Procurement in Big Science Centres: politics or technology? Evidence from CERN

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Abstract: Procurement from Big Science Centers (BSC) yields a variety of spillover effects that can ultimately have growth enhancing consequences for their partner countries. We study the determinants of procurement for the biggest research infrastructure ever built: the Large Hadron Collider (LHC) at CERN. Using a unique cross-section database of firms that have registered to become industrial partners of the LHC program, we estimate the determinants for potential suppliers of receiving an order from CERN. We compare the relative weight of firms' technological features and CERN's procurement rules aimed at securing a juste retour for its Member States. Our results point to a strong impact of technological factors, while also highlighting the importance of political constraints related with CERN's procurement rules as well as the presence of a home bias. Since the constraints related with the achievement of a juste retour affect directly or indirectly the procurement policy of many European BSCs our results have policy implications that go beyond the CERN case study.

Key Words: big science; procurement; innovation; hi-tech; CERN.

JEL Codes: C21; C25; H57; O32; O38.

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1 Introduction

Public procurement is increasingly used as strategic lever by governments; in fact, their large purchases of goods and services can also be exploited to pursue broader targets such as economic, environmental and innovation policies. As of 2016, 24 OECD countries reported to use public procurement as a demand-side innovation policy (OECD, 2016; Edler and Georghiou, 2007). The importance of procurement as a policy tool is explained, inter alia, by its volume. For European OECD countries government procurement expenditure in 2015 accounted on average for 11.9% of Gross Domestic Product (GDP), ranging from 7.3% of GDP for Ireland to 20.2% of GDP for the Netherlands (OECD, 2016).

By virtue of the sheer size of their research infrastructures and scientific instruments and the generous budget they manage, procurement from Big Science Centers (BSCs) has the potential of being an important tool for the innovation policies of governments funding them. While BSCs are purposefully built to address broad and complex research questions, their Member States (MS) fund them not only for the promise of scientific discoveries, but also for the the economic and societal spillovers they can generate (Autio et al., 2004; Florio et al., 2018a; Vuola and Hameri, 2006). For this reason, the procurement rules of several European BSCs incorporate, or are inspired by, the so-called juste retour principle. This is a general understatement that MS should be compensated for their contribution to the BSC's budget with an equitable distribution of procurement contracts. Singling out which factors drive the procurement of BSCs is thus of direct interest for policy makers. Moreover, identifying the determinants of procurement at BSCs is key for firms wishing to gain a better understanding of the paths and potential bottlenecks they might face when participating to tenders.

The present paper considers the determinants of procurement for Big Science projects, focusing on the tension between firms' embodied technological knowledge and the BSCs' procedures and political constraints. Our study relies on a unique cross-section database of firms that have registered to become industrial partners for the construction of the biggest research infrastructure ever built: the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN). We compare the relative weight of firms' technological features and CERN's procurement rules aimed at securing a juste retour for its MS. Our results, based on the estimation of binary response models, point to a strong impact of technological factors, while also highlighting the importance of political constraints related with CERN's procurement rules, as well as the presence of a home bias that increases the probability of becoming suppliers for French and Swiss firms.

We contribute to different strands of the literature. First, the branch of the literature that deals with the relationship between BSCs and their industrial partners has showen that there are a variety of benefits for all parties involved (Vuola and Hameri, 2006; Bressan and Bianchi-Streit, 2005), but has remained silent about the determinants of the procurement process.[1] Second, while there is a wide array of empirical and theoretical contributions focusing on the explanation and consequences of the presence of a home bias in government procurement (see e.g. Shingal, 2015, and references therein), we provide for the first time evidence of its existence also in BSCs.

The rest of the paper is organized as follows. Section 2 provides a background on CERN, its procurement policy and discusses the juste retour principle in BSCs. Data, methods and research questions are presented in Section 3. Section 4 is devoted to descriptive statistics and main results, while additional empirical evidence and robustness checks appear in Section 5. Section 6 concludes.

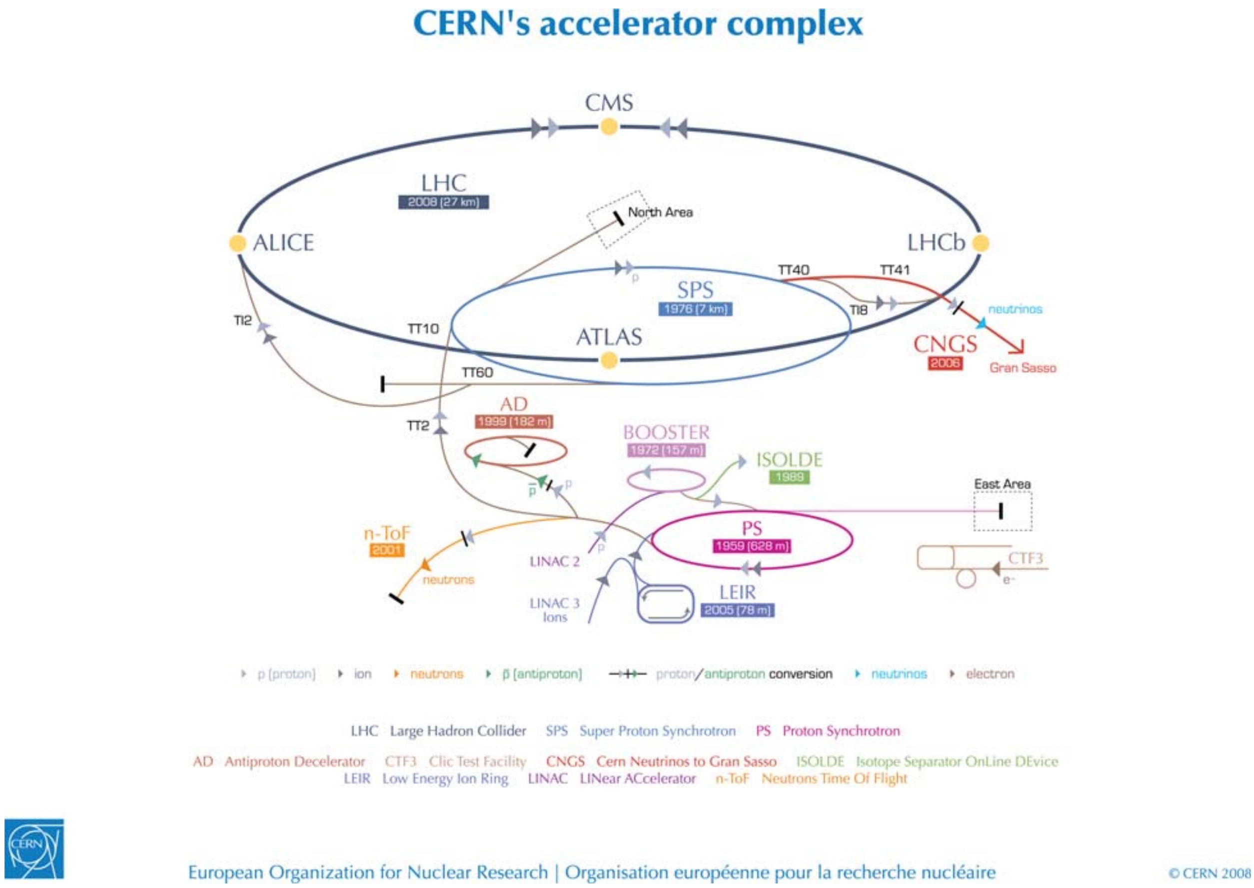
2 Procurement at CERN and the juste retour principle in Big Science

2.1 CERN: Background

CERN, located in Geneva, Switzerland, is a leading research institution in the field of fundamental physics whose mission is to push the frontiers of science and technology (Nilsen and Anelli, 2016). There are 22 MS – each with a single vote at the CERN Council – that run the Organization, contribute to capital and operating costs of its programs and express

[1] These benefits include technological innovation, learning and other spillover effects (Florio et al., 2018b; Tuertscher et al., 2014) that also generate increased sales and cost savings for hi-tech firms (Bianchi-Streit et al., 1984; Castelnovo et al., 2018).

Figure 1: The accelerator complex at CERN



Source: `https://cds.cern.ch/record/1260465`

their vote in the Council that approves the Organization's activities, adopts its budget and reviews expenditure.[2] CERN research involves over 17,500 people belonging to about 1,500 institutes from all over the world (CERN, 2018).

The LHC, built between 1995 and 2008, is hosted in a 27km circumference underground tunnel located beneath the border between Switzerland and France. Although the LHC is installed in the tunnel that hosted CERN's previous big accelerator – the Large Electron-Positron Collider, dismantled in 2000 – its construction involved additional civil engineering works (e.g. for the excavation of large caverns that host the detectors[3]). The main scientific

[2]As of January 2018 MS are: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland and United Kingdom. Cyprus, Serbia and Slovenia are Associate MS in the pre-stage to Membership. India, Lithuania, Pakistan, Turkey and Ukraine are Associate MS.

[3]Detectors are machines that gather information used by physicists to identify particles. The largest detector at the LHC is ATLAS. It weighs 7,000 tonnes and has the dimensions of a cylinder – 46 meters long and 25 meters in diameter – that sits in a cavern 100 meters below ground (https://atlas.cern).

goal of the LHC is to test the limits of the Standard Model of particle physics – a set of theories embodying the current understanding of fundamental forces and particles in the Universe, as well as their interactions (Evans, 2016).

As shown in Figure 1 the LHC is part of an accelerator complex, that is a succession of machines with increasingly higher energies (Evans, 2016). Each accelerates a beam of particles before injecting the beam into the next machine in the chain. Inside the LHC, which is the last element of this chain, two beams of particles[4] travelling in opposite directions, at close to the speed of light, are made to collide at four points around the machine. There are seven experiments – run by collaborations of scientists from institutes from all over the world – installed at the LHC (i.e. ALICE, ATLAS, CMS, LHCb, LHCfm, TOTEM, MoEDAL) each with a different research goal. The four biggest experiments are ALICE, ATLAS, CMS and LHCb; these are installed in underground caverns built around the four collision points of the LHC beams. CERN is a member and finances of each of these experimental collaborations, but these are individual entities funded independently from CERN.

The total construction cost of LHC was of 4,332 MCHF (CERN, 2019b). During the 1995-2015 period, about 4,200 firms were involved in CERN's activities (CERN, 2019a). New solutions developed for research purposes by CERN with the involvement of the industry have found applications in many fields including computing, medical, biomedical and aerospatial technologies (Battistoni et al., 2016; Florio et al., 2018a; Jewell, 2008), suggesting the importance for society as a whole of its activities, due to the spillovers in several fields and across different actors.

While research at CERN currently focuses on LHC operations, there are also experiments at other accelerators and facilities. See Figure 1. CERN's Medium-Term Plan helps obtaining a rough estimate of the relative importance of LHC and non-LHC experiments. The total expenses over the 2017-22 period are expected to amount to 7,145 MCHF (CERN, 2017, p. 16). A considerable amount of this budget, 4,615 MCHF (64.6%), is devoted to scientific programs, projects and studies, while the rest is made up of centralized expenses (including personnel and energy) and other outlays for infrastructures and services. Ex-

[4] protons or ions – belonging to the group of particles called hadrons –

penses for the LHC program represent 60.6% of this amount (or 39.1% of the total budget), while the remaining 39.4% (or 25.5% of the total budget) is devoted to non-LHC activities.

2.2 Procurement at CERN

CERN has a complex set of procurement rules and procedures that combine technological aspects with "political" constraints, making the process of becoming a supplier not immediately predictable. CERN's procurement policy is based on three pillars (CERN, 2015): (*i*) to guarantee that contracts satisfy technical and financial requirements (*ii*) to keep costs as low as possible and (*iii*) to achieve balanced industrial returns for its MS.

Several correction mechanisms are thus in place to achieve these three goals that also include compliance with the juste retour principle. However, as shall be clarified in Section 2.3, CERN's application of the juste retour principle is more nuanced than, for example, at the European Spatial Agency (see below).

When contracts exceed 100,000 CHF they should be awarded in compliance with the achievement of "well-balanced industrial return coefficients" for the MS. A MS is well-balanced if its return coefficient, defined as the ratio between that country's percentage share of the value of all contracts during the preceding four calendar years and its percentage contribution to the CERN Budget over the same period, is equal or greater than a certain threshold. On the contrary, poorly balanced countries have a return coefficient below this threshold.

Provided that technical, financial and delivery requirements of the contract are met, CERN has three main tools to improve the return coefficient to poorly balanced MS: limited tendering, alignment and splitting rules (see CERN, 2015, p. 37-42). In the case of limited tendering, only firms from poorly balanced MS can participate in the tendering procedures. Alignment instead gives priority to firms in poorly-balanced countries, even if they are not providing the lowest bid.[5] When technically feasible, contracts can also be split among multiple bidders to give an advantage to firms in poorly-balanced countries, even if they

[5] For instance, if the lowest bid is posted by a firm in a well-balanced country, CERN negotiates with the two lowest bidders in poorly-balanced MS, provided that their bids fall within 20% of that of the lowest bidder. If one of these two firms aligns its price to that of the lowest bidder in the well-balanced country, it gets the contract.

have not posted the most economically convenient bid. See Zilverschoon (1974); Åberg and Bengtson (2015); CERN (1993a,b) for further details.

2.3 The juste retour principle in Big Science Centres

The juste retour principle inspires – with different nuances – not just the procurement policy of CERN, but also that of many other European BSCs, where many sovereign countries contribute with their public funds to the institution's budget. The idea of a juste retour finds its roots in the 1984 Fontainebleau Agreement when during the European Council the UK Prime Minister Margaret Thatcher negotiated a reduction in the British contribution to the EU budget (Le Cacheux, 2005). This reduction was seen as a "compensation" for any shortfall between what the UK paid into the EU and what it got back. In particular, it was asked on the premise that, because of its relatively small farming industry, the UK benefited less than other countries from the Common Agricultural Policy.

Support for this principle is not universal and it has sparked several criticisms at the European level. These include a warning that the principle might go against the principles of the European Union (Rodgers, 1988) and that there might be a conflict with the requirement of granting the contact to the lowest bidder (OECD, 2010). Nevertheless, constraints related with the achievement of a juste retour condition the procurement policy of many BSCs in Europe. Its rationale, in the context of multi-actor research centers, is to ensure that the MS receive a value of contracts, via procurement, which is proportional to their contribution to the aggregate budget.

A leading example is the European Spatial Agency (ESA). Since its origin in 1975 ESA explicitly cites building a European space industry and increasing its competitiveness, as one of its objectives, leading to the application of a strict juste retour principle. Returns to a MS via contracts with ESA should amount to 100 per cent of that MS's contributions to ESA's budget (Rodgers, 1988). Similarly, the European Synchrotron Radiation Facility (ESRF) – located in Grenoble, France – "*aims for a juste retour with respect to the shareholders' contributions*" (ESFRI, 2018, p. 204) and considers a return coefficient computed as the ratio of expenditures by a MS and its contribution over the past three years (ESRF has 13

MS and 9 Scientific Associate countries)[6]. A less stringent application of the juste retour principle is implemented at European Molecular Biology Laboratory. This intergovernmental organization operates across six sites and has 26 MS. Although it does not have any strict obligation to provide a fair distribution of procurement orders to its MS, it does strive for delivering a juste retour to them (Cudraz, 2019).

3 Data, Methods and Research Questions

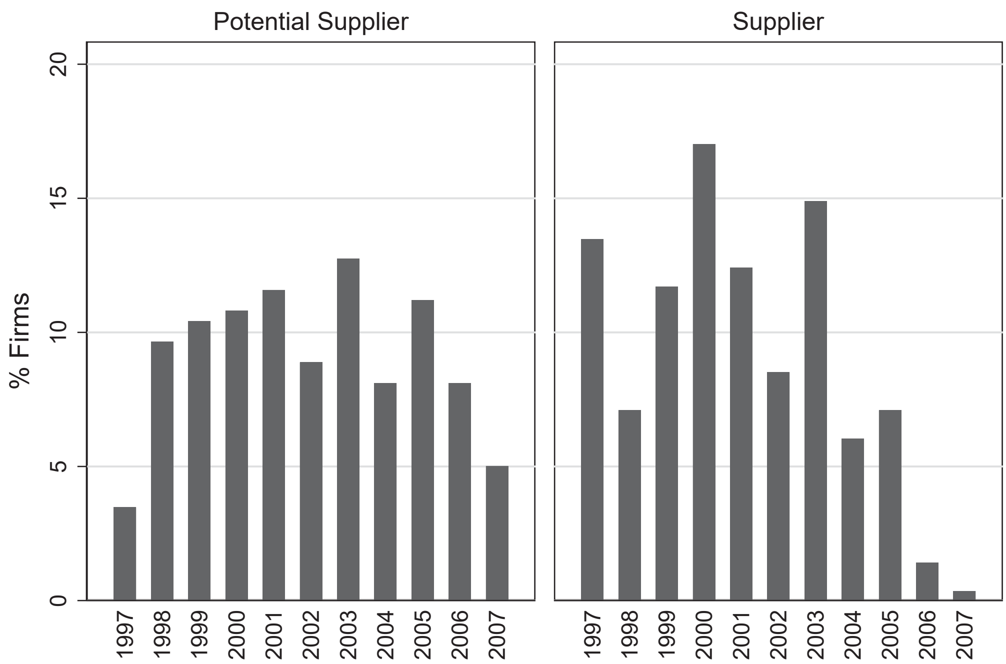
3.1 Data

We have assembled a unique cross-sectional dataset, combining information sourced from CERN and from the ORBIS database maintained by Bureau van Dijk, to identify 541 firms that over the 1997-2007 period have registered with the CERN Procurement and Industrial Services Group for collaborating at the construction of the LHC. Since, as we have seen in Section 2.1, the seven experimental collaborations installed at the LHC do have some procurement autonomy, firms in our database do not include all of the entities involved in the construction of LHC.

While the construction of the LHC started in 1995 and was completed in 2008, we rely on data for 1997-2007 period because – as shown in Figure 2 – in this sub-sample we have, for each year, both LHC suppliers and potential suppliers. Potential suppliers are firms that have registered with CERN but have never received an order during the time period considered in our analysis. Although we work with a cross-section database that portraits the current classification of firms into suppliers and potential suppliers, we need to capture the time-varying nature of some variables. In these cases, variables refer to the year of registration of firms to CERN's procirement database. Our empirical strategy exploits the fact that only 285 statistical units out of 541 – or 52.7% of the total – have actually received at least one LHC-related order. Figure 2 shows that, while the number of LHC

[6] ESFR is the most intense source of synchrotron-generated light, producing X-rays 100 billion times brighter than the X-rays used in hospitals (see `http://www.esrf.eu/about`). ESFR is a sort of "super-microscope" which records the position and motion of atoms in condensed and living matter. Researchers at ESFR explore materials and living matter in many fields including chemistry, material physics, archaeology and cultural heritage, structural biology and medical applications, environmental sciences, information science and nanotechnologies. See: https://www.cdti.es.

Figure 2: Distribution of firms over registration years



suppliers diminishes noticeably at the of end sample, potential suppliers are somehow more uniformly distributed, at least over the 1998-06 period. The reduction of suppliers in 2006 and 2007 is consistent with the fact that the LHC project was completed in 2008 when the experimental activity began. Moreover, we can see that the yearly number of suppliers – and to a lower extent also that of potential suppliers – varies considerably over sample period; this variability is linked with the LHC project schedule that dictates the intensity of tendering activities for the different components of the accelerator.

3.2 Dependent variable and empirical strategy

We model the conditional probability of becoming an industrial partner of CERN for firms that have registered to collaborate at the construction of the LHC. This is denoted as $p_i \equiv \Pr(y_i = 1 \,|\mathbf{x}_i)$, where y_i is binary variable that is equal to one for LHC suppliers and equal to zero for potential suppliers and $\mathbf{x}_i$ is a $(K \times 1)$ column vector collecting explanatory variables for firm i. Our baseline results rely on the following logit model:

$$y_i = \Lambda\left(\mathbf{x}_i'\boldsymbol{\beta}\right) = \Lambda\left(\mathbf{f}_i'\boldsymbol{\beta}_{\boldsymbol{f}} + \mathbf{z}_i'\boldsymbol{\beta}_{\boldsymbol{z}}\right) \tag{1}$$

where $\Lambda(m) \equiv \exp(m)/\left[1+\exp(m)\right]$ is the logit function and $\boldsymbol{\beta}$ is a $(K \times 1)$ vector of parameters. In Equation (1) the vector of explanatory variables $(\mathbf{x}_i)$ is partitioned into focus $(\mathbf{f}_i)$ and control variables $(\mathbf{z}_i)$, that we discuss in detail in Sections 3.3 and 3.4. A set of robustness checks, including the estimation of Probit models in place of Logit models, are presented in Section 5.

3.3 Focus variables

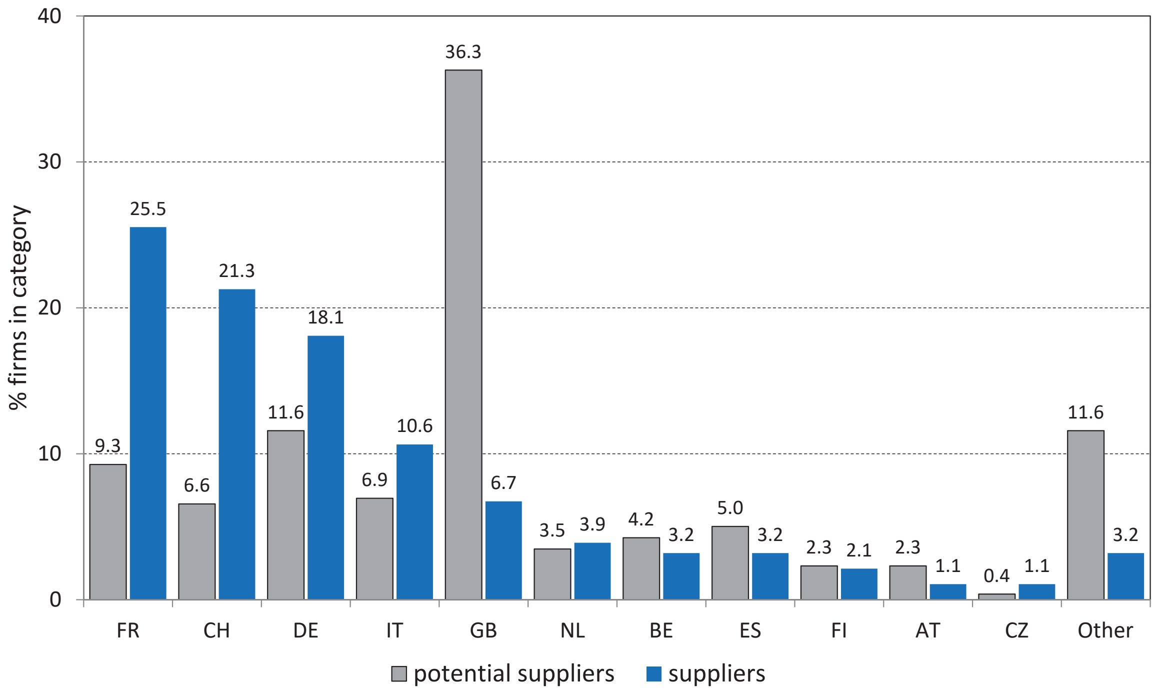
The focus explanatory variables $(\mathbf{f}_i)$ in our analysis capture the two main forces that are expected to affect the probability of receiving an LHC-related order: firms' technological expertise and CERN's procurement rules.

CERN seeks firms able to successfully deliver the technologies it requires to advance the frontier of knowledge in particle physics. The ability of firms to satisfy the technical requirements of the tender is one of the pillars of CERN's procurement policy. With the help of experts at CERN, we have created a dummy variable that classifies firms into hi- and lo-tech ("*Hi-tech*"). This variable equals one if a firm has registered for at least one order deemed as hi-tech.[7] A firm's technological expertise has an impact on its ability to decode CERN's requirements and deliver to the expected standards. The CERN-supplier relationship can be refereed to as a "dyad". If both parties of the dyad share high levels of technological expertise, learning processes and mutual understanding are enhanced (Autio et al., 2004). The construction of the LHC required the development of several new technologies, thus we expect hi-tech firms to have a comparative advantage over lo-tech competitors in becoming CERN's industrial partners.

Three variables related to procurement rules have been collected from CERN archives and databases. First, the industrial return of each country to CERN's budget ("*Ind. Ret.*").

[7]Examples of hi-tech items are magnets and radiofrequency cavities. Magnets are used to ensure that particles in the accelerator do not drift apart and are able to follow complex paths while maintaining speed. To accelerate particles, the accelerators are fitted with metallic chambers containing an electromagnetic field known as radiofrequency cavities. See: `https://home.cern/science/engineering`.

Figure 3: Geographical distribution of firms



This variable is related to the principle of juste retour according to which the aggregate value of contracts awarded to a MS should reflect its contribution to CERN's budget. The return coefficient of a MS is defined as the ratio between its percentage share of the value of all contracts over the preceding four years and its percentage contribution to the CERN Budget over the same period. CERN applies different return coefficients for supply and service contracts. Since we are not able to distinguish between these two types of contracts, we rely on an average for supplies and services. Given that the return coefficient measures the value of contracts recently awarded to firms in a given MS weighted by its contribution to CERN's budget, we expect this variable to be positively associated with the probability of becoming a supplier.

However, CERN does not implement a strict juste retour policy which would imply a one to one relationship between contribution to the budget and value of contracts awarded. Rather, CERN aims to achieve a balanced industrial return for its MS: it "weights" the percentage value of contracts awarded with the percentage contribution of each MS. If a MS is poorly balanced – provided that technical requirements are met – a set of correction mechanisms are activated to favor firms in those countries with the aim of improving the industrial return of that MS (see Section 2.2). To capture this aspect in our empirical model, we consider a dummy that characterizes the country as poorly or well balanced ("*Poorly balanced*"). We define a country as "poorly-balanced" if its return coefficients for services and supplies are both below their respective threshold; the probability of supplying an LHC-related order is expected to be positively associated with this variable.

To account for possible spatial proximity effects, we also include a dummy variable ("*Home*") that takes on value one if a firm is located in France or Switzerland. Figure 3 shows that 46.8% of suppliers are located either in France or Switzerland. Interestingly, the existence of a bias in favor of French and Swiss firms has been documented as early as 1992, with figures suggesting that France and Switzerland, while contributing to CERN's budget for 17% and 4%, respectively, received contracts accounting for 33% and 24% of total orders (Rodgers, 1992).

The existence of a home bias in CERN procurement is consistent with Breton and Salmon (1996) who showed that governments may discriminate in favor of local suppliers because geographic proximity may reduce monitoring costs (see also Williams, 2014). According to (Shingal, 2015), based on the analysis of previous literature on the subject, an underlying explanation for the existence of home bias in public procurement is related to the possibility of minimizing average procurement costs due to asymmetric information. Other possible drivers are related to the nature of the product or service under procurement; the number of domestic and international competitors in the specific market object of the contract; compliance costs, including search and monitoring costs which are lower for domestic suppliers; and practical considerations, including the language of the tender or the low value of the contract which might act as a deterrent for foreign firms.

We capture the time-varying nature of "*Ind. Ret.*" and "*Poorly balanced*" considering the value of these variables for the year when firms registered in the CERN procurement database. This issue is further investigated in Section 5.5.

3.4 Control variables

We include a large set of control variables ($\mathbf{z}_i$) to all our empirical models. We have retrieved information on firm size and primary NACE 2 digit activity code from the ORBIS database. Dichotomous variables classifying firms as large, medium or small enter the regression models as a set of size fixed effects ("*Size FE*").[8] Similarly, dichotomous variables are used to identify a firm's primary economic activity and enter the logit model as a set of sector fixed effects ("*Sector FE*").

As shown in Figure 2 both the number of actual and potential suppliers vary over time. These patterns are correlated with the schedule of the LHC program. Depending on the phases of the project's life cycle, there will be years with a higher (or lower) number of tenders and contracts awarded, which are independent of firms' characteristics or CERN's procurement policy. To capture these dynamics, we have constructed a set of dichotomous variables, one for each year in the 1997-2007 period ("*Registration year FE*"). Each of these binary variables equals one the year that the firm first registered to tender for an LHC contract and zero otherwise.

For each firm we also collect information on the number of orders they registered for, "*log(no. orders)*". This variable counts the number of applications by each firm in the database since its registration year. It captures different dimensions of a firm's relationship with CERN. If a firm applies several times in the procurement tendering procedure, it progressively gains understanding about the process and rules applied by CERN, thus increasing its knowledge and probability of success by means of experience (Tammi et al., 2014; Flynn and Davis, 2017). Moreover, a higher number of applications is expected to be associated with a decrease in cognitive distance between the potential supplier and CERN (Caloffi and Gambarotto, 2017). Both interpretations suggest a positive sign for the estimated coefficient on "*log(no. orders)*".

To further control for the fact that the longer a firm has been registered the more applications it has likely filed, thus leading to a higher probability of becoming a supplier,

[8]The ORBIS' definition of firm size summarizes three variables: operating revenues, total assets and employees. In ORBIS firms are divided into four size categories: very large, large, medium or small. We bundle together ORBIS' very large and large categories.

the number of years in the CERN database has been added. This variable ranges from 1 to 11 and is denoted as "*Years in CERN DB*".

3.5 Research questions

Having discussed CERN's procurement rules, as well as our data, we are now in a position to illustrate our research questions and tightly link them to our empirical strategy:

$\mathcal{RQ}_1$. Is the probability of becoming an industrial partner of CERN associated with firms' technological level?

$\mathcal{RQ}_2$. Are political constraints important? If so, such probability should also be associated with variables capturing CERN procurement rules.

$\mathcal{RQ}_3$. Is there a home bias in CERN's procurement? If so, geographical proximity should also increase the probability of becoming a supplier for the LHC project.

$\mathcal{RQ}_4$. What is the relative importance technological factors and political constraints?

Given the discussion in previous Sections, our expectations on estimated coefficients are the following. With respect to $\mathcal{RQ}_1$, we expect the coefficient on "*Hi-tech*" to be positive (Autio et al., 2004). Considering $\mathcal{RQ}_2$ we expect the coefficients on "*Ind. Ret.*" and "*Poorly balanced*" to be both positive, since political constraints affecting CERN's procurement rules will impact on a firm's probability of successfully initiating a supplier relationship (Åberg and Bengtson, 2015). A specific aspect, unrelated to technological or cost features of the contracts, is the existence of a possible home bias, summarized by the dichotomous variable "*Home*" in the set of focus variables. The literature and the previous empirical evidence discussed in Section 3.3 lead us to expect, for $\mathcal{RQ}_3$, the existence of a home bias affecting CERN procurement. As for $\mathcal{RQ}_4$, since CERN does not apply a strict juste retour policy and is a mission-oriented organization (Florio et al., 2018b), whose main goal is to push the frontier of research in particle physics, we expect that ensuring that the technical requirements of the contract are met should have a priority on the political constraints to its procurement activity.

4 Results

4.1 Descriptive Statistics

Table 1 shows the sample average of the main explanatory variables considered in our regression models dividing firms into LHC suppliers and potential suppliers. The last column of the table reports p-values for the two-sided null hypothesis that means are equal across the two groups.

As we can see potential suppliers and LHC suppliers do not show any statistically significant difference for what concerns the proportion of firms in each size class or in terms of the hi-tech classification. In fact, the percentage of hi-tech firms is 46% for potential suppliers and 47% for suppliers. The second and third row of Table 1 show that while suppliers' host country on average have a higher industrial return, a higher percentage of potential suppliers are located in poorly balanced countries. In both cases, the difference in mean is statistically significant at the 0.01 level. The fact that a higher percentage of potential suppliers is hosted in poorly balanced countries might signal that, given that CERN implements measures to provide a well-balanced return coefficient to the MS firms belong to, there is an incentive for firms in those countries to apply for an order.

Descriptive statistics also highlight that suppliers tend to be in the CERN procurement database for a longer time period and have also registered for more orders than potentials suppliers (4 versus 3 orders on average). Moreover, looking at the fourth row of Table 1, we see that a much higher percentage of suppliers, 46.81%, is located either in Switzerland or France. The difference in mean for these three variables is statistically significant at the 0.01 level.

Table 1: Sample average of variables for suppliers and potential suppliers

	Variable	Potential Supplier	Supplier	p-value
$\mathbf{f}_i$	Hi-tech (%)	46.33	47.16	0.8469
	Ind. Ret. (t=0)	0.95	1.71	0.0000***
	Poorly balanced (t=0) (%)	29.73	18.44	0.0022***
	Home (%)	15.83	46.81	0.0000***
$\mathbf{z}_i$	Small (%)	28.96	23.05	0.1186
	Medium (%)	35.91	37.59	0.6859
	Large (%)	24.32	26.60	0.5452
	Very Large (%)	10.81	12.77	0.4814
	Years in CERN DB	6.00	7.22	0.0000***
	log(no. orders)	1.05	1.32	0.0001***

Notes: the table shows the sample average for each focus $\mathbf{f}_i$ and control $\mathbf{c}_i$ variable in the first column. The last column shows the two-sided p-value for the null hypothesis equal of means.

4.2 Main Results

Table 2 shows estimates of the logit model in Equation (1). We consider three specifications that differ according to which of the focus variables are included in the model; moreover, we note that the same full set of control variables is included in all models. All inferences are based on the heteroscedasticity-consistent estimator of the covariance matrix, due to White (1980), to capture the effects of firms' unobserved and unmodeled heterogeneity.

In order to answer our main research questions we begin from the assessment of whether becoming a supplier is more likely for firms providing CERN with hi-tech expertise and solutions ($\mathcal{RQ}_1$). To this end, we note that the coefficient on the indicator variable "*Hi-tech*" is positive and statistically different from zero at the 0.01 significance level in all specifications. This supports the fact that, as documented by Vuola and Hameri (2006), the amount of hi-tech knowledge and expertise should increase the probability of becoming a supplier. Interestingly, the magnitude of the coefficient on "*Hi-tech*" does not vary much across specifications.

We now focus on the relative weight of CERN's procurement principles in determining the probability that a firm becomes a supplier, alongside with firms' technological expertise examined above ($\mathcal{RQ}_2$). To this end, we consider the value of contracts recently awarded to firms in a given MS weighted by its contribution to CERN's budget, that is the coefficient on "*Ind. Ret.*", that enters all specifications. Chances are that, *ceteris paribus*, firms belonging

Table 2: Logit models: factors affecting the probability of becoming LHC supplier

	(1) $\mathcal{M}_1$	(2) $\mathcal{M}_2$	(3) $\mathcal{M}_3$
Hi-tech	0.411*	0.408*	0.480**
	(0.215)	(0.216)	(0.219)
Ind. Ret. (t=0)	0.652***	0.661***	0.175
	(0.108)	(0.117)	(0.150)
Ind. Ret.× Poorly Bal. (t=0)		0.157	
		(0.678)	
Home			1.578***
			(0.435)
Years in CERN DB	0.395***	0.394***	0.401***
	(0.150)	(0.150)	(0.146)
log(no. orders)	0.570***	0.569***	0.625***
	(0.131)	(0.131)	(0.141)
Size FE	✓	✓	✓
Sector FE	✓	✓	✓
Registration year FE	✓	✓	✓
N	541	541	541

Notes: heteroscedasticity-consistent standard errors in parentheses; "*" p-value < 0.10, "**" p-value < 0.05, "***" p-value < 0.01; "N" is the number of observations. We included sets of dichotomous variables corresponding to size of firms ("Size FE"), two-digits NACE codes are included ("Sector FE") and year of registration with CERN ("Registration year FE").

to MS with high industrial return will be more likely to obtain the deal with respect to firms hosted in a country with a low industrial return. This is part of CERN's overall procurement policy, given that – as discussed above in Section 2.2 – it is an international venture based on the monetary contributions of its MS. Columns (1-3) of Table 2 show that, as expected, the probability of becoming CERN's industrial partners is positively associated with the industrial return the MS that hosts the firm. The coefficient on "*Ind. Ret.*" is statistically significant at the 1% level in $\mathcal{M}_1$ and $\mathcal{M}_2$, while it is much smaller and statistically not distinguishable from zero in $\mathcal{M}_3$, when "*Home*" is added to the model.

As a way of enforcing the juste retour principle, CERN implements a set of procurement rules – such as, limited tendering, alignment and splitting rules – with the aim of improving the return coefficient of its MS. To capture the role of these rules in determining the probability of becoming a supplier of CERN, in model $\mathcal{M}_2$ we interact "*Ind. Ret.*" with the indicator variable "*Poorly balanced*", that takes on unit value if the firm's home country is poorly balanced and zero otherwise. Because of the enforcement of a set of rules aimed at improving the return coefficient in poorly balanced countries, we expect a positive sign on the coefficient of this interaction term.[9]

While the estimated sign is consistent with this prediction, the impact of the interaction with "*Poorly balanced*" is not statistically distinguishable from zero. A possible explanation is that this rule applies only to contracts above a certain monetary value, and depends on whether the contract is for "services" or "supplies". Moreover, we are considering only a sub-sample of all CERN's suppliers, namely those that contributed to the construction of the LHC. It might well be that compliance with political constraints is done within the whole universe of suppliers (see Section 2.2).

Finally, to provide an answer to $\mathcal{RQ}_3$, the variable "*Home*" enters $\mathcal{M}_3$ to control for the existence of localized effects in the choice of suppliers (Williams, 2014) and verify whether Swiss and French firms have a greater chance of becoming suppliers. See Figure 3. Notice that, since Switzerland and France are always well-balanced, we cannot simultaneously include "*Home*" and "*% Poorly balanced*". An increase in the probability of securing an order for firms in CERN's host countries – that we refer to as home bias – could reflect the fact that geographical proximity facilitates monitoring, as well as communications and interactions with CERN offices due to language and cultural factors. Moreover, geographical proximity can also reduce the costs of procurement, including search and monitoring costs. We do find evidence of a home bias: the estimated coefficient on "*Home*" is positive and statistically significant at the 0.01 level. The inclusion of this variable makes the coefficient on "*Ind. Ret.*" statistically not distinguishable from zero. This is explained by the fact that the highest average values of "*Ind. Ret.*" are recorded for Switzerland and France.

We now turn to control variables, $\mathbf{z}_i$. We see that, as expected, the estimated coefficient

[9]There are two reasons for considering an interaction term. First, it captures the fact that the association between "*Ind. Ret.*" and the probability of becoming a supplier is expected to be different in poorly or well-balanced MS. Second, the classification of a MS as poorly-balanced depends on "*Ind. Ret.*" being below a threshold value. We have estimated also two alternative specifications of $\mathcal{M}_2$. In the first, we simply added to $\mathcal{M}_1$ "*Poorly balanced*" as an intercept shifter, without the interaction term; in the second, we included both this intercept shifter and the interaction between "*Poorly balanced*" and "*Ind. Ret.*". In all cases, the effect of "*Poorly balanced*" is statistically indistinguishable from zero. Results are available upon request from the authors.

on "*Years in CERN DB*" is positive and statistically significant at the 0.01 level, thus suggesting that the longer a firm has been registered in the CERN database, the higher the likelihood of becoming a supplier. A similar effect is captured by "*log(no. orders)*": the coefficient on this variable is also positive and statistically distinguishable from zero at the 0.01 level. This is in line with Tammi et al. (2014) who suggested that the ability of firms to gather relevant information and use it to increase their knowledge of the tenders is associated with higher bidding activity. Flynn and Davis (2017) refer to this aspect as "procedural capability", showing that it has a significant effect on the number of tenders submitted and ultimately on the contracts obtained. Also, a higher number of applications increases a firm's chance to interact directly with CERN officials and to make itself known, thus increasing reciprocal knowledge. This aspect can also be seen as an increase in a firm's relational capability (Flynn and Davis, 2017).

As an additional control, we have considered the firms' size. With respect to size, the literature has shown that smaller firms are at a disadvantage with respect to larger firms in obtaining contracts (see e.g. Flynn et al., 2015). A joint test of hypothesis reveals that coefficients on "*Size FE*" are statistically not distinguishable from zero.

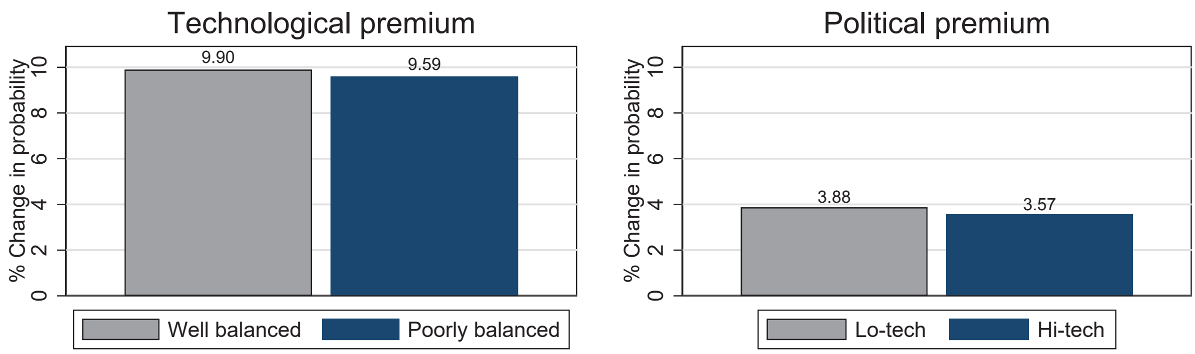
Sector fixed effects based on 2-digit NACE codes have also been included in all models to control for the fact that there might be a pattern relating the probability of becoming a supplier and the activities and services provided by the firms which, in turn, depend on their sector of activity.

Lastly, we have added variables for each firm's year of registration to control for the number of firms that register each year. These variables also control for the possibility that there might be pattern relating the phases of the LHC project's life cycle and the probability of receiving an order. In fact, Figure 2 reveals that there are years with a higher (or lower) number of tenders and contracts awarded, which are independent of firms characteristics or CERN's procurement policy. A joint test of hypothesis reveals that coefficients on "*Registration year FE*" are statistically distinguishable from zero.

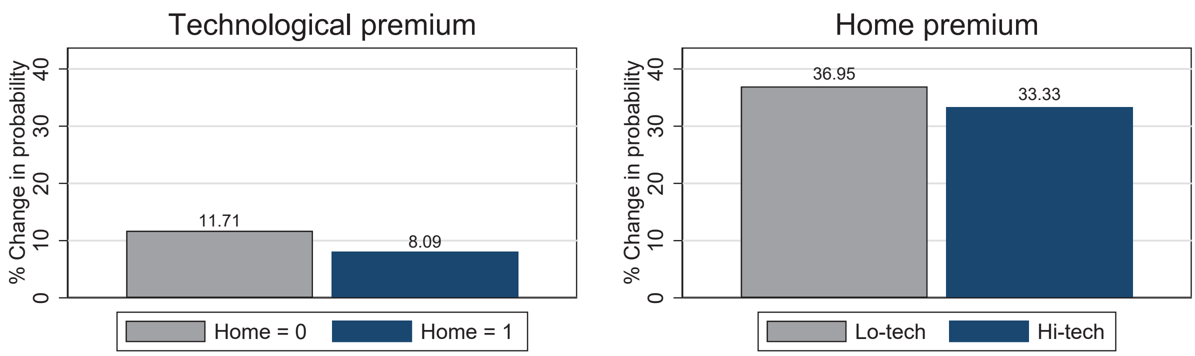
4.3 On the relative importance of technological factors and political constraints

In order to compare the relative weight of technological factors and political constraints ($\mathcal{RQ}_4$), we consider the fitted values from our models. Figure 4 provides a rough quantitative assessment of how technological and political factors affect the probability that firms start collaborating with CERN. We plot the change in fitted probabilities ($\Delta\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$) derived from models $\mathcal{M}_2$ and $\mathcal{M}_3$ in Table 2. Each panel shows the change in the estimated probability conditional on explanatory variables taking on different values.

Figure 4: Change in fitted probability from $\mathcal{M}_2$ and $\mathcal{M}_3$



(a) $\Delta\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$ from $\mathcal{M}_2$



(b) $\Delta\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$ from $\mathcal{M}_3$

Notes: the figures show the variation in fitted probabilities ($\Delta\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$) conditional on explanatory variables taking on different values. The two graphs in the top (bottom) panel are based on model $\mathcal{M}_2$ ($\mathcal{M}_3$). The top-left panel shows $\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$ for hi-tech firms in well-balanced (gray bar) and poorly-balanced countries (blue bar). The top-right panel shows $\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$ for hi-tech (gray bar) and lo-tech firms (blue bar) in poorly-balanced countries. The bottom-left panel shows $\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$ for hi-tech firms not hosted in France or Switzerland (gray bar; *Home*=0) and for those located in France or Switzerland (blue bar; *Home*=1). The bottom-right panel shows $\widehat{\Pr}(y_i = 1 \,|\mathbf{x}_i\,)$ for hi-tech (gray bar) and lo-tech firms in France or Switzerland (blue bar). The remaining explanatory variables are set equal to their sample average if continuous or equal to zero if dichotomous.

The two graphs in the top panel are based on estimates from $\mathcal{M}_2$. The fitted probability in well-balanced countries is 63.13% for hi-tech firms and 53.23% for lo-tech firms. In poorly-balanced countries these fitted probabilities equal 66.70% and 57.11% for hi- and lo-tech firms, respectively. The top-left panel shows what we refer to as "technological premium" for firms in well- and poorly-balanced countries. The height of the leftmost (gray) bar in this plot is 9.90% and represents the increase in the fitted probability due to being a hi-tech firm in a well-balanced country with respect to being lo-tech in the same country. In poorly-balanced countries this estimate is 9.59%, thus suggesting that the "technological premium" is higher in well-balanced countries.

The top-right panel shows what we refer to as "political premium" for hi- and lo-tech firms. This is an estimate of $\Delta\widehat{\Pr}\,(y_i = 1\,|\mathbf{x}_i\,)$ associated with being hosted in a poorly-balanced country compared to being hosted in a well-balanced country. As we can see, the "political premium" is equal to 3.88% and to 3.57% for lo- and hi-tech firms, respectively. This suggests that the "political premium" is higher in for lo-tech firms. Moreover, comparison of the two plots in the top of Figure 4 highlights that, consistently with CERN's procurement principles, technical requirements have a priority over providing a well-balanced return to its MS; in fact, the estimated "political premium" is much lower that the estimated "technological premium".

The two graphs in the bottom panel are instead based on estimates from $\mathcal{M}_3$. The fitted probability of providing an LHC-related order for firms located outside France and Switzerland is 48.97% if these are hi-tech and 37.26% if these are lo-tech. In France or Switzerland these fitted probabilities increase to 82.30% and 74.21% for hi- and lo-tech firms, respectively. The bottom-left panel shows that the estimated "technological premium" from $\mathcal{M}_3$ is 8.09% for firms in France or Switzerland and is 11.71% for firms located elsewhere. Moving to the bottom-right graph, we see that the height of the leftmost (gray) bar in this plot is 36.95%; this represents the increase in the fitted probability due to being a lo-tech firms hosted in France or Switzerland with respect to being lo-tech in other MS. For hi-tech firms this estimate is 33.33%, thus suggesting that the home bias is higher for lo-tech firms.

Overall, estimates of the technological premium – suggesting a higher probability of becoming CERN suppliers for hi-tech than lo-tech firms – are similar across models: these range from 8.09% to 11.71%. Interestingly, the contribution of correction mechanisms aimed at favoring firms in poorly-balanced MS seems to be more important for lo-tech firms than for hi-tech firms. This can be explained recalling that one of CERN's procurement principle – and possibly the most relevant, given the its mission-oriented nature Florio et al. (2018b) – is to ensure that the technical requirements of the contract are met. Moreover, it also possible that the less specific is the product required by CERN, the easier it is to implement correction mechanisms aimed at favoring firms in poorly-balanced countries and the larger is the pool of firms that can deliver that order. This would also explain why we report a larger home bias for lo-tech than for hi-tech firms. Last, but not least, when focusing on Figure 4b we can see that the contribution of the home bias is much larger than that of the technological premium; on the contrary, Figure 4a highlights that the technological premium is associated with a higher increase in probability of becoming a supplier than the political premium.

5 Additional results and robustness checks

5.1 Exclusion of host countries

As shown in Figure 3, firms hosted at the Swiss-French border near CERN's facilities make up 45.8% of suppliers. Interestingly, in the years for which we have data, both countries are always characterized as being well balanced and have the some of the highest industrial returns. Furthermore, Swiss and French firms might in general benefit from a positive home bias, as documented in Section 4.2. Firms located in Switzerland and France may thus follow different strategies and exhibit different behavior in their tendering behavior with respect to firms hosted in other MS.

To verify the extent to which these factors might influence our results, in columns 2 and 4 of Table 3 we have excluded Swiss and French firms from the sample used to estimate $\mathcal{M}_1$ and $\mathcal{M}_2$, respectively. Overall, results are confirmed with three interesting qualifications. First, possibly due to the reduction in sample size that tends to magnify the estimated standard errors, the estimated coefficients on "*Hi-tech*" in columns 2 and 4 retain the positive sign but become not statistically distinguishable from zero at any conventional level. Second, in both cases the coefficients on "*Ind. Ret.*" increase. Third, in column 4 the estimated coefficient on the interaction term is positive and larger than in the baseline specification in column 3. This result could be driven by the fact that, once firms from home countries, which might have an advantage related to a proximity bias, are excluded, the correcting mechanism aimed at favoring firms in poorly-balanced countries becomes more relevant.

5.2 Who is driving the home bias? Who is gaining from it?

Up to now we have never attempted to disentangle whether the home bias is driven by French or Swiss firms in our sample. We investigate this issue in column 6 of Table 3, where in model $\mathcal{M}_3$ "*Home*" is replaced by two dichotomous variables that identify firms in France and Switzerland. As we can see, the main results are unchanged, however we can now highlight that the home bias seems to be primarily driven by firms in France.

A related question, investigated in columns 7 and 8, is whether all firms enjoy equal benefits from the existence of an home bias. To answer this question, we have estimated $\mathcal{M}_3$ separately for hi- and lo-tech firms. As we can see from the last two columns of Table 3, the coefficient on "*Home*" is positive on both samples, but it is statistically distinguishable from zero only for lo-tech firms.

Table 3: Logit models - more on the home bias

	(1) $\mathcal{M}_1$	(2) $\mathcal{M}_1^{\text{no Home}}$	(3) $\mathcal{M}_2$	(4) $\mathcal{M}_2^{\text{no Home}}$	(5) $\mathcal{M}_3$	(6) $\mathcal{M}_3^{\text{CH, FR}}$	(7) $\mathcal{M}_3^{\text{lo-tech}}$	(8) $\mathcal{M}_3^{\text{hi-tech}}$
Hi-tech	0.411*	0.419	0.408*	0.410	0.480**	0.482**		
	(0.215)	(0.273)	(0.216)	(0.275)	(0.219)	(0.218)		
Ind. Ret. (t=0)	0.652***	0.886*	0.661***	1.295**	0.175	0.434	0.161	0.757*
	(0.108)	(0.486)	(0.117)	(0.593)	(0.150)	(0.362)	(0.194)	(0.408)
Ind. Ret.			0.157	1.228				
× Poorly Bal. (t=0)			(0.678)	(0.840)				
Home					1.578***		1.795***	1.178
					(0.435)		(0.598)	(0.739)
CH						0.549		
						(1.341)		
FR						1.352***		
						(0.503)		
Years in CERN DB	0.395***	0.332**	0.394***	0.319**	0.401***	0.400***	0.204	0.830
	(0.150)	(0.137)	(0.150)	(0.138)	(0.146)	(0.146)	(0.139)	(1.388)
log(no. orders)	0.570***	0.730***	0.569***	0.732***	0.625***	0.628***	0.535***	0.984***
	(0.131)	(0.157)	(0.131)	(0.157)	(0.141)	(0.142)	(0.189)	(0.283)
Size FE	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓
Registration year FE	✓	✓	✓	✓	✓	✓	✓	✓
N	541	364	541	364	541	541	264	215

Notes: see notes to Table 2. $\mathcal{M}_j^{\text{no Home}}$ for $j = 1, 2$ indicates that the model has been estimated after omitting French and Swiss firms. $\mathcal{M}_3^{\text{lo-tech}}$ $\left(\mathcal{M}_3^{\text{lo-tech}}\right)$ denotes that the sample includes only lo-tech (hi-tech) firms.

Table 4: Logit models – excluding 2006 and 2007

	(1) $\mathcal{M}_1$	(2) $\mathcal{M}_1^{\text{excl. 2007}}$	(3) $\mathcal{M}_1^{\text{excl. 2006/07}}$	(4) $\mathcal{M}_2$	(5) $\mathcal{M}_2^{\text{excl. 2007}}$	(6) $\mathcal{M}_2^{\text{excl. 2006/07}}$	(7) $\mathcal{M}_3$	(8) $\mathcal{M}_3^{\text{excl. 2007}}$	(9) $\mathcal{M}_3^{\text{excl. 2006/07}}$
Hi-tech	0.411^{*}	0.451^{**}	0.362	0.408^{*}	0.447^{**}	0.356	0.480^{**}	0.521^{**}	0.432^{*}
	(0.215)	(0.216)	(0.221)	(0.216)	(0.217)	(0.222)	(0.219)	(0.220)	(0.224)
Ind. Ret. (t=0)	0.652^{***}	0.673^{***}	0.675^{***}	0.661^{***}	0.686^{***}	0.695^{***}	0.175	0.181	0.213
	(0.108)	(0.112)	(0.119)	(0.117)	(0.121)	(0.129)	(0.150)	(0.154)	(0.160)
Ind. Ret. × Poorly Bal. (t=0)				0.157	0.225	0.345			
				(0.678)	(0.680)	(0.678)			
Home							1.578^{***}	1.619^{***}	1.508^{***}
							(0.435)	(0.442)	(0.437)
Years in CERN DB	0.395^{***}	0.385^{***}	0.196^{***}	0.394^{***}	0.384^{***}	0.194^{***}	0.401^{***}	0.366^{***}	0.188^{**}
	(0.150)	(0.087)	(0.071)	(0.150)	(0.087)	(0.071)	(0.146)	(0.086)	(0.073)
log(no. orders)	0.570^{***}	0.581^{***}	0.599^{***}	0.569^{***}	0.580^{***}	0.597^{***}	0.625^{***}	0.637^{***}	0.650^{***}
	(0.131)	(0.131)	(0.135)	(0.131)	(0.131)	(0.135)	(0.141)	(0.141)	(0.145)
Size FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Registration year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
N	541	527	500	541	527	500	541	527	500

Notes: see notes to Table 2. $\mathcal{M}_j^{\text{excl. 2007}}$ for $j = 1, 2, 3$ indicates that the model has been estimated after omitting 2007. Similarly, $\mathcal{M}_j^{\text{excl. 2007}}$ for $j = 1, 2, 3$ denotes that 2006 and 2007 have been omitted.

Table 5: Probit models: factors affecting the probability of becoming LHC supplier

	(1) $\mathcal{M}_1^{Probit}$	(2) $\mathcal{M}_2^{Probit}$	(3) $\mathcal{M}_3^{Probit}$
Hi-tech	0.260**	0.258**	0.294**
	(0.127)	(0.128)	(0.128)
Ind. Ret. (t=0)	0.380***	0.385***	0.114
	(0.057)	(0.062)	(0.085)
Ind. Ret. × Poorly Bal. (t=0)		0.093	
		(0.404)	
Home			0.905***
			(0.243)
Years in CERN DB	0.202***	0.201***	0.199***
	(0.069)	(0.069)	(0.071)
log(no. orders)	0.346***	0.346***	0.372***
	(0.077)	(0.077)	(0.080)
Size FE	✓	✓	✓
Sector FE	✓	✓	✓
Registration year FE	✓	✓	✓
N	541	541	541

Notes: see notes to Table 2.

5.3 Exclusion of 2006-2007

Inspection of Figure 2 highlights that, due to the completion of the construction phase, LHC suppliers drop dramatically in number at the end of the sampling period. On the contrary, potential suppliers do not experience a similar sharp drop. Thus, as a robustness check, we exclude first 2007, then also 2006 from each model. Our baseline results are confirmed in terms of sign, magnitude and largely also in terms of statistical significance of the estimated coefficients when 2007 is excluded. A noticeable difference is the reduction of the coefficient on "*Hi-tech*", that in the case of $\mathcal{M}_1$ and $\mathcal{M}_2$ becomes also statistically not distinguishable from zero, when 2006 and 2007 are excluded. This might signal that near the completion of the construction phase of the LHC programme all hi-tech orders had already been completed.

5.4 Probit models

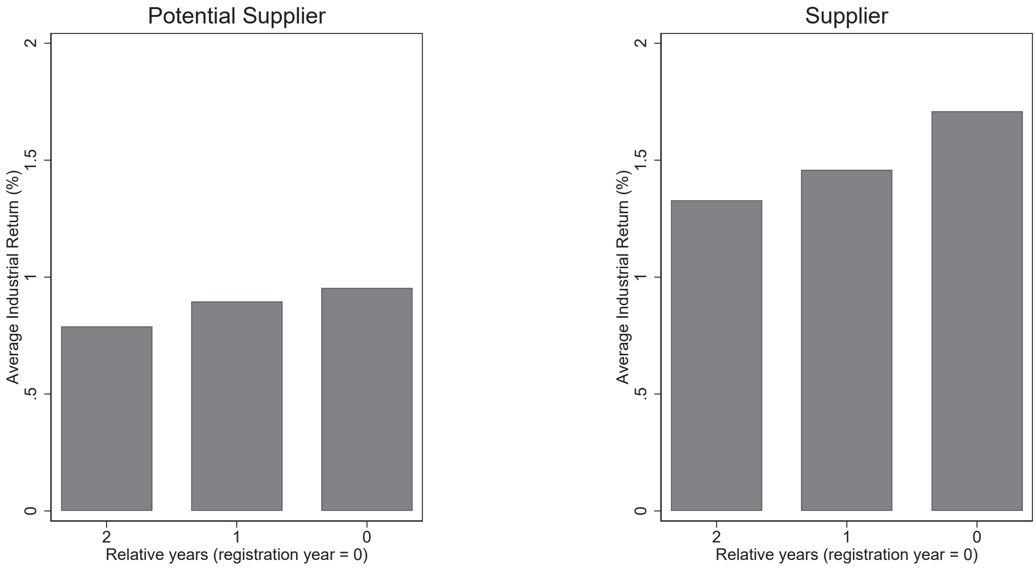
Results in Section 4.2 rely on a logit model. As a further robustness check, Table 5 shows estimates of probit models, that is we substitute the logit function $\Lambda(z)$ with the standard normal cumulative distribution function in Equation (1). Results in Table 5 highlight that our results are not affected by the selection of probit model in place of a logit model.

5.5 Lagged values

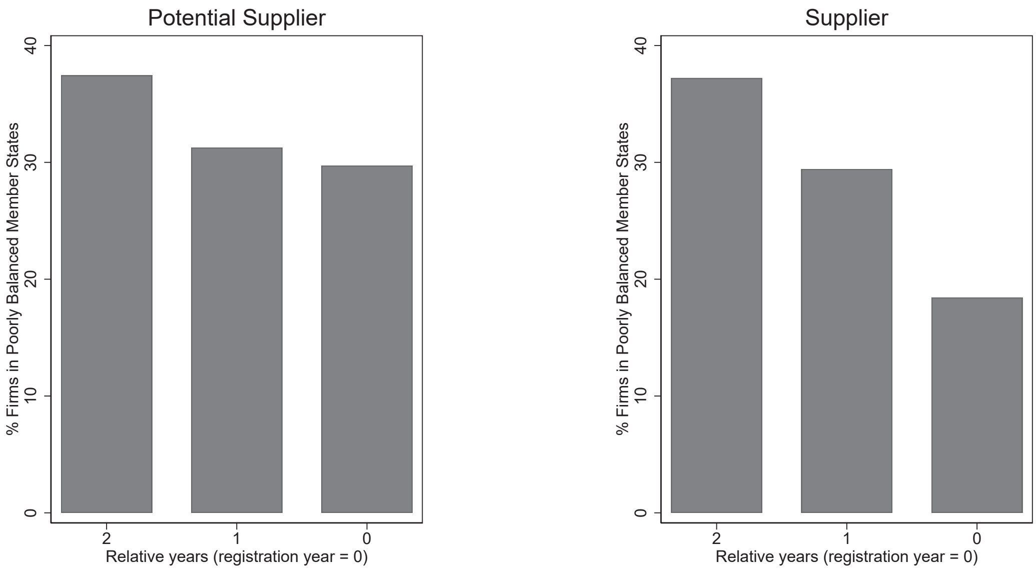
As shown in Figure 5(b) there seems to be a temporal pattern linking the date when a MS is declared poorly-balanced and the number of firms that register in the CERN procurement database. More precisely, the percentage of both potential suppliers and LHC suppliers in poorly-balanced MS is highest two years before the registration in the CERN procurement database. On the contrary, Figure 5(a) highlights that the average industrial return is highest the year the firm registered with CERN.

Because of lags between the date of the registration and the date when the tender is awarded, the probability of becoming a suppliers might depend not on the status of the MS the year the firm registered with the CERN Procurment Office but on the country's industrial return and status in previous years. If this is the case, we might observe a positive association between the probability of becoming supplier and the status of the country in earlier periods. To investigate this issue columns 2 and 3 of Table 6 report estimates of model $\mathcal{M}_2$ after assigning to "*Poorly balanced*" unit value if the country was poorly-balanced one or two years before a firm registered with CERN and zero otherwise. Similarly, we consistently change the value of "*Ind. Ret.*". While our main conclusions are unaffected, the magnitude of the estimated coefficient on the interaction between "*Ind. Ret.*" and "*Poorly balanced*" increases when moving from column 1 to column 3. Nevertheless, also in this case, the estimates are never statistically distinguishable from zero.

Figure 5: Average industrial return and firms in poorly balanced Member States



(a) Average industrial returns over relative years



(b) Percentage of firms in poorly balanced MS over relative years

Notes: relative years indicate the value of the variable ℓ years before the year the firm registered with CERN.

Table 6: Logit model $\mathcal{M}_2$ with lags of "*Ind. Ret.*" and "*Poorly Balanced*"

	(1) $\mathcal{M}_2$	(2) $\mathcal{M}_2^{(\ell=1)}$	(3) $\mathcal{M}_2^{(\ell=2)}$
		ℓ	
	0	1	2
Hi-tech	0.408*	0.410*	0.398*
	(0.216)	(0.216)	(0.215)
Ind. Ret. (t=ℓ)	0.661***	0.651***	0.673***
	(0.117)	(0.116)	(0.129)
Ind. Ret. × Poorly Bal. (t=ℓ)	0.157	0.118	0.197
	(0.678)	(0.686)	(0.721)
Years in CERN DB	0.394***	0.489***	0.494***
	(0.150)	(0.147)	(0.147)
log(no. orders)	0.569***	0.564***	0.552***
	(0.131)	(0.133)	(0.131)
Size FE	✓	✓	✓
Sector FE	✓	✓	✓
Registration year FE	✓	✓	✓
N	541	541	541

Notes: see notes to Table 2. Lags of variables are associated with $\ell > 0$: $t = \ell$ denotes the value of the variable ℓ years before registering with CERN for the first time.

5.6 Supply and service contracts

As discussed in Section 3.3, CERN distinguishes between contracts for supplies and services. Service contracts are multi-year contracts for the provision of services to be performed on the CERN site. Supply contracts cover contract that is not defined as a service contract and include R&D contracts, maintenance and leasing contracts covering data processing, printing and telecommunication equipment. Our data does not allow to distinguish between supplies and services, therefore our main results are based on the average industrial return for these two kind of contracts. Similarly, we have defined MS as poorly-balanced if their industrial returns for both supplies and contracts are lower than a certain threshold value.

Table 7: Logit models – "*Ind. Ret.*" and "*Poorly Balanced*" based on contracts for supplies and services

	(1) $\mathcal{M}_1$	(2) $\mathcal{M}_1^{\text{Suppl.}}$	(3) $\mathcal{M}_1^{\text{Serv.}}$	(4) $\mathcal{M}_2$	(5) $\mathcal{M}_2^{\text{Suppl.}}$	(6) $\mathcal{M}_2^{\text{Serv.}}$	(7) $\mathcal{M}_3$	(8) $\mathcal{M}_3^{\text{Suppl.}}$	(9) $\mathcal{M}_3^{\text{Serv.}}$
Hi-tech	0.411*	0.407*	0.401*	0.408*	0.406*	0.414*	0.480**	0.485**	0.477**
	(0.215)	(0.216)	(0.214)	(0.216)	(0.218)	(0.215)	(0.219)	(0.221)	(0.217)
Ind. Ret. (t=0)	0.652***	1.187***	0.411***	0.661***	1.204***	0.389***	0.175	0.628***	0.027
	(0.108)	(0.189)	(0.068)	(0.117)	(0.231)	(0.070)	(0.150)	(0.239)	(0.101)
Ind. Ret. × Poorly Bal. (t=0)				0.157	0.057	-0.997			
				(0.678)	(0.457)	(0.970)			
Home							1.578***	1.243***	1.870***
							(0.435)	(0.371)	(0.452)
Years in CERN DB	0.395***	0.416***	0.384***	0.394***	0.416***	0.385***	0.401***	0.414***	0.400***
	(0.150)	(0.150)	(0.144)	(0.150)	(0.151)	(0.144)	(0.146)	(0.153)	(0.143)
log(no. orders)	0.570***	0.564***	0.564***	0.569***	0.563***	0.566***	0.625***	0.623***	0.626***
	(0.131)	(0.131)	(0.131)	(0.131)	(0.132)	(0.132)	(0.141)	(0.139)	(0.142)
Size FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sector FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Registration year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
N	541	541	541	541	541	541	541	541	541

Notes: see notes to Table 2. $\mathcal{M}_j^{\text{Suppl.}}$ and $\mathcal{M}_j^{\text{Serv.}}$ for $j = 1, 2, 3$ denote $\mathcal{M}_j$ with "*Ind. Ret.*" and "*Poorly Balanced*" based only on contracts for supplies and services, respectively.

In Table 7 we re-estimate all our models considering the MS's status and industrial return based either on supplies or services. Our main results are mostly unaffected, however we notice that in all cases wen focusing on supply contracts the coefficient on "*Ind. Ret.*" tends to increase.

6 Conclusions

We have explored the factors that are expected to affect firms' probability of becoming a supplier of a BSC such as CERN. Our results suggest that along with a set of elements related to firms' ability to navigate the tendering process, there is an evident tension between suppliers' technological expertise and political constraints related with CERN's procurement rules. While it is clear that firms bringing hi-tech knowledge have a higher chance of becoming suppliers, the weight of belonging to MS that, relative to what they receive via contracts, contribute significantly to CERN's budget or that are awarded a preferential treatment since they are poorly balanced is relevant.

Our results are important for several reasons. First, the impact of procurement at BSC are potentially high in terms of knowledge spillovers for suppliers and the economy as a whole (see e.g. Autio et al., 2004), profits of suppliers Florio et al. (2018b) and their innovative activity Åberg and Bengtson (2015). Second, the choice of suppliers and their geographical location also has a role in public policies. In fact, our results should be framed within the wider debate on the role of BSCs as potential instruments for national innovation policies. If CERN's procurement activity is seen as an element contributing to a country's public effort towards innovation, the factors influencing the probability of becoming a supplier should be understood and accepted. We have shown how both technological and political factors affect this process and this should be taken into account when analyzing the role of BSCs as instruments of overall innovation policies. Our empirical results suggest that the probability of becoming a supplier is driven first and foremost by technological factors, while the importance of procedures and procurement rules is not negligible, but smaller in relative terms. We have also documented the existence of a relevant home bias in the choice of the suppliers, an aspect which can be considered part of CERN's procurement rules and constraints. While more research is needed to pinpoint the origins and implications of this bias, factors that might influence this effect are related to the localized nature of some goods and services to be provided and to the potential role of procurement as a form of compensation for localized negative spillovers from BSC. Third, since CERN might commit to the construction of Future Circular Collider (FCC), a much bigger collider with respect to LHC (planned diameter of 80-100 km) to explore the implications of more intense collisions (See Bastianin and Florio, 2019 and `https://fcc-cdr.web.cern.ch/`), an understanding of its procurement policy, highlighting potential aspects that could be improved upon, appears relevant. While we have documented that CERN does not apply a strict juste retour policy when awarding contracts to firms located in different MS, it is clear that a MS's position in terms of balanced industrial returns is a significant element in the decision process. An evaluation of the implications of this policy, which has in time been criticized (Hameri and Nordberg, 1999), in terms of the characteristic of the firms selected to become CERN suppliers might be necessary before significant amounts[10] of public funds are committed to the construction of a new, giant, research infrastructure such as FCC.

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[10]Preliminary figures are in the range of 15 billion euros, see https://home.cern/news

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Appendix