The socio-economic impact of large-scale research infrastructures: From the LHC to the FCC

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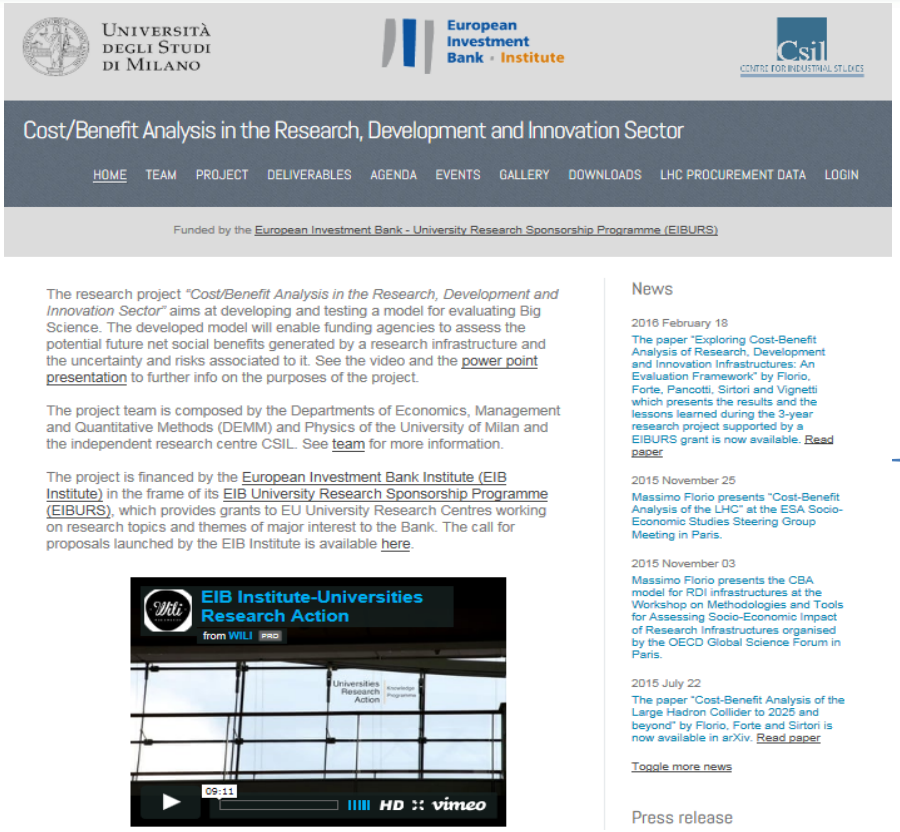
Background



EIBURS
EIB University Research Sponsorship Programme
2012-2015

http://www.eiburs.unimi.it/

- Developing a **CBA theoretical model for evaluating research infrastructure projects (RI).**
- Enabling funding agencies to **assess the potential future net social benefits** generated by a RI.
- **Testing the CBA model** on two particle accelerators: LHC and CNAO (National Hadrontherapy Centre for Cancer Treatment).

The CBA model (1)

- The expected economic net present value of the RDI infrastructure $[\mathbb{E}(ENPV_{RDI})]$ over the ***time horizon (T)*** is defined as the difference between expected ***benefits*** and ***costs*** valued at shadow prices and discounted at the ***social discount rate (r)***.

- The model breaks down ***intertemporal benefits*** into two broad classes – use and non-use benefits – and compares these benefits with costs.

- The expectation operator implies that ***all critical variables are considered as stochastic***.

- All the ***benefits should be related to the main economic agents***: **firms, consumers, employees, taxpayers**.

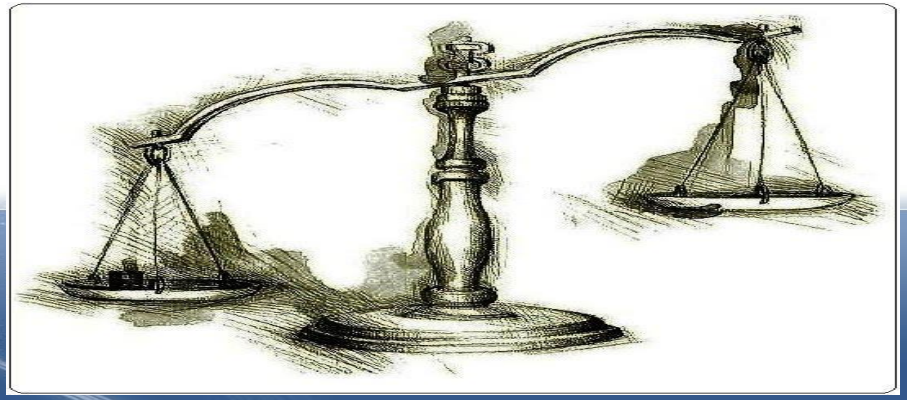
The CBA model (2)

$$\mathbb{E}(ENPV_{RDI}) = \mathbb{E}(EPV_{Bu}) + \mathbb{E}(EPV_{Bn}) - \mathbb{E}(EPV_{Cu})$$

B_u = Use benefits

C_u = Costs

B_n = Non Use benefits



The CBA model: Costs and Benefits

$\mathbb{E}(ENPV_{C_u})$

The present value of COSTS is the sum of the:

- **economic value of capital** (K)
- **labour cost of scientists** (L_s)
- other **administrative and technical staff** (L_o)
- other **operating costs** (O)
- **negative externalities** if any (ε).

$$\mathbb{E}(ENPV_{C_u}) = \sum_{t=0}^{\mathcal{T}} s_t \cdot (k_t + l_{st} + l_{ot} + O_t + \varepsilon_t)$$

The present value of BENEFITS is the sum of the:

- **Firms** (T)
- **Employees** (H)
- **Users** $(A + S + C)$

→ **Use Benefits** B_u

- **Taxpayers** $(QOV + EXV)$

→ **Non Use Benefits** B_n

$$\mathbb{E}(ENPV_{B_u}) = \sum_{t=0}^{\mathcal{T}} s_t \cdot (T_t + H_t + A_t + S_t + C_t)$$

$$\mathbb{E}(ENPV_{B_n}) = (\mathrm{QOV} + \mathrm{EXV})$$

The CBA model: Benefits

Use Benefits B_u

FIRMS

Technological externalities (T_t)

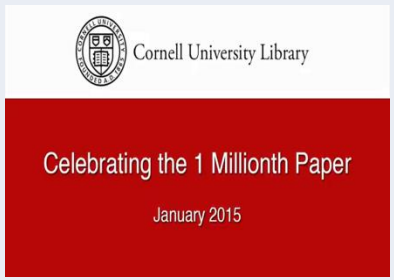
EMPLOYEES: early career researchers

Human Capital Formation (H_t)

CONSUMERS

Social benefits to consumers of services (A_t)

SCIENTISTS



Knowledge output (S_t)

VISITORS

Cultural effects (C_t)

Non Use Benefits B_n

?

Quasi option value (QOV)

TAXPAYERS

Existence value (EXV)

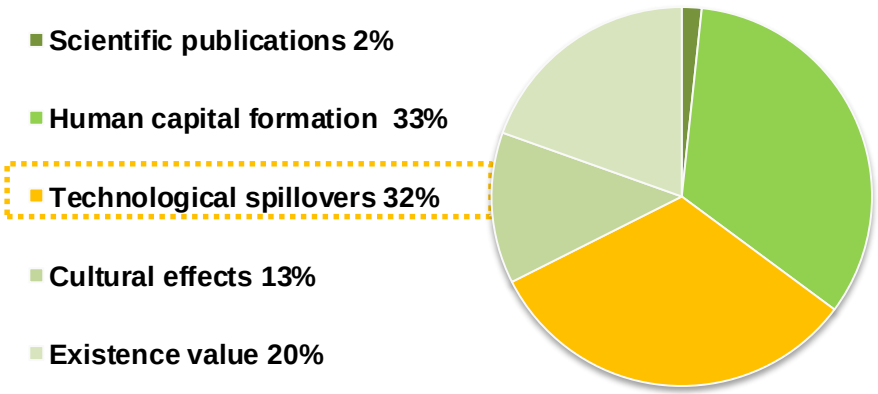
CONSUMERS

LHC: CBA in a nutshell (1)

LHC: summary of costs and benefits (Billion, EUR)	
COSTS:	13.5 ± 0.4
USE BENEFITS:	
Knowledge Formation	0.3 ± 0.1
Human Capital	5.5 ± 0.3
Technological Spillovers	5.3 ±1.7
Cultural	2.1 ± 0.5
NON-USE BENEFITS:	
Existence Value	3.2 ± 1.0

- **Human capital, technological spillovers, cultural + existence value each give about 33% of benefits** (publications are negligible)
- **Uncertainty largest on technological spillovers**
- More than **90% chance of positive** NPV

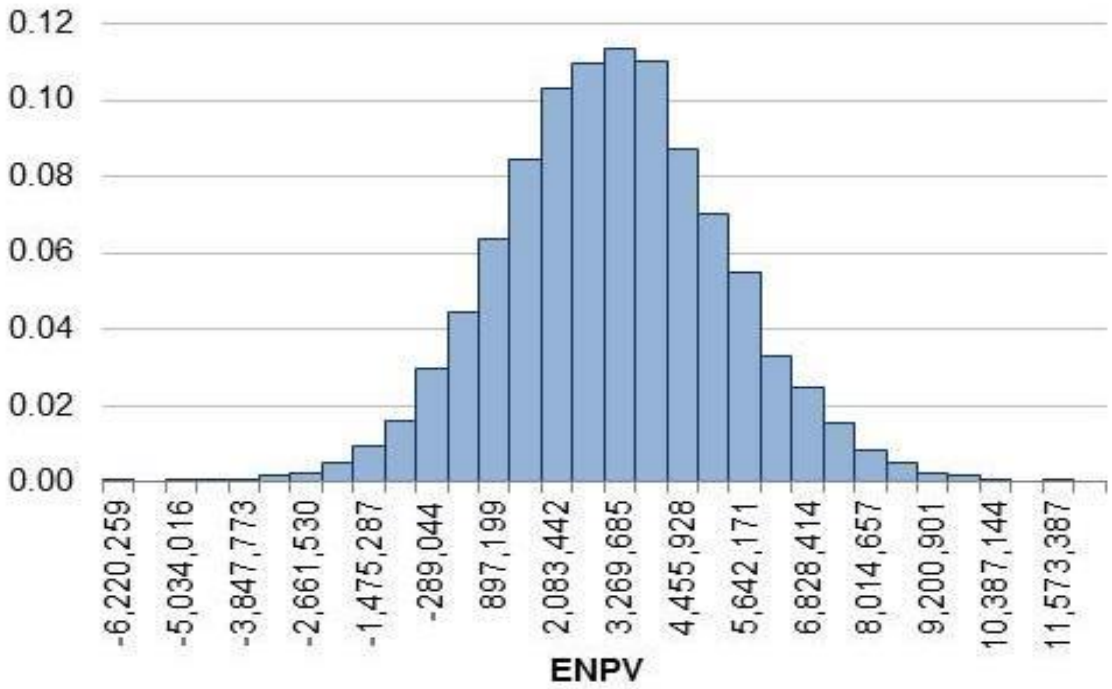
TOTAL MEASURED BENEFITS



LHC: CBA in a nutshell (2)

ESTIMATED PARAMETERS OF DISTRIBUTION	
Mean	2,855,528
Median	2,825,860
Standard Deviation	2,134,763
Minimum	-6,220,259
Maximum	11,573,387
Estimated probabilities	
Pr. ENPV ≤ 0	0.086
Montecarlo error	
3 ϭ 10,000	0.02

PROBABILITY DENSITY FUNCTION



Focus on Technological impact

What can we learn from the LHC about the impact on firms?

- Earlier studies at CERN were based on interviews to managers. They concluded that **for each Euro of procurement there will be 3 Euro of sales** to other customers (or cost savings).
- Problems: **not updated**, **selection bias**, and sales per se are **not a social benefit**.
- **Lessons for the FCC Study**.

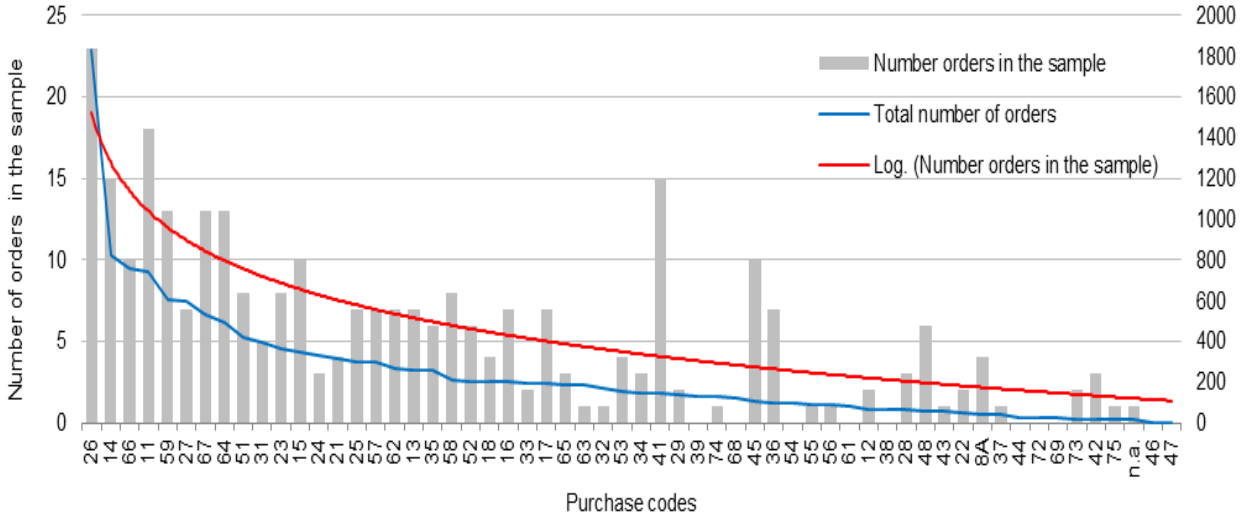
Benefits on firms: Technological spillovers

The present value of technological spillovers (T_t) is given by:

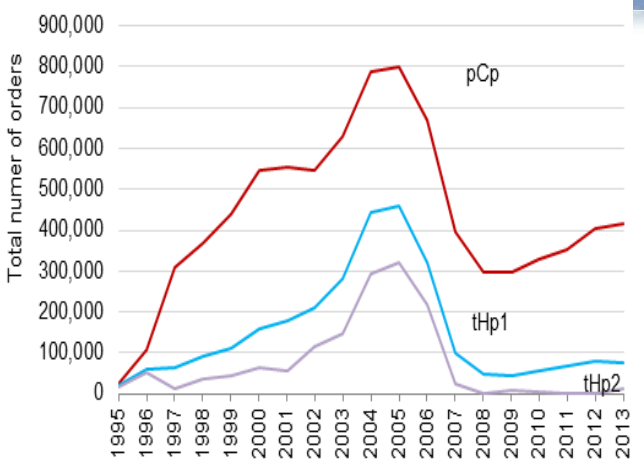
- the **discounted incremental social profits Π_{jt}** generated by **companies (j)** of the RI's supply chain which have benefitted from a learning effect;
- and **other externalities**.

$$T = \sum_{j=1}^{J} \sum_{t=0}^{\mathcal{T}} s_t \cdot \Pi_{jt}$$

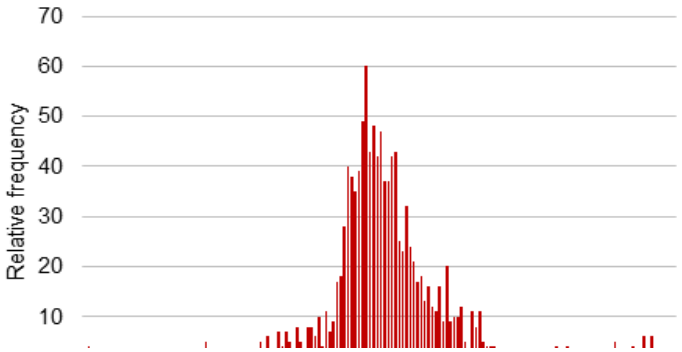
LHC: Technological spillovers



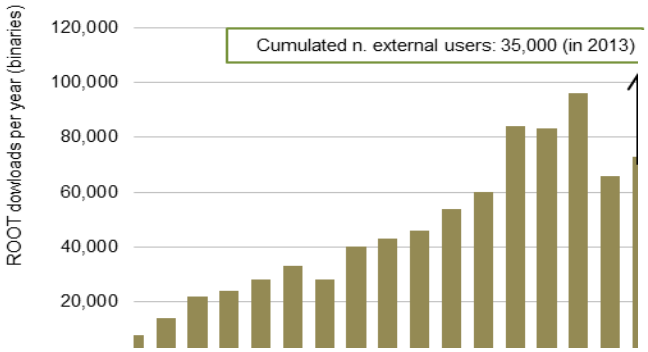
a) Benefits to firms in the supply chain. Sample of 300 orders by purchase code compared with all LHC orders



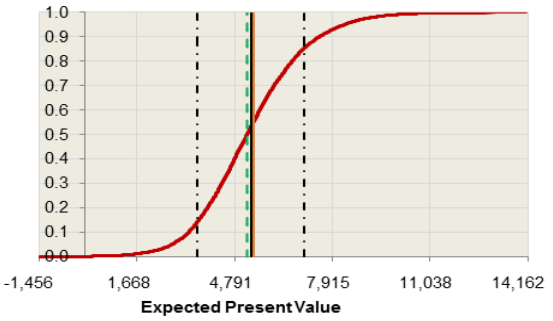
b) CERN external procurement - commitment for total and high-tech orders



c) Distribution of EBITDA 2013 from ORBIS in firms at NACE industry levels matched with CERN codes



d) ROOT download data



e) ENPV Cumulative distribution function (Montecarlo simulation after 10,000 extractions) conditional to PDF of critical variables (kEUR 2013)

Evidence from an ongoing study (1)

Florio, M., Castelnovo, P., Sirtori, E., Rossi, L., Forte, S.
The economic impact of CERN procurement: evidence from the Large Hadron Collider

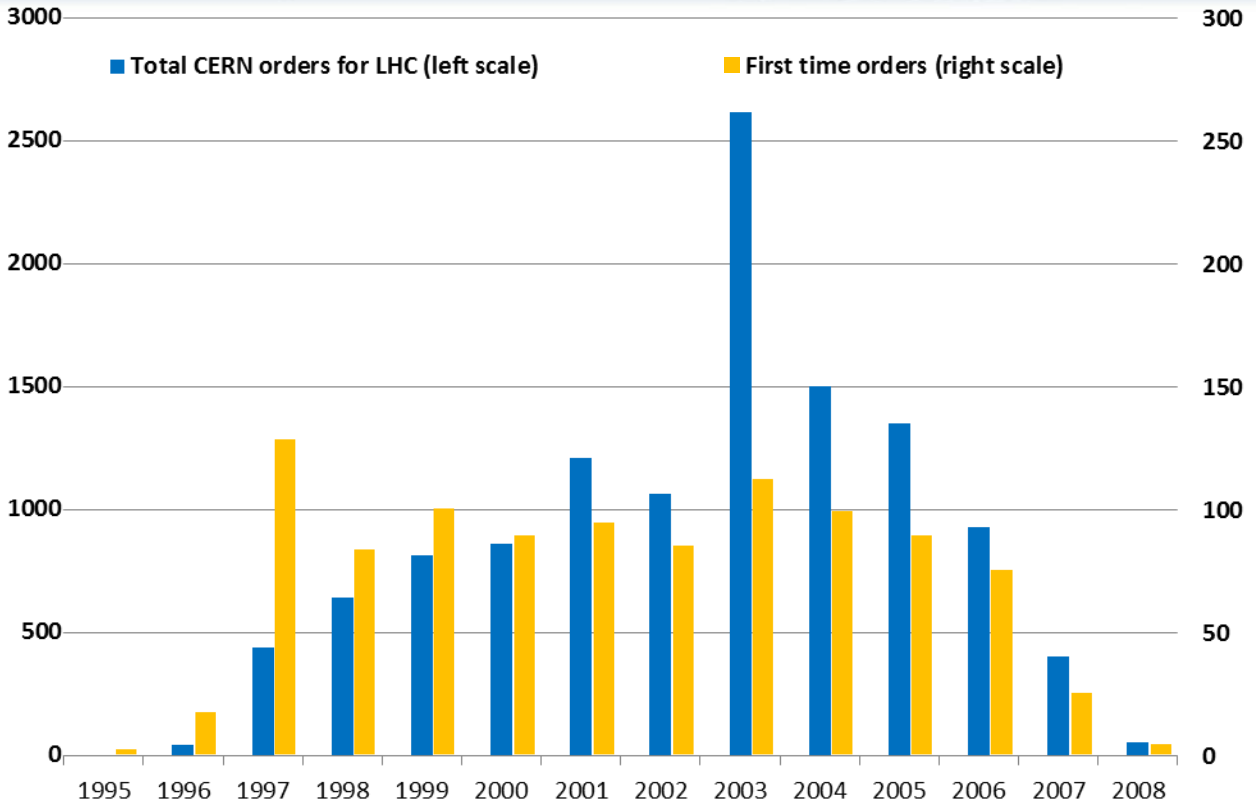
- Objective: discovering whether there has been **a long-term "learning by doing" effect** on CERN suppliers' profitability, beyond the initial order.
- Access to **CERN database on procurement** data for LHC between 1995 and 2008**. 1360 suppliers** from **35 countries** with least one order of over **CHF 10,000**. A total of **11,969 orders**. Out of the original list of LHC suppliers, **1,060 companies** have been identified in AMADEUS and ORBIS. Companies (**in total 500**) - for which core financial indicators over the time span 1991-2013 - were selected for a detailed analysis.
- Methodology entailed the **collection of 23-year long time series** of financial data (1991-2013) for a large sample of companies, controlling for **time trends**, f**irm-level** and country-level possible **confounding factors**.

Evidence from an ongoing study (2)

- Research question: ***Is there any evidence in the data that the profit margin of suppliers of the LHC increased over time after the initial contract with CERN***?
- Most interesting performance variable is the **profit margin, defined as the ratio of EBIT (Earnings Before Interest and Taxes)** to operating revenues. It is around 4.6% on average in the sample.
- A **dynamic panel data model** was built. The following variables were included amongst the controls: **profit margins** (lagged one year), **the firms' total assets** (control for size of the supplier) and **yearly GDP change in the country** where the firm was located and in the **OECD area, a time trend variable**, **year fixed effects.**

LHC: Technological spillovers (1)

Distribution by year of LHC procurement orders and of first-time orders to a supplier

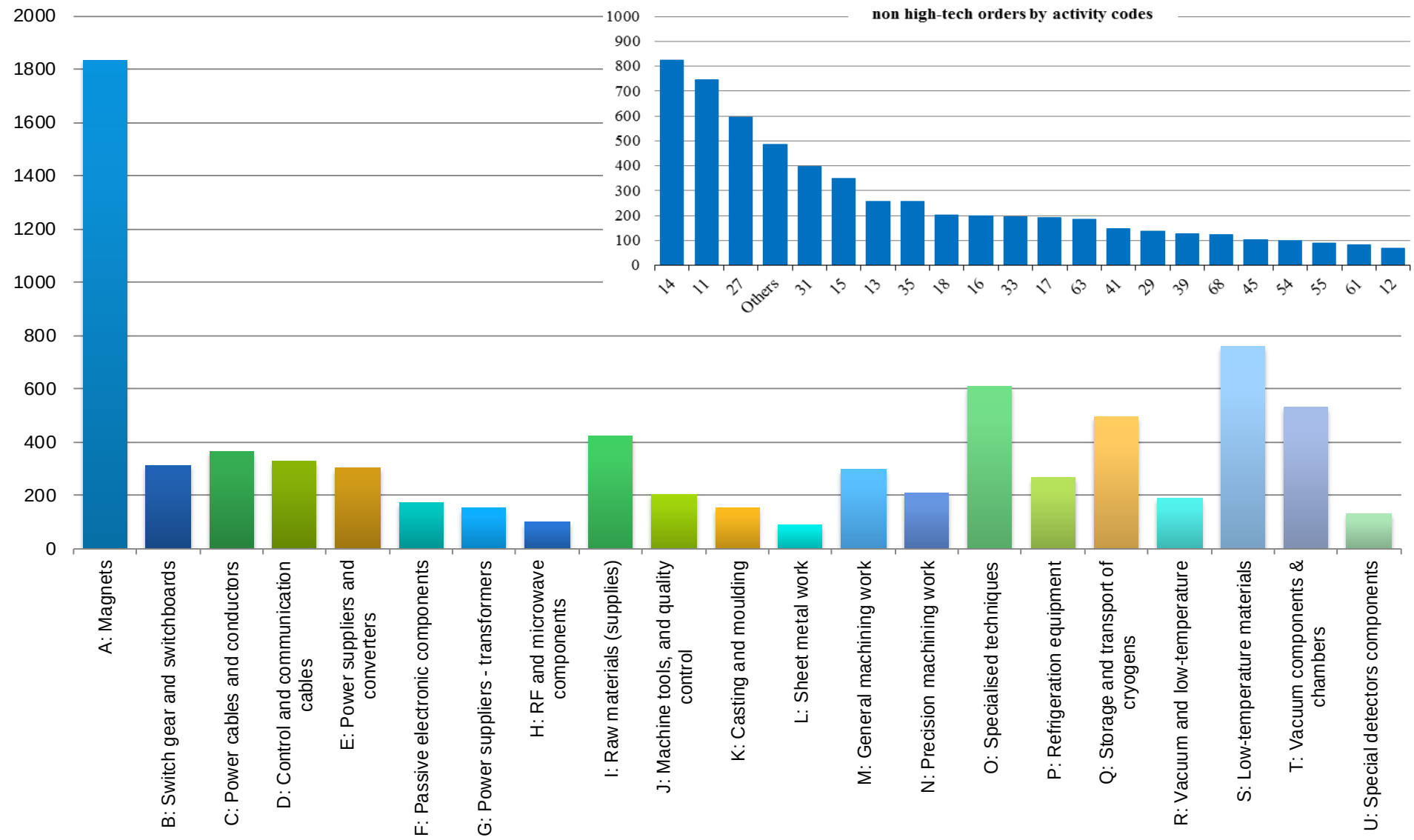


	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total CERN orders for LHC (left scale)	5	44	443	646	818	866	1212	1068	2621	1504	1355	929	403	55
First time orders (right scale)	2	17	128	83	100	89	94	85	112	99	89	75	25	4

Total CERN orders each year is the sum of the number of all the orders above CHF 10,000 in that year, including multiple orders to individual firms. First time orders are the number of orders that were agreed with a firm for the first time in that year. (First orders of 1995=2; 1996=17; 2008=4). *Source: Processing of CERN data.*

LHC: Technological spillovers (2)

Distribution of high-tech CERN procurement orders for LHC by activity code



Percent share of number of orders. Minor items omitted. *Source: CERN data*

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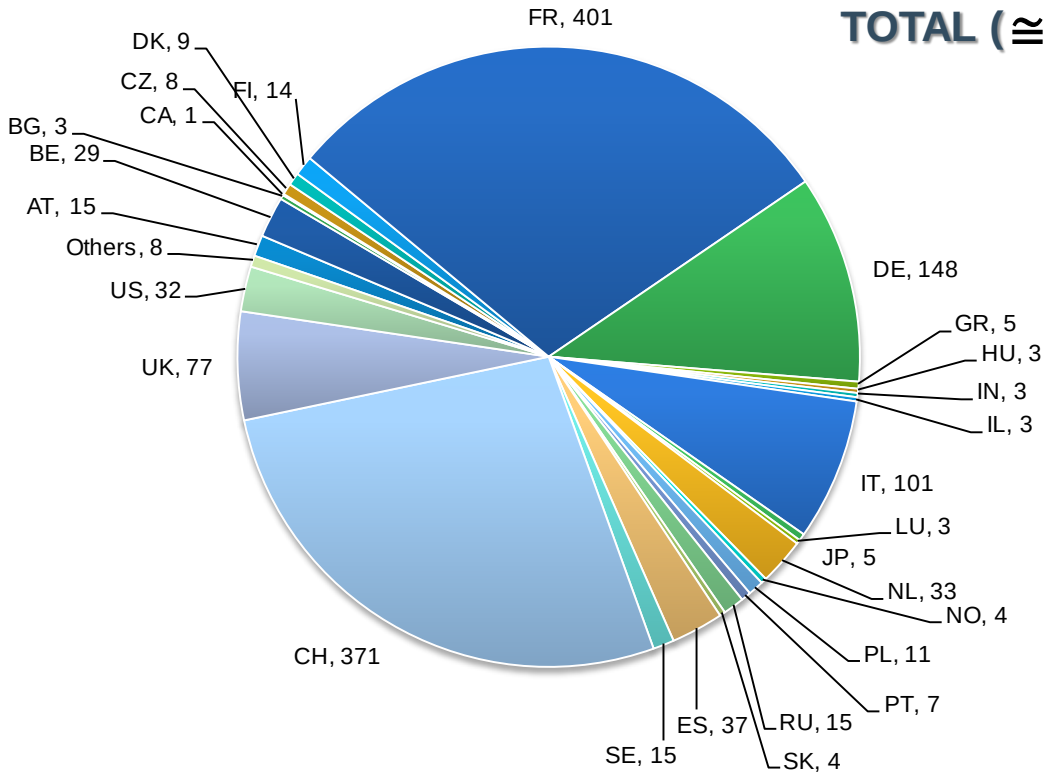
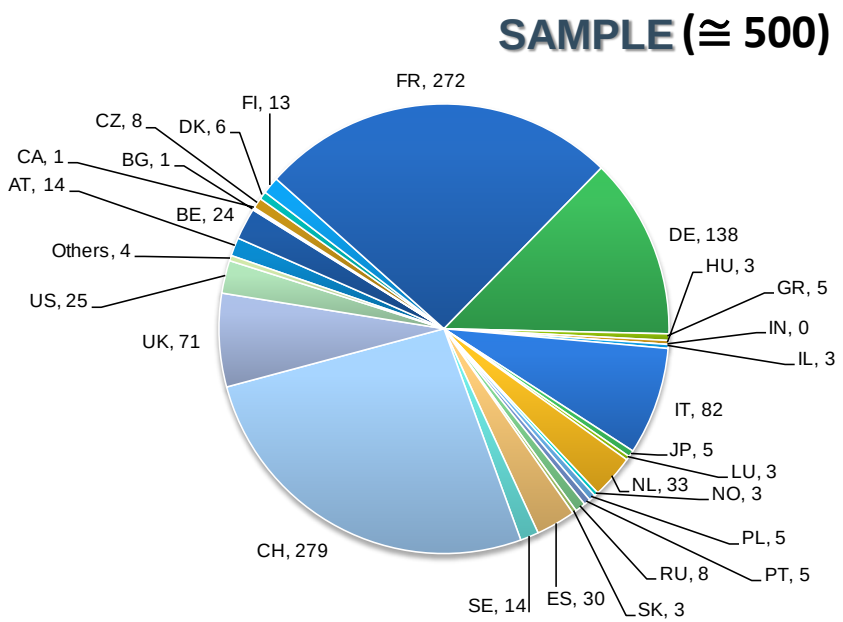
LHC: Technological spillovers (3)

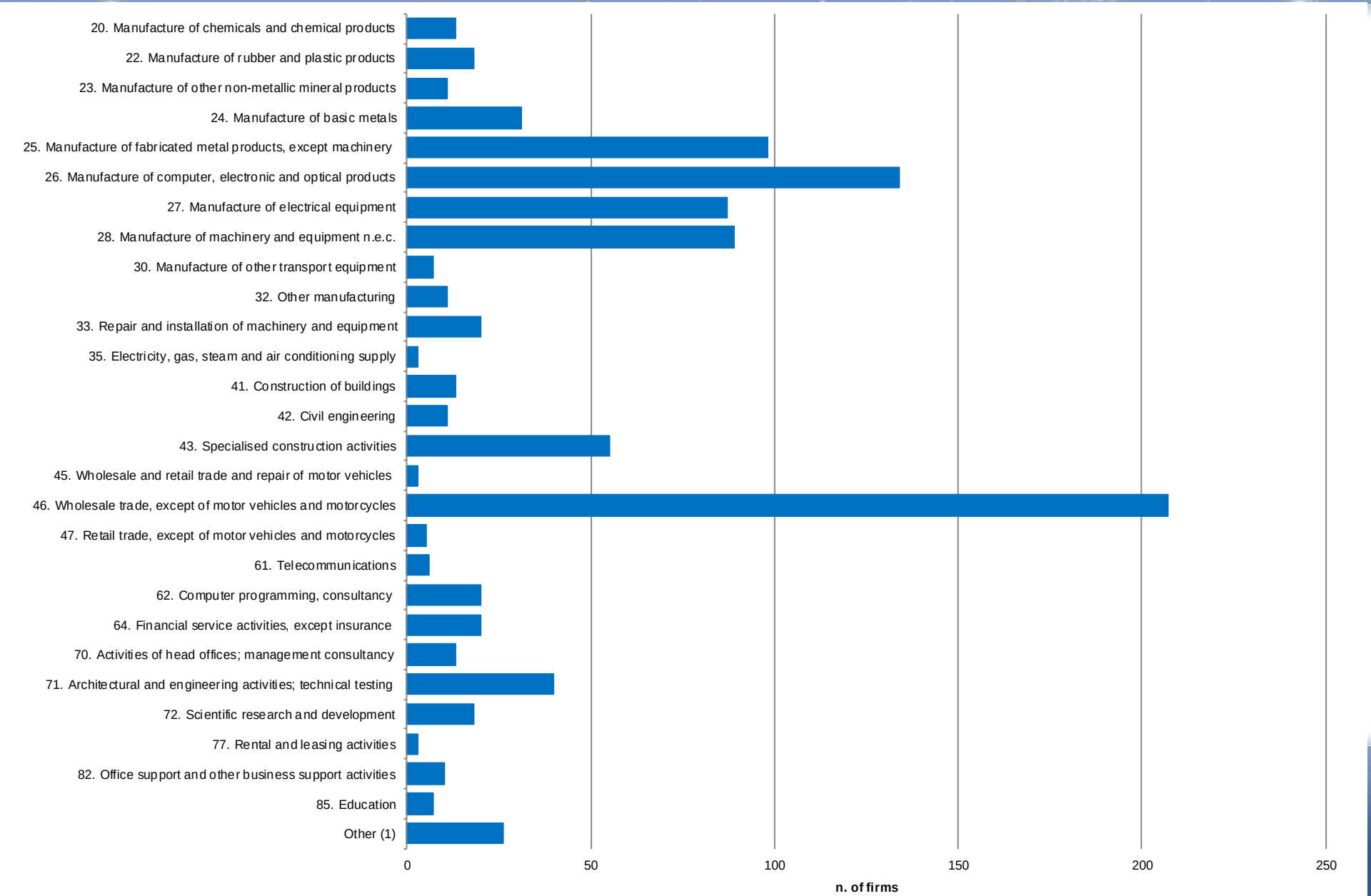
Distribution of LHC suppliers across countries





LHC: Technological spillovers (4)

LHC suppliers distribution by NACE code



LHC: Technological spillovers (5)

EBIT margin descriptive statistics

	average	std. dev.	25th	median	75th
Total sample	4.58%	12.94	1.21%	4.26%	8.45%
High-tech	4.62%	13.44	1.35%	4.46%	8.53%
Non-hi-tech	4.52%	11.98	0.95%	3.84%	8.15%

EBIT margin = EBIT/Operating Revenues. 25th and 75th are percentiles.
Source: Processing of CERN and AMADEUS-ORBIS data

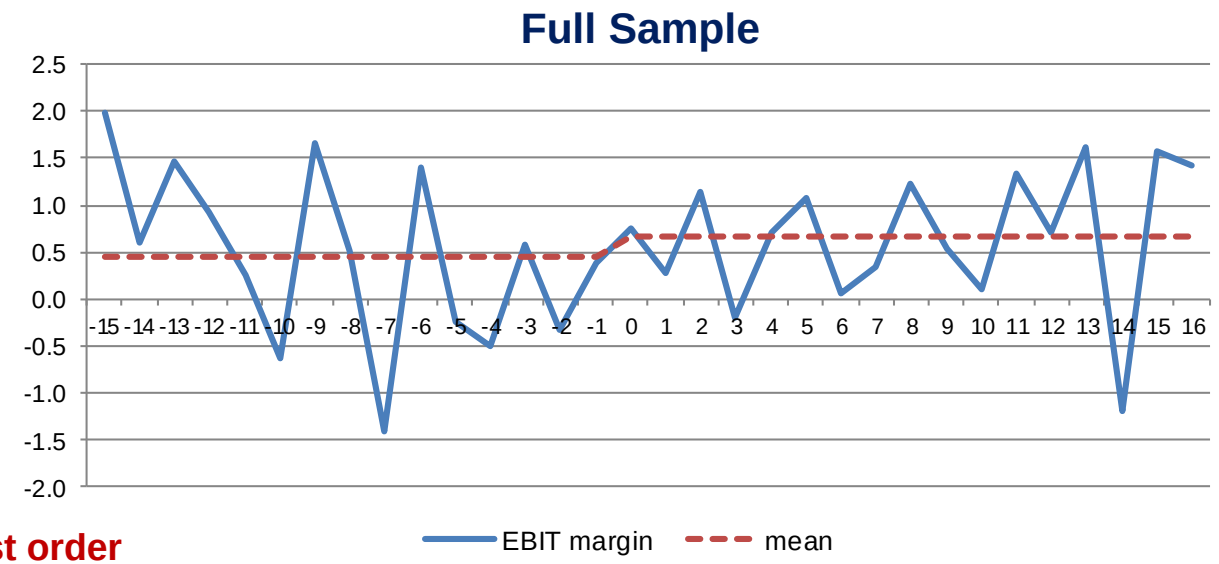
LHC: Technological spillovers (6)

		EBIT MARGIN (%)	
	Full Sample	High-Tech Firms	Non High-Tech Firms
CERN Effect	0.673**	1.007***	0.642
p-value	(0.032)	(0.001)	(0.256)
Firm Level Controls			
ΔTotal Assets[1]	YES	YES	YES**
ΔEBIT margin, 1-year lagged value	YES***	YES***	YES***
Macroeconomic Controls			
ΔGDP growth rate, firm's country	YES**	YES*	YES***
ΔGDP growth rate, OECD Area	YES	YES	YES**
Year fixed effect	YES***	YES***	YES***
Time trend	YES***	YES***	YES***
Constant	YES***	YES	YES***
Number of observations	4856	3017	1676
Number of Firms	333	203	118

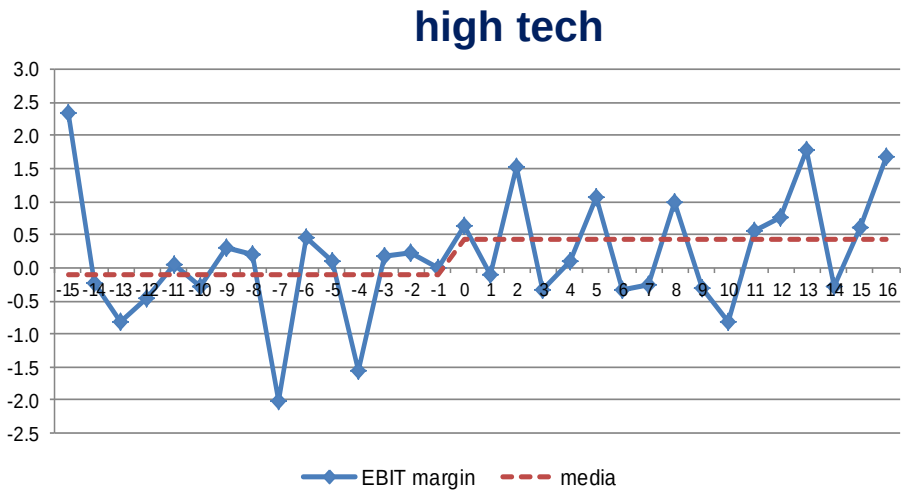
Regression results

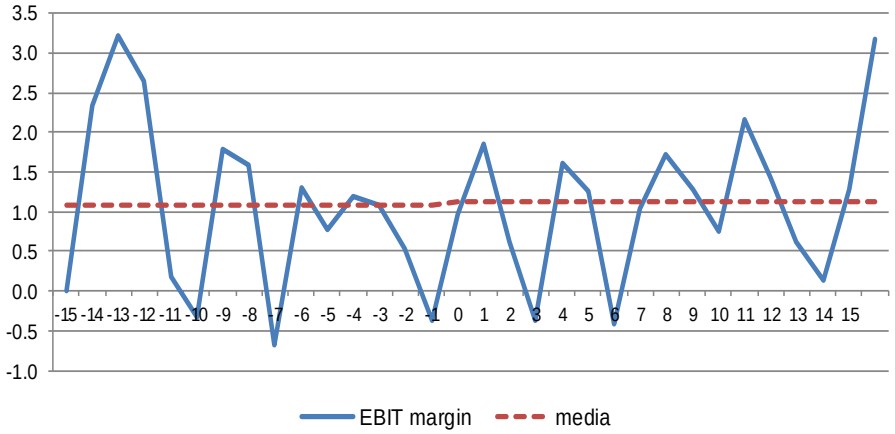
Standard Errors are clustered by country.
** p < 0.1, ** p < 0.05, *** p < 0.01*

EBIT margin



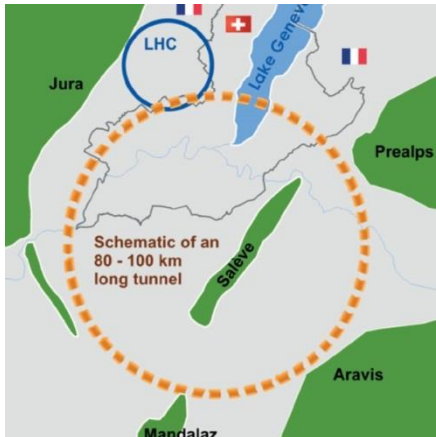
0= Year of the 1st order





Conclusions: Future Research

- **Testing the model** on other Research Infrastructures
- **Forecasting technological spillovers** with a control group of firms (non-CERN suppliers)
- Estimating **human capital** effects with **econometric 'treatment' techniques**
- Developing a **forecasting model for media impact of outreach**
- Expanding the contingent valuation of **willingness to pay for discoveries**
- Applying the model to the **Future Circular Collider**




Exploring Cost-Benefit Analysis of Research, Development and Innovation Infrastructures: An Evaluation Framework

Discussion Paper

Florio, M., Forte, S. and Sirtori, E.
2016

Forecasting the Social Impact of the Large Hadron Collider: A Cost-Benefit Analysis to 2025 and Beyond.

Available at
http://arxiv.org/abs/1603.00886

Forthcoming on Technological Forecasting & Social Change, **Special Issue on the Social Impact of Research Infrastructures at the Frontier of Science and Technology**

THANK YOU

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