



The economic impact of technological procurement for large-scale research infrastructures: Evidence from the Large Hadron Collider at CERN

Paolo Castelnovo^a, Massimo Florio^{a,*}, Stefano Forte^b, Lucio Rossi^c, Emanuela Sirtori^d

^a Department of Economics, Management, Quantitative Methods, Università degli Studi di Milano, Italy

^b TIF Lab, Department of Physics, Università degli Studi di Milano and INFN, Sezione di Milano, Italy

^c CERN - Accelerator & Technology Sector and Department of Physics, Università degli Studi di Milano, Italy

^d CSIL Centre for Industrial Studies, Milano, Italy

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ABSTRACT

The Large Hadron Collider at CERN, the European Organisation for Nuclear Research, is the world's highest-energy particle accelerator. Its construction (1995–2008) required frontier technologies and close collaboration between CERN scientists and contracting firms. The literature on “Big Science” projects suggests that this collaboration generated economic spillovers, particularly through technological learning. CERN granted us access to its procurement database, including suppliers of LHC from 35 countries for orders over 10,000 Swiss Francs. We gathered balance-sheet data for more than 350 of these companies from 1991 to 2014, which include the years before and after that of the first order received. The study assesses, in quantitative terms, whether becoming a CERN supplier induced greater R&D effort and innovative capacity, thus enhancing productivity and profitability. The findings – which controlled for firms' observable characteristics, macroeconomic conditions, and unobserved time, country, industry and firm-level fixed effects – indicate a statistically significant correlation between procurement events and company R&D, knowledge creation and economic performance. The correlation is chiefly driven by high-tech orders; for companies receiving non-high-tech orders, it is weaker, or even statistically not significant.

1. Introduction

“Big Science” projects are expensive and the ultimate social impact of discovery is hard to predict, especially where basic research is concerned (Martin and Tang, 2007; Bornmann, 2012, 2013; Godin and Doré, 2004). It may take decades to understand how knowledge of fundamental features of nature could be of any practical use, and in the meantime governments are expected to support investment in science in hopes of highly uncertain social returns. But there also exist immediate benefits that are observable even during the construction of a large research infrastructure (Salter and Martin, 2001). Some of these benefits stem from unprecedented technological challenges in meeting the exacting standards of cutting-edge experimental devices that demand close collaboration between laboratories and firms in the supply chain of machines that serves for scientific discovery. Such collaboration may generate learning effects that spill over from basic research as a positive externality to firms thanks to procurement contracts. Technological learning can help firms generate and process innovation and ultimately increase their growth opportunities (Turner, 2015).

We have studied this effect in relation to CERN, the European Organisation for Nuclear Research. CERN is the world's leading particle physics laboratory and its role and impact have been extensively studied by economists, from the three papers of Martin and Irvine (1984a, 1984b, 1984c) to more recent work by the OECD (2014). CERN hosts the Large Hadron Collider (LHC), where the Higgs boson was discovered in 2012. The LHC, built between 1993 and 2008, consists of a 27-kilometer underground ring between Switzerland and France. Particle beams are collided at four points where detectors are located, each of which is operated by an experimental “collaboration”, a team involving CERN staff as well as scientists from universities and research institutes from various countries. In their observations, the four detectors produce enormous amounts of data per second that is transmitted to a series of computing nodes around the world, which are connected through the worldwide LHC computer grid. The LHC is indeed, like the title of L.R. Evans' book, a “marvel of technology” (Evans, 2009).

The technological features of the LHC are extremely demanding. CERN, its collaborators, and firms with procurement contracts have had to closely cooperate to solve entirely new problems in a series of fields,

* Corresponding author.

E-mail address: massimo.florio@unimi.it (M. Florio).

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including superconductivity, cryogenics, electromagnets, ultra-high vacuum, distributed computing, rad-resistance materials, and fast electronics (Evans, 2009; Giudice, 2010). The large number of suppliers, the international scope of procurement, the wide range of sectors, and the duration of the construction process offer an ideal setting for our central research question: namely, how best to measure the economic impact of technological procurement on the performance of suppliers in Big Science.

In fact, when the introduced innovation is so radical as to constitute a discontinuity, it may generate technological advances that pervade many sectors and have a protracted impact on the entire economic system. Such innovations, described as “General Purpose Technologies” (GPTs), have been investigated, among others, by Bresnahan and Trajtenberg (1995); Helpman (1998), and Jovanovic and Rousseau (2005). The World Wide Web, invented at CERN in 1989, in addition to being perhaps the most famous example of technological spillover from Big Science, is a notable example of GPT breakthrough.

More in general, there is clear, albeit unsystematic, evidence that the firms working for CERN have learned new solutions and then developed new products for other customers outside of the scientific field (see for instance Amaldi, 2012; Nielsen and Anelli, 2016). Examples in the medical sector include hadrontherapy (Battistoni et al., 2016) and the new open source software “TIGRE” (Tomographic Iterative GPU-based Reconstruction) for PET scanners. As regards transportation, one of CERN’s suppliers for ultra-high vacuum technology was able to partner with Hyperloop Transportation Technology, a company that is developing a very high, even ultrasonic, speed transport system thanks to the know-how and experience that was acquired while working on the LHC¹. “VESPER” (Very energetic Electron facility for Space Planetary Exploration missions in harsh Radiative environments) found application in the aerospace industry. The potential applications of “KRYOLIZE”, a novel cryogenic software for sizing relief valves that protect against overpressure, also interest the food industry. Superconductivity, a core feature of the magnets developed to steer the LHC particle beams, may find application in various fields, ranging from medicine, with “particle therapy,”² to aerospace, with hybrid propulsion systems, to agriculture, with fruit sorting machines, to energy, with Uninterruptible Power Supply (UPS) systems³ (see Aschauer et al., 2017).

Three different approaches have been taken to gauging the economic effects of technological learning stemming from a procurement relationship with large basic research infrastructures (Salter and Martin, 2001; Hall et al., 2010; Autio et al., 2004): case studies, surveys, and input-output or other aggregate statistical methods. Detailed case histories provide interesting qualitative insights into suppliers’ learning effects and subsequent commercial developments (Arenius and Boisot, 2011; OECD, 2014). Case studies on the impact of research have been used extensively in the U.K. as part of a unique assessment exercise including 7000 case studies (Van Noorden, 2015).

Surveying stakeholders is another helpful approach. A survey of CERN suppliers (Autio, 2014) found that collaboration with CERN was instrumental to product innovation, new R&D, starting a new business unit, or opening a new market, and that more than 40% of the respondent firms reported that after the contract they were more internationalised and had benefited from technological learning. The average combined value of suppliers’ sales to other clients and cost savings was reported to be three times the amount of the CERN order. Florio et al. (2017) report the findings of a recent survey of over 600 CERN suppliers, confirming lasting effects on performance,

organisation, and behaviour.

Finally, aggregate statistical approaches have been adopted for decades to study the effects of scientific programs ranging from NASA (Bezdek and Wendling, 1992) to biotechnology (Webb and Whyte, 2009). Typically, input-output tables of average national or regional inter-industry linkages and investment multipliers were used to compute the impact of research spending by an agency or project on GDP or productivity.

All three approaches are informative, but none provides a true empirical measurement, strictly speaking, of the direct effects of procurement on suppliers: case studies, with their specific histories, are unavoidably heterogeneous in method, including narrative and other qualitative approaches; surveys of company managers provide some statistical evidence but are likely to be affected by self-selection as well as respondents’ judgment and memory; input-output models and other aggregate econometric approaches heavily depend on certain macroeconomic assumptions (Macilwain, 2010), in that they apply average output and employment multipliers that are used for the entire economy, which may or may not be relevant for contracting firms in Big Science projects.

Our empirical strategy is innovative: we consider the procurement contract between a firm and its client, i.e. the institution that manages the research infrastructure, as an event whose effects can go beyond the immediate impact (i.e. the first order received) to change the firm’s performance over time, even net of confounding factors such as macroeconomic conditions. In this perspective, we apply firm-level panel microeconometrics to study the long-run effects of CERN procurement on suppliers’ R&D activity, knowledge production, productivity, and - ultimately - profitability. This approach is replicable for any other Big Science project in principle.

CERN granted us access to the LHC procurement data from 1995 to 2008. There were 1296 suppliers with at least one order of over SFR 10,000, for a total of 11,969 orders. Orders went to firms in 35 different countries including China, Japan, Russia, and the United States, but over 99% of the orders, based on their value, were placed with European firms, mostly in CERN member states, which are preferred in CERN procurement. We recorded the location, year, order value, and activity code of each supplier. We then classified each order on a technology intensity scale.

From the original list of LHC suppliers (which included other laboratories, joint ventures, etc.) we selected those whose core financial indicators were available in a public database (Amadeus or Orbis) for the 1991–2014 period, which is a sufficiently long time to empirically test the impact of the procurement contracts. We also wanted to identify patents that had been filed by the same firms by using the Patstat database. Some 360 companies satisfied these criteria, giving us a sample that produced from 3300 to 5800 observations, depending on which dependent variable was considered.

Our hypothesis is that becoming a CERN supplier may induce more intensive effort in R&D and knowledge creation, leading to improvements in productivity and profitability, especially for high-tech suppliers. We build on the framework of Crépon et al. (1998), augmented by the impulse variable, consisting in the date of the first order by CERN.

To test the chain of consequences from the procurement event, our causal variable, to the sequence of R&D investments, patent filing, productivity gains and - ultimately - higher profitability, as a first step we built a set of single-equation empirical models where we test whether a CERN procurement effect is detectable at each step of the logical chain. After controlling for firm characteristics, such as assets and other size variables, time and country-fixed effects (as well as industry ones when appropriate), and macroeconomic factors, we found that being an LHC supplier is correlated with yearly changes in our empirical proxies for each item in the logical chain. CERN orders are correlated with changes in suppliers’ intangible assets, increases in the number of patent filings, changes in labour productivity, and ultimately increases in

¹ <https://kt.cern/success-stories/hyperloop>.

² “Particle Therapy” is a variant of radiotherapy that irradiates tumor tissue with protons and light ions (Aschauer et al., 2017: 15).

³ “UPC systems are devices for energy storage that can deliberately take on and deliver power when necessary” (Aschauer et al., 2017: 2).

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