ z statistics in parenthesis
* Significant at 1%.
** Significant at 5%
Sectoral dummies were omitted in the table.

Table 6. Oil and gas and non-oil and gas suppliers by performance of R&D

	Non-oil and gas		Oil and gas		INTTEC of R&D performers (%)
Size Cohort	Non-R&D	R&D	Non-R&D	R&D	
Less than 10	114	3	103	6	36.4
10 to 29	175	37	168	55	11.9
30 to 99	217	134	152	230	6.0
100 to 249	88	215	39	249	4.5
250 to 499	16	145	2	129	3.5
500 to 999		81	1	76	4.3
1000 or more	1	86		102	5.5
Total	611	701	465	847	5.4

Source: Own elaboration using RAIS.

Table 7. Two Part Regression

	Probit Model++	Marginal effects after probit	OLS model+
petro	0.517*	0.186*	0.009*
	(8.00)	(8.1)	(2.7)
size3	1.214*	0.332*	-0.229*
	(6.63)	(9.04)	(-9.77)
size4	2.042*	0.524*	-0.289*
	(11.6)	(15.3)	(-12.78)
size5	2.930*	0.583*	-0.297*
	(16.13)	(21.69)	(-13.16)
size6	3.691*	0.488*	-0.312*
	(17.42)	(22.71)	(-13.73)
size7	4.602*	0.435*	-0.307*
	(11.52)	(23.84)	(-13.36)
size8	4.751*	0.461*	-0.301*
	(10.92)	(26.81)	(-13.14)
experience	0.005*	0.002*	0.000**
	(6.81)	(6.75)	(2.49)
capacity	1.519*	0.550*	0.152**
	(9.78)	(9.57)	(15.74)
HHI	2.334*	0.845*	0.061*
	(2.59)	(2.6)	(2.44)
Number	2624	2624	1548
LR chi 2(20)	1521.28		
F(20, 1527)			36.36
Adjusted R2			0.31
Pseudo R2	0.42		

+ t statistics in parenthesis.
++ z statistics in parenthesis
* Significant at 1%.
** Significant at 5%
Sectoral dummies were omitted in the table.

Table 8. Two Part Regression, by firm size

	Less than 250 employees			250 or more employees		
probit	Probit++	Marginal effects after probit++	OLS+	Probit++	Marginal effects after probit++	OLS+
petro	0.503*	0.196*	0.005	0.900*	0.015	0.017*
	(7.49)	(7.64)	(0.98)	(3.00)	(1.49)	(3.69)
size3	1.232*	0.456*	-0.229*			
	(6.68)	(7.95)	(-8.8)			
size4	2.056*	0.694*	-0.290*			
	(11.6)	(16.83)	(-11.54)			
size5	2.950*	0.823*	-0.296*			
	(16.11)	(34.99)	(-11.84)			
size7				1.067**	0.010	0.005
				(2.41)	(1.46)	(0.84)
size8				1.245**	0.013	0.014**
				(2.55)	(1.65)	(2.62)
HHI	1.853	0.729	0.066	0.661	0.009	0.000
	(1.64)	(1.64)	(1.25)	(0.35)	(0.35)	(-0.01)
experience	0.005*	0.002*	0.000*	0.008	0.000	0.000
	(6.65)	(6.66)	(2.83)	(1.61)	(1.21)	(0.26)
capacity	1.548*	0.609*	0.162*	1.636**	0.023	0.151*
	(9.58)	(9.63)	(12.2)	(2.45)	(1.38)	(11.52)
N	1985		929	639		600
LR chi2	860.31			46.89		
F			29.08			12.83
Adjusted R2			0.33			0.21
Pseudo R2	0.31			0.26		

+ t statistics in parenthesis.
++ z statistics in parenthesis
* Significant at 1%.
** Significant at 5%
Sectoral dummies were omitted in the table.