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The Impact of Public Procurement on Financial Barriers to Green Innovation

Evidence from the European Community Innovation Survey*

Dorothea Schäfer[&,§], Andreas Stephan[&] und Sören Fuhrmeister[&]

Abstract

The purpose of this study is to identify whether an innovative company's likelihood of facing financial constraints is different when the company possesses a public procurement contract (PP). Theory suggests that the treatment effects of public procurement, particularly when mediated by the demand-pull effect, may lower a company's funding constraints for innovation. We test this theory and apply extended probit models (eprobit) with treatment and selection to control for an omitted variable bias. Our findings indicate that the treatment effect of PP on the likelihood of facing financial constraints is highly significant and positive. The increased pre-funding requirements that usually come along with PP may actually overcompensate the possibly constraint-reducing effects from a demand-pull or certification effect of PP. The treatment effect of PP is particularly strong for internal financial constraints backing the notion, that PP increases the need for upfront funding.

Keywords: public procurement, green public procurement, financial constraints, green innovation, sustainable finance, small and medium-sized enterprises

JEL: G30, O16/O31, Q56

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1 Introduction

Public procurement is a crucial factor in modern economies: every year, public authorities in the EU spend around €2 trillion (14% of GDP) on the purchase of services, works, and supplies.[1] Moreover, it is also a highly political issue: while public procurement has long been seen as a useful tool to foster (green) innovation, Russia's recent attack on Ukraine has also highlighted the importance of not just securing supplies of technology, commodities, and energy sources, but also of diversifying sources. The 2021 coalition agreement in Germany that initiated the Scholz German administration mentions the terms placing ("Vergabe") and procurement ("Beschaffung") 36 times and underlines the government's intention to use PP as an instrument to accelerate the transition to a green economy while streamlining bureaucratic processes and favoring small and medium-sized enterprises.

To analyze the relationship between funding barriers, success in public procurement, and green innovation, we use the Community Innovation Survey (CIS), which is conducted bi-annually in EU member states, EFTA countries, and EU candidate countries. The CIS provides micro firm data, including a wide range of indicators on environmental innovation activities, public funding, turnover from innovative products, as well as financial and other barriers to innovation. The 2014 wave also includes a wide range of data about the companies' public procurement contracts.

While previous research focuses exclusively on the effect of public procurement on innovation, we begin by estimating the effect of innovation on the chance of winning a PP contract. In doing so, we account for the potential incentive of public authorities to select firms that are already more innovative than others in order to maximize the probability of success of their innovation policies. Moreover, innovative firms may be more likely to be able to submit a bid for an innovative PP competition than their non-innovative peers (Guerzoni & Raiteri 2015). We find clear evidence that innovative firms have a higher chance to possess a PP.[2] Therefore, we apply eprobit models with endogenous treatment and selection when assessing whether PP matters for the financial constraints of innovative firms.

Economic theory suggests that the *certification effect* of public procurement, particularly when mediated by the *demand-pull effect*, may lower a company's funding constraints (Ghisetti 2017;

1 Source: https://ec.europa.eu/growth/single-market/public-procurement_en

2 https://ec.europa.eu/growth/single-market/public-procurement/strategic-procurement/innovation-procurement_de

Li, Chen, Gao & Xie 2019; Dai, Li & Chen 2021). Our findings show that the treatment effect of PP on the probability of facing financial constraints is highly significant and positive. The increased pre-funding requirements that usually come along with PP may overcompensate for the potentially constraint-reducing effects from a demand-pull or certification effect of PP. In particular, public procurement may affect internal funds as working capital is usually generated internally. The results for internal financial constrains indicate that the treatment effect of PP is indeed particularly strong if a company indicates a lack of internal funds. The likely reason behind our second finding is that there is a need to prefund expenditures on labor and inputs because the revenues from PP often only flow later, after the goods or services have been sold. Consistent with this, we find that the likelihood is higher for a company with PP that public de-risking is of medium or high importance for realizing environmental innovation.

Our research contributes to the vast literature of the importance of financial barriers for innovation. We add to the rather new, but increasingly more important, strand that focuses on the mediating role of public procurement in easing financial barriers to green innovation. Our results suggest that polices aimed at promoting innovation in general, or green and renewables-related innovation in particular, through PP can be successful. However, it is essential to recognize that winning a PP contract for a firm comes with additional requirements for funding. As a result, the likelihood to face financial constraints increases with a public procurement contract. Our evidence clearly supports the 2014 EU procurement regulation reform and confirms the importance of removing financial barriers for green innovation and for strengthening SMEs (Hoekman and Taş 2022).

The remainder of the paper is organized as follows. In Section 2, we briefly review the existing literature on public procurement and its impact on innovation, as well as on the demand-pull and certification hypotheses of relaxing financial barriers. We then begin our empirical analysis in Section 3 by presenting the data and describing the key features of the dataset. In Section 4, we report and discuss the estimation results. The applied extended probit regression (eprobit) command is described in the Appendix. Section 5 concludes.

2 Literature Review

Public Procurement and innovation

The effect of winning public procurement contracts on innovation investments is an active research topic. The focus is almost entirely on the effect of PP on innovation. Based on a survey

of 1149 German firms, Aschhoff and Sofka (2009) find that both public procurement and knowledge spillover from universities have similarly positive impacts on innovation success. Moreover, PP is particularly efficient for smaller firms in economically strained regions and in the field of distributive or technological services.

Czarnitzki et al. (2018) discover a robust and significant effect of innovation-directed public procurement (IPP) on a firms' turnover with innovative products and services. The effect seems to be restricted to innovations that are new to the firm but not new to the market. Guerzoni and Raiteri (2015) apply a matching approach to a dataset of 5,200 European firms. They observe that firms with IPP contracts are more likely to increase their private spending on innovation activities and point out possible reinforcement interactions between demand-side (PP) and supply-side (tax credits, subsidies) policy instruments.

Similarly, Caravella and Crespi (2021) analyze the effects of regular public procurement (RPP) and IPP on private R&D investments for a sample of Italian firms and find that IPP stimulates R&D investments only when combined with supply-push measures such as soft loans, tax deductions, and grants. Shin and Lee (2021) observe that South Korean firms with IPP contracts experience a higher rate of change in total factor productivity as well as a higher growth rate of value-added than firms with RPP.

Using a panel dataset of 5,400 German firms, Zipperer (2019) shows that public procurement contracts have a demand-pull effect on general innovation, but finds no conclusive evidence regarding environmental innovation. She reveals heterogenous effects for different sectors: while companies in the water supply and waste management industry are more likely to introduce product innovation, firms in the electricity and gas sector are more likely to introduce process innovations after winning a PP. In addition, Zipperer finds a slow but persistent demand-pull effect of PP on general product innovations for firms in the manufacturing sector. With a cross-sectional difference-in-differences approach, Krieger and Zipperer (2021) argue that winning a PP contract triggers a demand-pull for SMEs, which increases their probability to introduce environmental product innovations by 25 percentage points. However, the authors find no significant effect for larger companies or for the introduction of environmentally friendly process innovations.

Public procurement can create or enlarge the market demand for certain goods or services, thereby compensating for costs and reducing the risks of R&D activities. Horbach et al. (2012) confirm the importance of market demand for promoting environmental innovations. Using

German CIS data on 1,300 companies, they show that 27% of the firms in the sample innovated because of customer demand, while only 10% did so because of government subsidies.

Ghisetti (2017) applies a matching approach to a dataset of 3,000 European manufacturing firms and finds that companies with a PP contract are 11.1 percentage points more likely to innovate environmentally and 6.6 percentage points more likely to innovate in general. She argues that PP, as an instrument to reduce the risks associated with innovation, particularly regarding uncertain demand, could be well suited to foster environmental innovation.

The literature above neglects the potential incentive of public authorities to select firms that are already more innovative than others to support own innovation targets. Another missed issue is the possibility that innovative firms are more likely to submit a bid for an innovative PP competition than their non-innovative peers (Guerzoni & Raiteri 2015).

Public Procurement and financial barriers to innovation

Dai et al. (2021) examine the quantitative importance of the *demand-pull effect* of PP by applying causal mediation analysis to a sample of high-tech firms in China. They find that the demand-pull effect leads to an increase in R&D investment and high-tech product sales, demonstrating the effectiveness of PP in stimulating research & development. In addition, their causal analysis reveals that the treatment effects of public procurement, particularly when mediated by the demand-pull effect, improve the firms' access to external financing. They infer from their results that public agencies, if able to identify promising innovative projects or firms, could use public procurement to ease market failures of financing for innovation. The funding of new products and services faces particular barriers and constraints as potential investors often have scarce knowledge about the market potential of the innovation. In addition, in the starting phase innovative investments are often investments in well-educated and highly trained people. Investments in human beings cannot be pledged as collateral with a bank in contrast to investments in goods (Schäfer et al., 2017).

Literature on the *certification effect* of PP is scant. Dai et al. (2021) argue that winning a PP contract can serve as a certificate or signal of the quality of recipient firms, which in turn stimulates innovation by attracting external investors and relaxing financial constraints. They show that the certification effect leads to a significant increase in R&D investment. The effect was even more pronounced for financially constrained small and young firms.

Baum et al. (2021) use official SMEs balance sheet data from AMADEUS. By conducting a difference-in-difference analysis they find that a lower equity ratio and a higher short-term debt ratio increase the companies' probability of success in a public tender. In addition, success means that the enterprise can continue to work after the award with a lower equity ratio than comparable firms without an award. This finding supports the *certification effect* hypothesis. It may indicate that success in a PP is a substitute for a company's own financial strength, thus facilitating access to external financing after receiving an award.

The research on the impact of PP financial constraints largely neglects the issue that innovative firms are more prone to participate in and win a tender than non-innovative firms. This is surprising since promoting innovation via public procurement would require at least that tendering firms are able to demonstrate capability of innovation.

Public de-risking and innovation

More literature is available on the certification effect of government subsidies: Lerner (1999) is the first scholar to empirically examine the long-run effects on firms' financing of the United States Department of Energy's Small Business Innovation Research (SBIR) program. He observed that SBIR award winners are more likely to later receive venture capital funding, although the effect is confined to areas with substantial venture capital activities and more pronounced in high-tech industries. Larger subsidies are found to not have a larger effect, confirming the certification hypothesis.

In contrast, although Howell (2017) finds that early-stage grants of the SBIR program ease financing constraints, she provides empirical evidence that the effect does not work via the certification mechanism. Instead, grants enable companies to manufacture prototypes, which they would otherwise not be able to finance. Feldman and Kelley (2006) also argue that government subsidies may serve as a signal for project or company quality. They observe that award winners of the US Advanced Technology Program subsequently attract larger amounts of R&D funding from non-government actors like venture capitalists.

Using a Flemish dataset of 1,600 firms, Meuleman and De Maeseneire (2012) find further evidence that receiving R&D subsidies is a positive signal about SME quality and results in better access to long-term debt. They find no effect on short-term debt and external equity finance. The certification effect of R&D grants is stronger in case of higher asymmetric information, while the relative size of the grant does not affect the likelihood of attracting external investors.

Chen et al. (2018) examine the impact of R&D and non-R&D government subsidies on initial public offering (IPO) performance of a sample of 269 Chinese enterprises. They argue that while R&D subsidies initially convey a positive signal, above a certain threshold, investors become increasingly concerned about the risks and uncertainties associated with R&D activities. Non-R&D subsidies, on the other hand, would serve as a positive signal of government confidence in companies' capabilities. Finally, Li et al. (2019) find that Chinese companies receiving public R&D subsidies enjoy a positive certification effect easing financial constraints of firms that borrow from banks. This effect is stronger for unlisted firms and in regions with weaker intellectual property rights protection.

We complement the above cited research. After investigating the role that being capable of innovation may have for a company's success in public procurement, we test in the centerpiece of our research the relevance of demand pull and certification effect of public procurement contracts for both potential innovators and potentially green innovators. Both, the demand pull and certification effect imply that firms with a public procurement contract are less likely to face financial constraints.

3 Data and Sample Description

Data

The analysis is based on the European Community Innovation Survey (CIS), which aims to provide information about innovation activities in enterprises. The survey is conducted every two years in the European Union, EFTA countries, and EU candidate countries. The CIS is implemented using a standardized core questionnaire[3] to ensure cross-country comparability and is designed to provide information on a variety of innovation activities (product, process, organizational and marketing innovation) at the firm level, broken down by country, economic sector, and company size class.

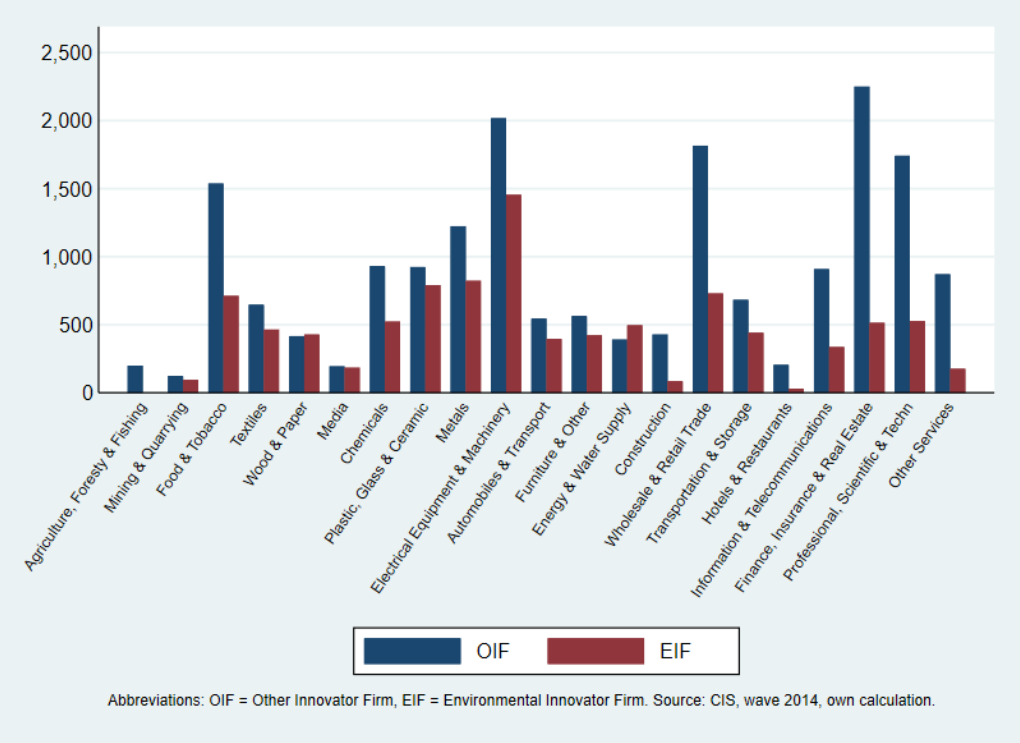
The CIS 2014 wave, which covers the activities of firms during the three-year reference period 2012-14 has a section on public procurement. In addition, the CIS 2014 provides a wide range of indicators on innovation activities, public funding, turnover from innovative products, financial constraints and other barriers to innovation. It also contains a module on innovations with environmental benefits.

3 Available at: https://ec.europa.eu/eurostat/cache/metadata/Annexes/inn_cis9_esms_an4.docx

Sample Description

We start with some descriptive findings. Figure 1 illustrates how environmental innovations are distributed across industries. Environmental innovation is found in every industry; however, the number of active companies differs widely. Environmental Innovator Firms (EIF) are especially frequent in Electrical Equipment/Machinery, Plastic/Glass/Ceramic, and Metals, but are rare in Hotels/Restaurants, Mining/Quarrying and Construction. In addition, we observe a higher number of Other Innovator Firms (OIF) relative to EIF in less energy-intensive industries like Finance/Insurance/Real Estate, Professional, Scientific & Technical Activities, and Wholesale/Retail Trade.

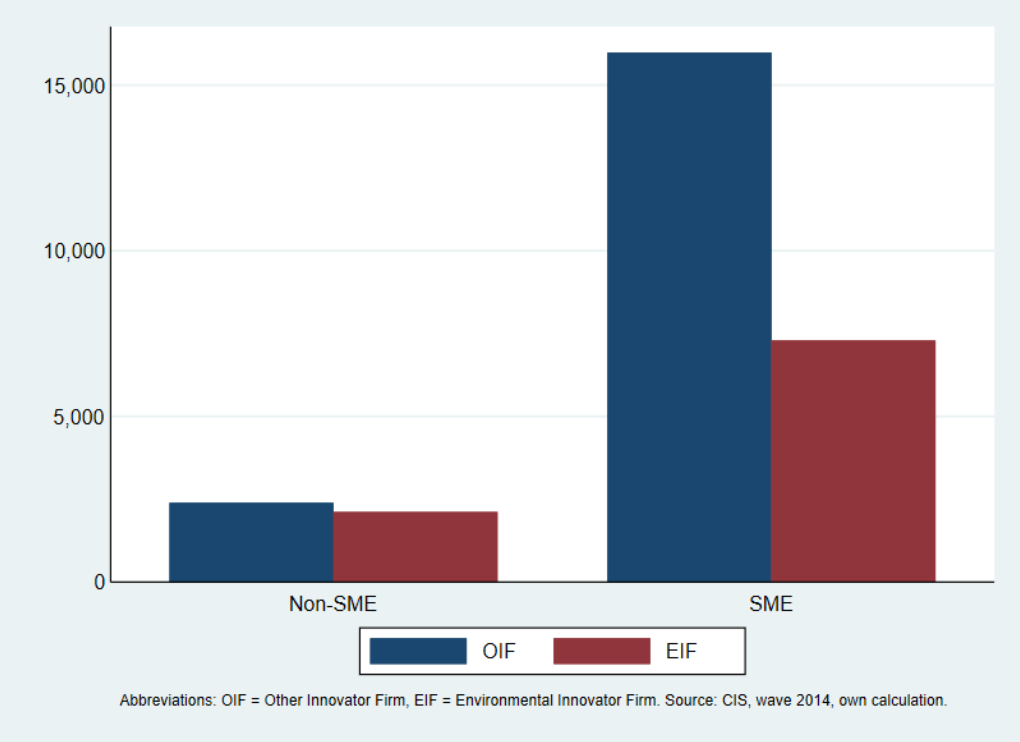
FIGURE *1*: DISTRIBUTION OF ENVIRONMENTAL INNOVATION ACROSS INDUSTRIES



Source: CIS 2014, own calculations.

Figure 2 shows the number of Small and Medium-sized Enterprises (SMEs) by innovator categories. We find that the number of OIF exceeds the number of EIF in both SMEs and non-SMEs. However, the relative importance of Environmental Innovator Firms is greater for non-SMEs than for SMEs.

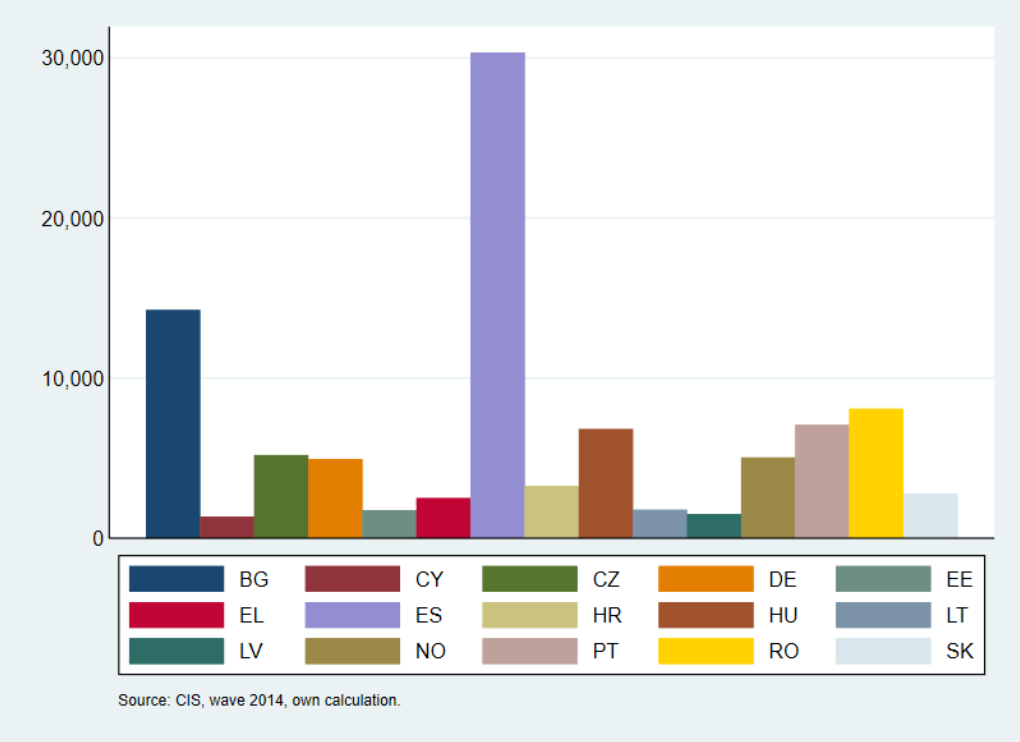
FIGURE *2*: NUMBER OF SMES BY INNOVATOR CATEGORIES



Source: CIS 2014, own calculations.

Figure 3 displays the number of enterprises by country. The Community Innovation Survey 2014 comprises a total of 98,809 companies across 15 European countries, with the largest proportion of firms operating in Spain (31 %) and Bulgaria (14%).

FIGURE *3*: NUMBER OF ENTERPRISES BY COUNTRY



Source: CIS 2014, own calculations.

Table 1 reports the share of Small and Medium-sized Enterprises (SMEs) among innovative and non-innovative firms. While around 84 percent of the innovators are SMEs, the share is even higher for *non-nnovators* at 92 percent. In addition, Table 1 distinguishes between Environmental Innovator Firms (EIF) versus Other Innovator Firms (OIF), as well as Environmental Innovator Firms Renewables (EIFR) versus Environmental Innovator Firms Other (EIFO). The share of SMEs in OIF is about 87 percent compared to an SME share in EIF at 78 percent. In addition, the share of SMEs is significantly higher for EIFO (86 %) than for EIFR (74 %). To put these findings into perspective: 89.7 percent of the firms in the entire sample are SMEs. This means that the proportion of SMEs in the EIF and EIFR categories is significantly lower than the sample average.

TABLE *1*: THE SHARE OF SMALL AND MEDIUM-SIZED ENTERPRISE (%)

Innovator (Product/Process) vs Non-Innovator (Product/Process)			
	Innovator	*Non-Innovator*	*t-test*
SME	83.77	92.08	0.00***
Environmental Innovator Firms vs Other Innovator Firms			

	EIF	*OIF*	*t-test*
SME	77.51	86.98	0.00***

EIF Renewables vs EIF Other			
	EIFR	*EIFO*	*t-test*
SME	74.03	85.94	0.00***

Notes: Results of two-sample t-test for equal means. **** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations. Abbreviations: Innovator = firm has introduced product or process innovation (Non-Innovator = otherwise), EIF = firm has introduced an innovation with environmental benefits (OIF = if no environmental benefits), EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

Table 2 displays differences in the importance of public funding for innovation. The rows in bold contain the results of a two-sample *t*-test for equal means for the full sample. The proportion of firms receiving public funding from central governments or the EU is significantly higher for EIF compared to OIF. On the other hand, the share of firms receiving public funding from local authorities or the EU's framework program is significantly higher for OIF than for EIF. In contrast, the share of firms receiving public funding is significantly higher for EIFR compared to EIFO in all four categories. Looking at the breakdown between SMEs and non-SMEs, it becomes clear that non-SMEs receive more public funding than SMEs. Only in the subgroup of "Local or regional authorities" does this tendency partially reverse. Overall, the largest proportion of firms report receiving funding from the central government or the EU, while funding from local or regional authorities plays only a negligible role.

TABLE *2*: IMPORTANCE OF PUBLIC FUNDING FOR INNOVATION (%)

Public funding by	*EIF*	*OIF*	*t-test*	*EIFR*	*EIFO*	*t-test*
Local or regional authorities	7.35	12.94	0.00***	8.07	5.81	0.00***
SME	7.58	13.08	0.00***	8.13	6.57	0.02**
Non-SME	8.18	1.92	0.00***	8.18	1.92	0.00***
Central government	28.91	23.55	0.00***	32.54	21.04	0.00***
SME	27.68	23.33	0.00***	31.18	21.21	0.00***
Non-SME	34.33	26.23	0.00***	37.30	22.25	0.00***
European Union	20.71	10.34	0.00***	22.74	16.32	0.00***
SME	19.93	10.21	0.00***	21.70	16.66	0.00***
Non-SME	24.78	11.70	0.00***	26.76	16.76	0.00***
EU's Framework	11.96	17.58	0.00***	13.64	7.49	0.00***

Programme						
SME	10.56	15.93	0.00***	11.91	7.57	0.00***
Non-SME	15.48	26.67	0.00***	17.30	7.18	0.00***

Notes: Results of two-sample t-test for equal means. *** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations. Abbreviations: EIF = firm has introduced an innovation with environmental benefits (OIF = if no environmental benefits), EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

Table 3 shows whether companies conducted in-house Research & Development (R&D) during the three years from 2012 to 2014. Compared to OIF (52 %), the share of firms with internal R&D activities is significantly higher for EIF (57 %). Similarly, the share of firms with internal R&D is significantly higher for EIFR (62 %) than for EIFO (46 %). Furthermore, non-SMEs are significantly more likely to report in-house R&D activities than SMEs.

TABLE *3*: R&D ENGAGEMENT OF DIFFERENT TYPES OF INNOVATOR FIRMS (%)

	EIF	*OIF*	*t-test*	*EIFR*	*EIFO*	*t-test*
In-house R&D	56.97	51.81	0.00***	61.84	45.81	0.00***
SME	53.34	51.19	0.00***	58.10	44.02	0.00***
Non-SME	70.05	57.96	0.00***	72.97	57.59	0.00***

Notes: Results of two-sample t-test for equal means. *** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations. Abbreviations: EIF = firm has introduced an innovation with environmental benefits (OIF = if no environmental benefits), EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

Table 4 reports the share of graduate employees for different innovator firms. Graduates reflect a company's ability to innovate. We find that EIF have an overall significantly higher proportion of graduate employees than OIF. If we further distinguish between EIFR and EIFO, we find that the share of graduate employees is significantly higher overall for EIFR. The breakdown into SMEs and non-SMEs reveals that the share of graduate employees is higher for non-SMEs.

TABLE *4*: SHARE OF GRADUATE EMPLOYEES FOR DIFFERENT INNOVATOR FIRMS (%)

Share of graduates	*EIF*	*OIF*	*t-test*	*EIFR*	*EIFO*	*t-test*
Over 10%	34.98	30.62	0.00***	36.02	32.47	0.00***
SME	32.48	31.06	0.03**	33.62	30.08	0.00***
Non-SME	43.84	27.50	0.00***	43.10	47.15	0.15
Over 25%	28.12	18.23	0.00***	28.95	26.13	0.01**
SME	25.75	18.49	0.00***	26.55	24.07	0.02**

Non-SME	37.60	16.34	0.00***	36.86	40.93	0.14
Over 50%	21.68	4.79	0.00***	22.42	19.90	0.01**
SME	18.66	4.31	0.00***	19.13	17.67	0.13
Non-SME	34.29	8.48	0.00***	33.79	36.79	0.25

Notes: Results of two-sample t-test for equal means. **** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations. Abbreviations: EIF = firm has introduced an innovation with environmental benefits (OIF = if no environmental benefits), EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

Table 5 provides a breakdown of the share of graduate employees by industry/sector. Not surprisingly, companies in the Finance, Insurance & Real Estate sector or in the Information & Telecommunications sector, as well as in the field of Professional, Scientific & Technical Activity have the highest share of employees with a university degree by far.

TABLE *5*: PERCENTAGE OF EMPLOYEES WITH UNIVERSITY DEGREE BY INDUSTRY

Industry	Percentage of employees with university degree				
	<25%	25% to < 50%	50% to < 75%	> 75%	Total
Agriculture, Forestry & Fishing	840	62	15	10	927
	90.61	6.69	1.62	1.08	100 %
Mining & Quarrying	740	118	51	53	962
	76.92	12.27	5.30	5.51	100 %
Food & Tobacco	5,731	672	160	76	6,639
	86.32	10.12	2.41	1.14	100 %
Textiles	4,892	233	61	72	5,258
	93.04	4.43	1.16	1.37	100 %
Wood & Paper	2,601	190	57	52	2,900
	89.69	6.55	1.97	1.79	100 %
Media	961	158	54	38	1,211
	79.36	13.05	4.46	3.14	100 %
Chemicals	1,234	743	248	113	2,338
	52.78	31.78	10.61	4.83	100 %
Plastic, Glass & Ceramic	3,816	425	86	50	4,377
	87.18	9.71	1.96	1.14	100 %
Metals	5,027	515	106	108	5,756
	87.33	8.95	1.84	1.88	100 %
Electrical Equipment & Machinery	4,676	1,405	553	289	6,923
	67.54	20.29	7.99	4.17	100 %
Automobiles & Transport Equipment	1,408	235	50	40	1,733
	81.25	13.56	2.89	2.31	100 %
Furniture & Other	2,215	262	91	62	2,630
	84.22	9.96	3.46	2.36	100 %
Energy & Water Supply	2,567	518	200	143	3,428

	74.88	15.11	5.83	4.17	100 %
Construction	2,202	305	93	104	2,704
	81.43	11.28	3.44	3.85	100 %
Wholesale & Retail Trade	8,821	2,068	1,212	1,061	13,162
	67.02	15.71	9.21	8.06	100 %
Transportation & Storage	5,535	606	295	263	6,699
	82.62	9.05	4.40	3.93	100 %
Hotels & Restaurants	1,401	127	32	62	1,622
	86.37	7.83	1.97	3.82	100 %
Information & Telecommunications	818	588	765	772	2,943
	27.79	19.98	25.99	26.23	100 %
Finance, Insurance & Real Estate	1,150	996	1,460	2,465	6,071
	18.94	16.41	24.05	40.60	100 %
Professional, Scientific & Technical Activity	1,189	896	1,385	2,131	5,601
	21.23	16.00	24.73	38.05	100 %
Other Services	3,233	717	428	363	4,741
	68.19	15.12	9.03	7.66	100 %
Total	61,057	11,839	7,402	8,327	88,625
Percent	68.89	13.36	8.35	9.40	100 %

Notes: The first row shows frequencies, and the second row shows percentages. Source: CIS 2014, own calculations.

Table 6 contains descriptive statistics on the turnover of different innovator firms. In 2014, EIF had a significantly higher total turnover (in millions of euros) than OIF. Likewise, EIFR had a significantly higher total turnover than EIFO. In addition, OIF generated a higher proportion of their turnover from innovations that were new to the market or new to the company than did EIF. When comparing EIFR and EIFO, we cannot observe any significant difference in terms of their respective share of turnover from innovations that are new to the company.

TABLE 6: TURNOVER FOR DIFFERENT INNOVATOR FIRMS

Turnover	*EIF*	*OIF*	*t-test*	*EIFR*	*EIFO*	*t-test*
Total turnover in 2014 (in million of euros)	84.35	58.56	0.00***	109.62	23.03	0.00***
SME	11.45	15.97	0.00***	13.11	7.98	0.00***
Non-SME	340.48	347.83	0.87	390.35	116.86	0.00***
% of turnover from innovation new to market	9.96	14.07	0.00***	10.08	9.63	0.34
SME	10.17	14.50	0.00***	10.25	9.99	0.62
Non-SME	9.28	11.62	0.00***	9.56	7.71	0.13
% of turnover from innovation new to firm	14.21	19.91	0.00***	14.20	14.24	0.94

SME	14.60	20.22	0.00***	14.57	14.66	0.88
Non-SME	12.97	18.25	0.00***	13.14	12.17	0.41

Notes: Results of two-sample t-test for equal means. *** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations.
Abbreviations: EIF = firm has introduced an innovation with environmental benefits (OIF = if no environmental benefits), EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

Table 7 shows the importance of barriers to innovation. It should be noted that these obstacles were only indicated by No Innovators. The barriers explain why these firms are non-innovator firms. We observe that a large majority of firms face innovation constraints. Around 66 to 76 percent of the No Innovators complain about a lack of collaboration partners, lack of skilled employees within the enterprise, difficulties in obtaining government grants/subsidies, uncertain market demand for innovation ideas, respectively. These results apply similarly to SMEs and non-SMEs. In contrast, SMEs complain significantly more often than non-SMEs about too much competition in the market.

TABLE *7*: SHARE OF SMES AMONG NO INNOVATORS FACING INNOVATION CONSTRAINTS (%)

Innovation constraints	*SME*	*Non-SME*	*t-test*
Difficulties in obtaining gov. grants or subsidies	75.24	71.33	0.07*
Lack of skilled employees within enterprise	73.71	70.55	0.15
Lack of collaboration partners	69.30	65.79	0.13
Uncertain market demand for ideas for innovations	75.72	71.56	0.05*
Too much competition in market	76.62	68.72	0.00***

Notes: Results of two-sample t-test for equal means. *** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations.
Abbreviations: No Innovator = firm hasn't introduced product or process innovation.

Table 8 reports that the share of EIFR facing financial constraints is higher than the share of EIFO. The breakdown between SMEs and non-SMEs shows that the difference can be attributed to SMEs only. These results indicate that financial constraints are particularly relevant for small and medium-sized enterprises whose innovation is related to renewable energies.

TABLE 8: SHARE OF EIFR AND EIFO WITH FINANCIAL CONSTRAINTS

	EIFR	*EIFO*	*t-test*
Financial constraints	26.67	21.72	0.00***
SME	27.99	22.33	0.00***
Non-SME	22.88	18.91	0.09*

Notes: Results of two-sample t-test for equal means. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: CIS 2014, own calculations.
Abbreviations: EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

Table 9 shows the percentage of companies with a PP contract from 2012 to 2014. The share of enterprises with a procurement contract is not significantly different for EIF and OIF. Moreover, the percentage of companies with a procurement contract is higher for EIFR (29 %) than for EIFO (27 %), here the difference is statistically significant at the 10 percent level. To put these numbers into perspective, about 18 percent of all enterprises in the sample reported having a procurement contract, so the proportion is higher than the sample average in all subgroups.

TABLE 9: SHARE OF FIRMS WITH PROCUREMENT CONTRACTS (%)

	EIF	*OIF*	*t-test*	*EIFR*	*EIFO*	*t-test*
Procurement contract	28.56	28.07	0.49	29.22	27.24	0.07*
SME	27.71	27.61	0.89	28.21	26.87	0.27
Non-SME	29.83	31.04	0.52	30.28	28.18	0.44

Notes: Results of two-sample t-test for equal means. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: CIS 2014, own calculations.
Abbreviations: EIF = firm has introduced an innovation with environmental benefits (OIF = if no environmental benefits), EIFR = firm has introduced an innovation with environmental benefits related to renewable energies (EIFO = if environmental benefits are not related to renewables).

In the next step, we illustrate the importance of green innovation under a public procurement contract, abbreviated as Green Public Procurement (GPP). A company with GPP has undertaken innovation activities as part of a PP contract and those innovation activities have environmental benefits. Table 10 shows that the share of firms holding GPP contracts is significantly higher for EIFR than for EIFO. The breakdown between SMEs and non-SMEs shows that the difference can be attributed to both.

TABLE *10*: SHARE OF FIRMS WITH GPP FOR EIFR AND EIFO (%)

	EIFR	*EIFO*	*t-test*
GPP	34.19	21.56	0.00***
SME	33.88	22.98	0.00***
Non-SME	36.36	16.00	0.00***

Notes: Results of two-sample t-test for equal means. **** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations.
Abbreviations: GPP = firm undertook innovation activities as part of a PP contract and those innovation activities have environmental benefits, EIFR = firm has introduced an innovation with environmental benefits related to renewable energies, EIFO = if environmental benefits are not related to renewables.

Table 11 reports the proportion of environmental innovators firms facing financial constraints, differentiated by whether the EIFs undertook innovation activities within a PP contract (GPP) or did not have a PP contract (No PP but EIF). The share of companies experiencing financial constraints is significantly higher in the GPP group. Accordingly, financial constraints appear to be particularly relevant for firms with a PP contract.

TABLE *11*: SHARE OF FIRMS WITH GPP AND NO PP BUT EIF WITH FINANCIAL CONSTRAINTS (%)

	GPP	*No PP but EIF*	*t-test*
Financial constraints	35.69	31.45	0.04**
SME	36.45	32.52	0.10
Non-SME	34.52	29.17	0.21

Notes: Results of two-sample t-test for equal means. **** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations.
Abbreviations: GPP = firm undertook innovation activities as part of a PP contract and those innovation activities have environmental benefits, No PP but EIF = firm did not have a PP contract.

Table 12 shows the share of SMEs in four different sub-samples: firms with Public Procurement contracts (PP) versus companies without Public Procurement contracts (No PP) and firms with Green Public Procurement contracts (GPP) versus companies with Other Public Procurement contracts (OPP). While the share of SMEs in the PP, No PP and OPP groups is at around 90 percent, the share of SMEs in the GPP group is significantly lower at only 76 percent.

TABLE *12*: SHARE OF SMES FOR DIFFERENT TYPES OF PP (%)

	PP	*No PP*	*t-test*	*GPP*	*OPP*	*t-test*
SME	87.71	91.99	0.00***	76.47	87.50	0.00***

Notes: Results of two-sample t-test for equal means. **** p < 0.01, ** p < 0.05, * p < 0.1*. Source: CIS 2014, own calculations. Abbreviations: PP = firm has contract to provide goods or services to domestic or foreign public sector organizations (No PP = otherwise), GPP = firm undertook innovation activities as part of a PP contract and those innovation activities have environmental benefits (OPP = innovation activities didn't have environmental benefits).

4 Estimation and Results

Table 13 presents the summary statistics of the main variables used in the multivariate empirical analysis. We control for firm characteristics such as turnover, turnover and workforce growth, share of graduates in the workforce, and macro indicators like industry and home country. We pay special attention to small and medium-sized enterprises (SME).

The number of observations per variable differs substantially. About 43 percent of the 96,703 respondents have introduced product, process, organizational or marketing innovations, while about 29 percent have introduced product or process innovations (referred to as Innovator). In addition, of the 28,243 firms, about one-third are Environmental Innovator Firms (EIF), while two-thirds are Other Innovator Firms (OIF). Of the Environmental Innovator Firms, 70 percent are Environmental Innovator Firms Renewables (EIFR) and 30 percent Environmental Innovator Firms Other (EIFO). Moreover, about 17 percent of 61,262 respondents own a PP contract.

Table 14 takes up the question of whether the public procurement authorities tend to select the innovative rather than the non-innovative companies in a tender. This is the opposite of the causal connection that is mostly represented in the literature. The results provide evidence that the likelihood of having a PP contract *Prob(PP=1)* depends on innovation. The probit estimations in Columns (1)-(4) distinguish between four innovator types. The *Innovator All* specification includes product, process, organizational, and marketing innovators. Column (2) refers to core innovation in the form of product or process innovation (*Innovator*). The third specification considers environmental innovation (*EIF*) vs. innovation without environmental benefits. The explanatory variable in Column (4) is environmental innovation in the field of renewables (*EIFR*).

TABLE *13*: SUMMARY STATISTICS

	# of Obs	*Mean*	*SD*	*Min*	*Max*
Innovator All	96,703	0.4333	0.50	0	1
Innovator (Product or Process)	96,703	0.2921	0.45	0	1
Environmental Innovator Firm (EIF)	28,243	0.3408	0.47	0	1
Environmental Innovator Firm Renewables (EIFR)	9,625	0.7082	0.45	0	1
Financial Constraints (Lack of internal funds or credit/equity)	54,803	0.0582	0.23	0	1
Financial Constraints (Importance of public subsidies for being innovator)	12,385	0.2538	0.44	0	1
Public Procurement (PP)	61,262	0.1766	0.38	0	1
Green Public Procurement (GPP)	86,985	0.0084	0.09	0	1
Small and Medium-sized Enterprises (SME)	95,360	0.8966	0.30	0	1
Share of turnover from abroad 2012	67,995	2.1538	11.86	0	100
Turnover growth 2012-14	95,375	0.2350	1.02	-1	8
Employee growth 2012-14	95,818	0.1359	0.55	-1	4
Share of turnover from innovation new to market	29,999	0.0876	0.20	0	1
Share of turnover from innovation new to firm	30,113	0.1264	0.24	0	1
< 25% graduates	88,625	0.6889	0.46	0	1
25% to < 50% graduates	88,625	0.1336	0.34	0	1
50% to < 75% graduates	88,625	0.0835	0.28	0	1
> 75% graduates	88,625	0.0940	0.29	0	1

Note: This table presents number of observations (# of Obs), mean, standard deviation (SD), minimum (Min), maximum (Max). Source: CIS 2014, own calculations.

The coefficients in Column (1) show that being an *Innovator All* increases the probability of having a PP contract by 13 percentage points. Similarly, Column (2) indicates that being a product or process innovator increases the probability of possessing a PP contract by 12 percentage points. Column (3) shows that *EIF* vis-à-vis innovation without environmental benefits (*OIF*) increases the chance of possessing a PP contract by 6 percentage points. Finally, while renewable

energy innovation does not have a significant impact, overall environmental innovation appears to increase firm's chances of winning a PP contract.

As expected, company size matters. SMEs are about 6 percentage points less likely to possess a PP contract, regardless of the type of innovation considered. This seems to indicate that, at least in 2014, SMEs' chances of winning a PP contract were significantly lower than the chances of success of large companies. The European Commission has been trying to reduce the disadvantages of SME in procurement since the 1990s (EIM Business, 2004). However, according to our findings, there was still room for improvement in this respect in 2014.

Most of the control variables show significant results. The probability of having a PP contract decreases with the share of turnover from abroad in 2012. This finding could be due to the fact that companies with an already internationally diversified revenue stream are less in need of acquiring PP contracts. Employment growth significantly lowers the likelihood of a PP contract, while turnover growth increases it. Finally, an increasing share of graduate employees relative to the reference category of less than 25 percent of the workforce has a strong positive effect on the probability of obtaining a PP contract for all types of innovators.

TABLE *14*: CHANCE OF POSESSING A PP CONTRACT FOR DIFFERENT TYPES OF INNOVATORS AND SMES

	(1) *Prob(PP=1)* Innovator All	(2) *Prob(PP=1)* Innovator	(3) *Prob(PP=1)* EIF	(4) *Prob(PP=1)* EIFR
Innovator All	0.1273*** (0.01)			
Innovator		0.1141*** (0.01)		
EIF			0.0584*** (0.01)	
EIFR				0.0098 (0.02)
SME	-0.0584*** (0.01)	-0.0611*** (0.01)	-0.0592*** (0.02)	-0.0659*** (0.02)
Share of turnover from abroad	-0.0013*** (0.00)	-0.0013*** (0.00)	-0.0016*** (0.00)	-0.0011** (0.00)
Turnover growth 2012-14	0.0173*** (0.01)	0.0173*** (0.01)	0.0332*** (0.01)	0.0408*** (0.01)

Employee growth 2012-14	-0.0433***	-0.0403***	-0.0742***	-0.0716***
	(0.01)	(0.01)	(0.02)	(0.02)
% of turnover from innovation new to market	-0.0247	-0.0288	-0.0451	-0.0135
	(0.03)	(0.03)	(0.03)	(0.04)
% of turnover from innovation new to firm	-0.0828***	-0.0865***	-0.1057***	-0.0883**
	(0.03)	(0.03)	(0.03)	(0.04)
Share of graduates:				
25% to < 50%	0.0568***	0.0616***	0.0495***	0.0506**
	(0.01)	(0.01)	(0.02)	(0.02)
50% to < 75%	0.0923***	0.0942***	0.1020***	0.0917***
	(0.02)	(0.02)	(0.02)	(0.03)
> 75%	0.1022***	0.1057***	0.1394***	0.0943***
	(0.02)	(0.02)	(0.02)	(0.03)
Country variables	Yes	Yes	Yes	Yes
Sector variables	Yes	Yes	Yes	Yes
Observations	11,271	11,271	5,812	3,603

Notes: This table reports the average marginal effects of the probit models. Share of graduates < 25% is the base category.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses. Abbreviations: EIF = Environmental Innovator Firm, EIFR = EIF Renewables, SME = Small and Medium-sized Enterprises. For definitions see Table A in the Appendix. Source: CIS 2014, own calculations.

We now turn to the centerpiece of our research, namely the question of how a PP contract affects the financial constraints of an innovative company. The *financial constraints*-variable is taken from the survey question on barriers to innovation. We label firms as affected by financial constraints (FC) if they indicate that the lack of internal funding for innovation (internal FC) or the lack of credit or private equity (external FC) are highly important barriers to innovation. We infer from this indication that the companies have innovation projects but cannot pursue them due to lack of finance (Hottenrott and Peters 2012; Schäfer et al. 2017). In contrast, companies that report being innovative have overcome the barriers to innovation, otherwise they would not be innovators. Thus, financial constraints as barriers to innovation are only observed among potentially innovative but deterred and other non-innovative companies. In contrast, the main variable of interest, PP, and the other independent variables, such as SME, turnover and employment growth or industry, are observed for the entire sample of potentially innovative but deterred, non-innovative, and innovative firms.

TABLE *15*: THE IMPACT OF A PUBLIC PROCUREMENT CONTRACT ON A FIRM'S FINANCIAL CONSTRAINTS

Variable/Estimation technique	FC (1) Probit	FC (2) Eprobit with endogenous treatment	FC (3) Eprobit with endogenous treatment and selection	IFC (4) Probit	IFC (5) Eprobit with endogenous treatment	IFC (6) Eprobit with endogenous treatment and selection
ATE (PP vs NoPP)		0.4471***	0.4339***		0.3716***	0.3596***
		(0.06)	(0.06)		(0.06)	(0.07)
ATET (PP vs NoPP)		0.1212***	0.1552***		0.1076***	0.1411***
		(0.01)	(0.02)		(0.01)	(0.02)
PP	0.0242***			0.0218***		
	(0.01)			(0.01)		
SME	0.0310***	0.0529***	0.0537***	0.0361***	0.0554***	0.0552***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Export share of turnover	-0.0003**	0.0013***	0.0014***	-0.0002**	0.0012***	0.0014***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Turnover growth 2012-14	-0.0080**	-0.0085**	-0.0099**	-0.0084**	-0.0091**	-0.0110**
	(0.00)	(0.0o)	(0.00)	(0.00)	(0.00)	(0.01)
Employment growth 2012-14	-0.0167**	-0.0207***	-0.0227***	-0.0157**	-0.0204***	-0.0235***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Share of Graduates:						
25% to < 50%	0.0007	-0.0072	-0.0082	0.0008	-0.0047	-0.0052
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
50% to < 75%	-0.0288***	-0.0421***	-0.0500***	-0.0302***	-0.0404***	-0.0488***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
> 75%	-0.0135	-0.0361***	-0.0465***	-0.0164*	-0.0389***	-0.0495***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	16,698	16,698	24,873	16,698	16,698	24,873
Selected /Non-Selected			16,698/8,175			16,698/8,175
Industry/Country	Yes	Yes (main & auxillary equation)	Yes (main & auxillary equation)	Yes	Yes (main & auxillary equation)	Yes (main & auxillary equation)
Correlation of error of main equation		with error in treatment equation: significant	with error in treatment equation: significant, with error in selection equation: insignificant		error in treatment equation: significant	with error in treatment equation: significant, with error in selection equation: insignificant
Correlation of error of treatment equation			with error of selection equation: significant			with error of selection equation: significant

Notes: This table reports the average marginal effects of probit models and ATE/ATET for eprobit models. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Abbreviations: FC = Financial Constraints, IFC = Lack of Internal Finance, SME = Small and Medium-sized Enterprises. Source: CIS 2014, own calculations

The simple probit model applies only to the group of non-innovative firms, regardless of whether they are non-innovative or potentially innovative but deterred. However, unobserved factors that affect a firm's decision to not innovate may also affect the likelihood that a firm is subject to financial constraints, creating an endogenous sample selection problem. Therefore, we move from the simple to the extended probit regression approach. The approach allows us to model endogenous selection. Specifically, the error in the selection equation (the unobserved reasons why companies become either non-innovators or innovators) can be correlated with the error in the main outcome equation, the likelihood for financial constraints. A significant correlation would indicate that endogenous sample selection indeed occurs.

Moreover, possessing a PP contract is the result of a choice. Companies are not randomly assigned to a procurement contract and the choice is a treatment that affects the likelihood of facing financial constraints. Unobserved factors may affect the public procurement decision because they affect the likelihood of being subject to financial constraints. For example, the unobserved propensity (or resistance) of a house bank to accept a successfully acquired procurement contract as a sign for a high credit-worthiness of the company would affect the likelihood of having a procurement contract but also the likelihood of financial constraints for a firm. For this reason, we use the potential outcome model (POM) to capture the potentially endogenous treatment effect of PP. The covariates of the eprobit model are SME, turnover share from exports, turnover and employment growth, the share of graduated employees, and industry.

Table 15 shows the marginal effects of the estimations using the probit as well as two variants of the eprobit model (see Appendix for details). Specification (1)-(3) uses financial constraints (FC) in general (either internal or external) as the dependent variable while Columns (4)-(6) apply to internal financial constraints (IFC). Columns (1) and (4) report the marginal effects of the simple probit model. The eprobit models combine the main equation on the likelihood of financial constraint, the treatment effects model of public procurement, and the endogenous selection into innovation. The tests for a correlation between the errors of main equation and selection equation are insignificant indicating that there is not endogenous selection. In contrast, the tests of the correlation between the errors of main equation and treatment equation are highly significant. Therefore, we can reject the null hypothesis of no endogenous treatment.

The main findings are clear. The average marginal effect of having a PP contract significantly increases the probability of financial constraints. The two extended probit regression models in Columns (2)-(3) and (5)-(6) confirm the outcomes of the simple probit model but reveal that the true marginal effects of PP would be

underestimated in the simple probit model. The Average Treatment Effect (ATE) and Average Treatment Effect of the Treated (ATET) are highly significant and positive in all four specifications.

In interpreting the results, we focus on Column (2) and (5) because only the treatment is endogenous. The ATET is 0.12 and 0.11 in Column (2) and Column (5), respectively. Thus, for those who possess a PP contract, the average probability of facing financial constraints is 12 or 11 percent higher than if the firm did not have a PP contract. This finding implies that PP contracts exacerbate funding gaps for potentially innovative firms, most likely because processing the existing PP contracts requires additional working capital and leads to even greater challenges in realizing potentially existing innovation projects.

At first sight this result seems to contradict Baum et al. (2021) who find that a lower equity ratio and a higher short-term debt ratio is no bottleneck for a company's chance to win a public procurement contract and to conduct the project. However, it is important to note that Baum et al. (2021) consider SMEs in general while we evaluate potentially innovative firms. Financial institutions are particularly restrictive if innovative firms apply for funding. Moreover, the authors focus on information that outsiders such as banks have access to for assessing a company's financial strength while we use the CIS data which provides an individual assessment of a company's financial means required for pursuing an innovative project. The comparison with Baum et al. (2021) suggests that – given that a procurement contract exists – a potentially innovative company's perception of the importance of financial gaps as barrier to innovation might be different from the ex-post assessment by banks using information from balance sheet data.

The coefficient of the SME variable in Table 15 shows the expected result that smaller companies are more likely to face financial barriers to innovation than large firms (by around 5.5 percentage points). The effect of being an SME is corroborated both in the literature and in Table 8. A high turnover share for exports increases the probability of facing financial constraints, while turnover and employment growth significantly reduce the likelihood of financial constraints. A share of graduates in the workforce above 50 percent also significantly lowers the probability of facing financial constraints.

TABLE *16*: THE IMPACT OF A PUBLIC PROCUREMENT CONTRACT ON A INNOVATOR'S FINANCIAL CONSTRAINTS

	(1) *Prob(FC=1)*	(2) *Prob(FC=1)*	(3) *Prob(FC=1)*	(4) *Prob(FC=1)*	(5) *Prob(FC=1)*
	Environmental innovation	Environmental innovation vs. other innovation		Environmental innovation tagged to renewables vs. other innovation	
Variable / Estimation technique	Probit	Eprobit with endogenous treatment	Eprobit with endogenous treatment and selection	Eprobit with endogenous treatment	Eprobit with endogenous treatment and selection
ATE (PP vs NoPP)		0.4176***	0.3632***	0.4091***	0.3955***
		(6.79)	(2.73)	(0.08)	(0.06)
ATET (PP vs NoPP)		0.2941***	0.2179***	0.3197***	0.4289***
		(11.68)	(2.62)	(0.04)	(0.11)
PP	0.0364**				
	(0.02)				
SME	0.0294	0.0554**	0.0472**	0.0745***	0.1407***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.05)
Share of turnover from export	-0.0014***	0.0010**	0.0009**	0.0006	0.0006
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Turnover growth 2012-14	-0.0031	-0.0028	-0.0039	-0.0109	-0.0110
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Employment growth 2012-14	0.0492**	0.0483**	0.0378*	0.0642**	0.0644**
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Share of graduates					
25% to < 50%	0.0321	0.0006	-0.0002		
	(0.02)	(0.03)	(0.02)		
50% to < 75%	0.0188	-0.0365	-0.0430		
	(0.03)	(0.04)	(0.03)		
> 75%	-0.0267	-0.0965***	-0.0996***		
	(0.03)	(0.04)	(0.03)		
Observations	3,395	3,395	6,702	2,093	5,400
Selected /Non-Selected			3,395/3,307		2,093/3,311
Industry/Country	Yes	Yes (main & auxillary equation)	Yes (main & auxillary equation)	Yes (main & auxillary equation)	Yes (main & auxillary equation)
Correlation of error of main equation with		error in treatment equation: significant	error in treatment equation: significant., error in selection equation: insignificant	error in treatment equation: significant	error in treatment equation: significant, error in selection equation: insignificant
Correlation of error of treat-ment equation with			error in selection equation: significant		error in selection equation: significant

Notes: This table reports the average marginal effects of probit models and ATE/ATET for eprobit models. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

In a next step, we investigate how PP contracts affect the likelihood that innovative firms face financial constraints. The survey provides information on financial constraints for active innovators only in combination with environmental innovation. We define that an environmentally innovative firm is financially constrained (FC=1) if it reports that government grants, subsidies, or other financial incentives for environmental innovation were of either medium or high importance in the company's decision to conduct innovations with environmental benefits. Medium or high importance signals that the firm would not have undertaken the environmental innovation if those instruments had not been accessible. In other words, the de-risking of innovative projects via government grants, subsidies, or other financial incentives ensured that funding restrictions did not stand in the way of realizing the innovative project with environmental benefits. The *financial constraints*-variable is zero if those instruments are rated as irrelevant or of low importance for the firm's innovation decision.

The simple probit model applies only to the environmental innovators, but ignores the other innovators. However, an endogenous sample selection problem arises when unobserved factors that influence a firm's decision to conduct innovation with environmental benefits also affect the likelihood of being financially constrained. In addition, having a procurement contract may be the result of an innovator's choice and the same unobserved factors that influence the innovators' likelihood of facing financial constraints may also affect this choice. To account for potential endogeneity (see Appendix 2 for details), we switch again to the extended probit model.

Table 16 shows the average marginal effects with the binary variable FC as the dependent variable. For completeness, we report the coefficients of the simple probit model in Column (1). The coefficients in Columns (2) and (4) are computed from an extended probit regression with endogenous treatment only. Column (3) addresses the possibly endogenous selection into environmental innovation, while Column (5) focuses on the possibly endogenous selection of innovators into renewable-related innovation. The non-significance of the correlation between the errors of main and selection equation indicates that there is no need to include the selection equation in the eprobit model.

Again, the main findings are clear. The average marginal effect of having a PP contract significantly increases the likelihood that innovative firms face financial constraints. Average Treatment Effect (ATE) and Average

Treatment Effect of the Treated (ATET) are highly significant and positive in all eprobit regressions. In interpreting the results, we focus on Column (2) and (4) because only the treatment is endogenous. The ATET in Column (2) is 0.29, which implies that, for environmental innovators with a PP contract, the average probability of facing financial constraints is 29 percent higher than if the firm did not have a PP contract. In addition, the ATET in Column (4) is 0.32, which means that for environmental innovators related to renewables with a PP contract, the average probability of being exposed to financial constraints is 32 percent higher than if the firm did not have a PP contract. The coefficients of the SME variable again show the expected result. Smaller firms are more likely to face financial barriers to innovation than large firms (by around 5 and 7 percentage points for environmental innovation and environmental innovation related to renewables, respectively).

5 Conclusions

This study examines whether the likelihood of an innovative firm facing financial constraints is different if the firm possesses a public procurement contract. Theory suggests that the treatment effects of public procurement may lower a company's funding constraints for innovation. We test this theory using firm-level data from the European Community Innovation Survey and applying extended probit models with endogenous treatment and selection to control for the omitted variable bias. Our findings confirm that the treatment effect of PP on the probability of facing financial constraints is highly significant and positive. Innovative companies with a public procurement contract are more likely to face financial constraints than innovative companies without such a contract. We explain this result with the increased pre-funding requirements that typically arise with a public procurement contract. Higher up-front funding may actually overcompensate the potentially constraint-reducing effects of a demand-pull or certification effect of PP. Our findings also confirm the importance of removing financial barriers for green innovation from SMEs and clearly support the 2014 EU procurement regulation reform aimed to strengthening SMEs´ participation in European public tenders.

A public procurement contract may increase a company's working capital needs. Indeed, the treatment effect of PP is particularly strong for internal financial constraints, backing the notion that PP increases the need for upfront-funding. This need to pre-finance expenditures for labor and inputs, since PP revenues often flow only after the goods or services are actually sold, is also the likely reason behind our second finding. For a firm with a PP contract, the likelihood is higher that public de-risking is of medium or high importance for realizing environmental innovation.

Our research adds a missing piece to the vast literature on the importance of financial barriers for innovation. In particular, we contribute to the rather new, but increasingly more important, strand focusing on the mediating role of public procurement in easing financial barriers to green innovation. Our findings propose that polices aimed at promoting innovation in general, or green and renewables-related innovation in particular, through public procurement can be successful. However, it is essential to recognize that companies winning a PP contract may face additional financing requirements that may increase financial constraints. The good news is that public de-risking of innovative projects via government grants, subsidies, or other financial incentives is a complement to a public procurement contract. These instruments help companies to meet the increased funding requirements arising from a public procurement contract.

Up-to-date and more detailed data on involvement of innovative firms in public procurement tenders and their funding are necessary to shed more light on the relationship between innovative European firms' success in public tenders and their subsequent funding needs. This research is urgent. In the future, public tenders will become more important for fighting both climate change and economic uncertainty.

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7 Appendix

A1. Table A: Abbreviations

Abbreviation	**Definition**
SME	Small and Medium-sized Enterprise (SME) = 1 for firms that have **10 to 249 employees**; zero otherwise
PP	Public Procurement (PP) = 1 for firms that have a **contract to provide goods or services** to domestic or foreign public sector organizations; zero otherwise
GPP	Green Public Procurement (GPP) = 1 for firms that undertook **innovation activities as part of a PP contract** and those innovation activities have environmental benefits; zero otherwise
OPP	Other Public Procurement (OPP) = 1 for firms that undertook innovation activities as part of a PP contract but those innovation activities **did not have environmental benefits**; zero otherwise
Innovator (Product or Process)	Innovator (Product or Process) = 1 for firms that introduced **product or process innovation**; zero otherwise
Innovator All	Innovator All = 1 for firms that **introduced product, process, organizational or marketing innovation**; zero otherwise
EIFR	Environmental Innovator Firm Renewables (EIFR) = 1 for firms that introduced an innovation (product or process) with **environmental benefits related to renewable energies**; zero if environmental benefits are not related to renewables
EIFO	Environmental Innovator Firm Other (EIFO) = 1 for firms that introduced an innovation (product or process) **with environmental benefits not related to renewable energies**; zero if environmental benefits are related to renewables
EIF	Environmental Innovator Firm (EIF) = 1 for firms that introduced an innovation (product or process) **with environmental benefits** (EIF = EIFR + EIFO); zero if no environmental benefits
OIF	Other Innovator Firm (OIF) = 1 for firms that introduced an innovation (product or process) **with no environmental benefits**; zero if environmental benefits

A2. Background of Stata's extended probit regression (eprobit) command – formulas and estimation methodology

Stata's eprobit allows to extend a simple single equation probit model to capture modelling features such as endogenous covariates, endogeneous binary treatment, and non-random selection, to mention a few of the features. For further details we refer the reader to Stata's Extended Regression Models reference manual, Stata version 17.

The main probit equation of interest, for a binary outcome variable y_i, can be written as

$$y_i = 1\ (\beta x_i + \varepsilon_i > 0) \qquad (1)$$

where ε_i is a normally distributed error term. In our case, y_i denotes whether a firm is financially constrained or not, see Table 15. As a first extension of a simple probit model, let's consider the case of endogeneous binary treatment, $t_i \in \{0,1\}$, in our case of winning the public tender (see Table 15). The treatment is defined as

$$t_i = 1\ (\theta z_i + \vartheta_i > 0), \qquad (2)$$

Where $\varepsilon_i, \vartheta_i$ are jointly multivariate distributed, with variance-covariance

$$\begin{pmatrix} 1 & \rho_{\varepsilon v} \\ \rho_{\varepsilon v} & 1 \end{pmatrix}.$$

If $\rho_{\varepsilon v} = 0$the treatment can be considered as exogenous. Using the conditional potential outcome model (POM) notation framework, $POM(x_i, z_i, w_i) = E(y_i|x_i, z_i, w_i)$.

As an additional extension to endogenous treatment in Table 15, we also consider endogenous selection s_i which can be handled with eprobit as well. Denote that observation i is selected if binary indicator $s_i = 1$. Specifying $w_i$as the covariates which affect selection, selection is modelled as the following probit equation

$$s_i = 1\ (\alpha w_i + \omega_i > 0). \qquad (3)$$

The combined probit model of Eqs. (1)-(3) has then variance-covariance matrix $\sum$ for the three error terms with $\begin{pmatrix} 1 & \rho_{\varepsilon v} & \rho_{\varepsilon \omega} \\ \rho_{\varepsilon v} & 1 & \rho_{v \omega} \\ \rho_{\varepsilon \omega} & \rho_{v \omega} & 1 \end{pmatrix}$. Again, if $\rho_{\varepsilon \omega} = 0$ selection is exogenous.

In the eprobit models underlying Table 15, the selection indicator s_i describes whether the firm is an innovator or not. A priori, we assume that this feature is not randomly distributed over firms but is likely to be related to some firm characteristics that also affect the outcome and the endogenous treatment assignment. Because of this we expect to find correlations of error terms across the three equations which imply that unobserved factors are relevant for the selection but also for treatment and outcome equation.

The Likelihood specifications of the combined model are provided in Stata's Extended Regression Models reference manual. The results reported in Table 15 are marginal effects based on the estimated model parameters. The full estimation results are available from the authors upon request.