Financial constraints of firms with environmental innovation

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Summary: Using the Mannheim Innovation Panel, we explore whether Environmental Innovator Firms (*EIF*s) have higher financial needs and are more financially constrained than Non-Environmental Innovator firms (*OIF*s). We find that *EIF*s are more likely to have higher latent financial need in comparison to *OIF*s. This implies that *EIF*s have latent projects that they have not yet realized, but would implement if they had the financial means to do so. *EIF*s adopting environmental technologies have higher financial needs compared to firms that do not. One tentative conclusion from this finding is that public subsidies might mitigate the financial restrictions of environmental innovation.

Zusammenfassung: Anhand des Mannheimer Innovationspanels untersuchen wir, ob Umweltinnovatoren (Environmental Innovator Firms, *EIF*s) einen höheren Finanzbedarf haben und finanziell stärker eingeschränkt sind als Nicht-Umweltinnovatoren (Non-Environmental Innovator Firms, *OIF*s). Unser empirischer Befund besagt, dass Firmen, die Umwelttechnologien einsetzen mit größerer Wahrscheinlichkeit einen latenten Finanzbedarf aufweisen, als Nicht-Umweltinnovatoren. Dies bedeutet auch, dass Umweltinnovatoren über latente Projekte verfügen, die sie noch nicht realisiert haben, die sie jedoch umsetzen würden, wenn sie die finanziellen Mittel dazu hätten. Eine vorläufige Schlussfolgerung aus diesem Befund ist, dass öffentliche Subventionen die finanziellen Beschränkungen von Umweltinnovationen mildern könnten.

→ JEL classifications: G30, D22, O31
→ Keywords: Environmental innovation, innovation capability, funding gaps, financing restrictions

1 Introduction

Environmental innovation is a driving force underlying the achievement of a low-carbon economy and sustainable growth. The EU has pledged to implement the Eco-Innovation Action Plan through environmental policy and financing instruments in order to promote funding of green innovations in and by SMEs. A large-scale adoption of environmental technologies is needed for the transition to a low-carbon economy.

In this paper, we study whether Green Innovator Firms (*EIF*s) are more financially constrained than non-green innovator firms (Other Innovator Firms: *OIF*s). So far, we know little about this issue from the existing literature despite the pivotal importance that environmental innovations have for the planet's well-being. More empirical evidence is urgently needed to identify efficient political strategies that foster the financing of environmental innovation. We use the Mannheim Innovation Panel (MIP) to investigate whether *EIF*s suffer from specific financial constraints. In our study, environmental innovation comprises both process and product innovations. The former describes when firms adopt environmental technologies, while the latter describes firms that have launched new products or services on the market that have environmental benefits for the end user.

Currently, not only is environmental innovation still insufficient in quantity and quality, frequently it also lacks competitiveness (Alliance, 2013). Large firms are able to finance environmental technologies and innovation through the issuance of green bonds and climate-aligned bonds (ING, 2018, Bachelet et al., 2019). In Europe and especially in Germany such instruments are typically unavailable to small- and medium-size enterprises, which have limited access to capital markets. In the European Union more than 80 percent of corporate debt is financed by banks while in the US the capital market is the vastly dominating funding source (e. g. Demary, Hornik and Watfe 2016) and bond financing for SMEs is common. In fact, little is known from the literature about how Small and Medium-Sized Enterprises (SMEs) in Europe and in particular in Germany finance the use of clean energy and process technologies, or how SMEs finance innovations for these technologies, processes, and products. The funding possibilities for SMEs that are environmental innovators may still be limited due to immaturity of the market that may lead to a greater perceived risk of the investment in environmental innovation. The other reason that explains a potential lack of access to finance for SME-innovators in environmental technology and energy efficiency is due to market imperfections. In general, investment in innovation is often difficult to realize as complexity and risk of the investment is high and financial institutions shy away from supplying the required funds for those projects (Hottenrott and Peters, 2012, Schäfer et al., 2017). Yet, the high risk, or even uncertainty of innovation in general, may be even more pronounced for environmental innovation (Aghion et al., 2009, Ghisetti et al., 2017*a*), thereby creating a higher information asymmetry between borrowers and lenders. The latter may cause higher cost of capital for green projects, and thus create barriers for the development of green innovation.

The Eco-Innovation Action plan aims to achieve the Europe 2020 strategy objectives. It promotes eco-innovation in technologies and addresses the challenges of resource scarcity as well as bringing green growth and jobs. The main idea is to tackle specific bottlenecks that inhibit the competitiveness of environmental innovation. It recognizes that there are difficulties in both accessing the risk and in supplying the required funds. Access to finance is an important obstacle specifically for SMEs due to their opaqueness and a lack of administrative resources that is typical for small firms (Beck et al., 2006, Ghisetti et al., 2017*b*). Despite growing investment into green innovations, it takes longer for firms to have profitable green innovations compared to regular innovations

(Alliance, 2013, Mazzucato, 2015). In addition, innovative firms are in general characterized by intangible assets that are difficult to value as collateral (Brown et al., 2012, Cosci et al., 2016, Hall et al., 2016). Green innovator firms are not different in this respect.

According to Hottenrott and Peters (2012), access to external finance depends on the creditworthiness of firms. If innovation capabilities of firms that invest in environmental innovation are higher than the capabilities of firms that invest in non-environmental innovation, the funding gaps of environmental innovators would be higher even if both firm types have the same creditworthiness. Given a particular level of own funds and limited access to external finance, firms with higher innovation capabilities suffer from wider funding gaps. Via this channel, the innovation capabilities affect financial needs, and the severity of the firm's financial constraints.

The results of our exploratory study indicate that Environmental Innovator Firms have, on average, significantly higher financial needs for realizing innovation projects, even after controlling for structural differences such as size, industry and innovation capability. We infer from this finding that *EIF*s are more likely to own latent innovation projects that remain "in the drawer" because of insufficient supply with the required funds.

This paper contributes to the literature by providing new evidence on specific financial constraints for Environment Innovator Firms. In addition, we link the innovation capability of *EIF*s to their specific funding gaps.

The rest of the paper is structured as follows. We briefly review the literature in Section 2. Then we describe in Section 3 the data and the analytical strategy, and present our results. Section 4 concludes.

2 Previous Studies on Environmental Innovation and Financing Constraints

The issue of financing environmental innovation is of growing interest for both businesses and policy makers, since it can facilitate the shift to a low carbon economy. The financing of environmental innovation requires mobilizing large amounts of funds, (mostly) channeling them into long-term environmental innovation projects that are associated with immature and intricate technology (Olmos et al., 2012). It is common for general innovation to be subject to this opaqueness and information asymmetry between borrowers and investors; it is believed to be even more pervasive for environmental innovation (Cecere et al., 2014). Additionally, investment in environmental projects requires a long-term commitment and a long payback period, which reinforce the risk associated with environmental innovation (Ghisetti et al., 2017*b*). This leads to a difficulty in acquiring external financing for innovation projects; hence, firms will solely rely on internal cash flow, as stated by the pecking order theory of Myers and Majluf (1984). Therefore, choosing the best fitting financing options for environmental projects, while supporting the development and growth of environmental innovation, requires the involvement of various private and public actors. Nevertheless, the design of financing alternatives for environmental innovation is still nascent, thus making the discussion of how to finance environmental innovation a critical point in the policy debate.

The term environmental innovation is used in the literature interchangeably with "eco-innovation", "ecological innovation", "green innovation", and "clean innovation". We differentiate between "standard" innovation and environmental innovation by looking at the specific environmental goals that are embedded in innovation. We follow the definition of environmental innovation according to Rennings et al. (2013), "*Environmental innovations consist of new or modified processes, techniques, practices, systems and products to avoid or to reduce environmental harms. Environmental innovations may be developed with or without the explicit aim of reducing environmental harm.*" The other difference between environmental innovation and non-environmental innovation can be understood from the life-cycle perspective (Kemp and Pontoglio, 2011). Environmental innovation products are repairable when they are returned to the manufacturers and they have a long-life cycle (Janssen and Jager, 2002, Brouillat, 2009). According to Rennings (2000), Kemp and Oltra (2011) and De Marchi (2012), there is a difference in innovation dynamics between environmental innovation and non-environmental innovation. Environmental innovation produces double externalities, that is positive spillovers in both innovation and diffusion stages. This causes double market failures, i. e., private returns from investment in environmental technology is lower than social returns. Subsequently, underinvestment in environmental innovation exists because there is a lack of private financing justified by policy instruments, i. e., "regulatory push-pull".

Although the topic of financing innovation is deeply rooted in corporate finance and economics of innovation theory, empirical studies regarding the relationship between financing constraints, R&D investments, and innovation output show mixed evidence (Hall et al., 2016). Previous studies use direct measures (Fazzari et al., 1987, Brown et al., 2012) as well as indirect measures (Czarnitzki and Hottenrott, 2011, Hottenrott and Peters, 2012, Lahr and Mina, 2013) of financial constraints. Brown et al. (2012) find that financing constraints for R&D depend on the internal finance (changes in cash flows to smooth R&D) and on external equity finance. They also show that financing constraints are particularly relevant for young and small firms. Using direct measures of financing constraints, Hottenrott and Peters (2012) provide evidence that innovation capabilities cause financing constraints that, in turn, hamper the innovation activities of firms. Thus, Hottenrott and Peters (2012) conclude that, in general, "more money means more innovation." However, this result is questioned by Almeida et al. (2013), who find the reverse effect and the possible benefits of financing constraints on innovation performance by increasing firms' innovative efficiency and innovation performance. For the case of environmental innovation, Doran and Ryan (2016) investigate if firms with environmentally friendly features and products are associated with high innovation capabilities. Lööf et al. (2018) find similar evidence that green startups have higher innovation capabilities compared to non-green startups. Taking into account possible issues related to acquiring external funding and to higher innovation capability compared to non-environmental innovation, we hypothesize in this study that firms conducting environmental innovation are more likely to be financially constrained.

The next section elaborates further the data and methodology used to identify financing constraints in this paper.

3 Empirical Approach

3.1 Data and Variables

The Mannheim Innovation Panel (MIP) is a representative data set on the innovation activities of German firms commissioned by the German Federal Ministry of Education and Research (BMBF). Established in 1993, the Center for European Economic Research (ZEW) has collected data on innovation in Germany since then. We use the 2014 and 2015 waves since the respective questionnaires provide information on the firms' financial behavior and constraints as well as information on environmental innovation in processes and products. Specifically, we obtain information on financial sources and constraints from the 2014 wave, while we derive the environmental innovation variables from the 2015 wave. Since the funding behaviors and constraints variables are not available in the 2015 wave, merging the two mentioned waves enables us to investigate the funding sources and gaps for environmental innovators in earlier years (2011–2013).

The 2014 wave represents about 278,000 companies with sales of approximately 5,200 billion Euros and some 15.2 million employees (Rammer et al., 2008, Rammer and Peters, 2015). For the 2015 wave, the total sales of firms covered by MIP increases to 5,260 billion Euros and the total employees represented by firms in the MIP rises to 15.7 million people (Behrens et al., 2017). Table 1 describes the variables used in this study.

Table 1

Definition of variables used in this paper

Variable name	Definition			
Envinno1	=1 for process innovations with minor environmental benefits			
	=2 for process innovations with significant environmental benefits			
	=0 otherwise			
Envinno2	=1 for product innovations with minor environmental impact =2 for product innovations with significant environmental impact =0 otherwise			
EIF	Environmental process innovator firm, *Envinno1*			∈ {1, 2}
EIFP	Environmental product innovator firm, *Envinno2*			∈ {1, 2}
OIF	Non-environmental process innovator firm, *Envinno1*			= 0
OIFP	Non-environmental product innovator firm, *Envinno2*			= 0
fn	Financial need, *fn*			∈ [0,1,2]
Innovation capability *R&D continuous/occasionally*				
	=1 if R&D engagement is continuously or occasionally			
	=0 if not			
R&D Intensity	R&D expenditure over turnover (%)			
IS	Innovation expenditure over turnover (%)			
Graduated employees	The percentage of employees with university degree (%)			
CE	Costs for further education			
TC	Shares of employees' training costs over turnover (%)			
Controls	*CE, Size, Industry and RoS*			
Size	Firm size class:	1 = 1 bis 49,	2 = 50 bis 249,	3 = 250 employees and more
RoS	Return on sales in the last two years (%)			
Industry	21 industries based on NACE 2-digit code			
InnoNovel	The share of turnover from market novelties (%)			

Environmental product and process innovation

In addition to other innovation issues, such as innovation expenditure and the number of R&D employees, the MIP also addresses the question of whether an innovation is environmentally relevant and in what respect. Specifically, the MIP wave 2015 provides detailed information on innovations with an environmental impact. The first question addresses process innovations and reads: *During 2012 to 2014, did your enterprise introduce innovations that had any of the following environmental benefits, and if yes, was their contribution to environmental protection rather significant or insignificant?* Respondents are then required to select from a menu of nine alternatives: A. *Reduced energy use per unit of output;* B. *Reduced material use/use of water per unit of output;* C. *Reduced CO_2 "footprint" (total CO_2 production);* D. *Reduced air pollution (i.e. SO_x, NO_x);* E. *Reduced water or soil pollution;* F. *Reduced noise pollution;* G. *Replaced fossil energy sources by renewable energy sources;* H. *Replaced materials by less hazardous substitutes;* I. *Recycled waste, water, or materials for own use or sale.*

We classify a firm as *EIF* (Environmental Innovator Firm) if it responded as having introduced such innovations and as *OIF* (Other Innovator Firm) if it responded that it had not launched such an environmental innovation.

The second question asks specifically for product innovations: During 2012 to 2014 did your enterprise introduce new products or services with the following environmental benefits through the use of these products/services, and if yes, what was their contribution to environmental protection? The menu of answers comprises four types of product innovations causing A. *Reduced energy use;* B. *Reduced air, water, soil, or noise pollution;* C. *Improved recycling of product after use;* E. *Extended product life through longer-lasting; and* F. *More durable products.*

We classify a firm as *EIFP* (Environmental Innovator Firm-Product) if it confirms the introduction of these product innovations and as *OIFP* (Other Innovator Firm-Product) otherwise. Note that the first question addresses the issue of whether the firm has adopted cleaner or energy saving technologies, while the second question addresses the issue of whether the firm has launched innovations that create environmental benefits for the end-user of the product or service.

Financing needs and constraints

To assess the environmental innovators' specific funding needs and financial constraints, we use information from the 2014 wave on the funding behavior of the innovative firms in the sample. We employ Hall (2005)'s ideal test, which suggests that a firm's response on the question regarding usage of available additional funds can be used to identify the presence of innovation-driven funding gaps (= financial needs). If an *EIF* mainly intends to use additionally available funds for innovation purposes compared to an *OIF*, then *EIF*s are more likely to have funding gaps, or in other words, are financially more constrained. Those higher funding gaps can be caused for two distinct reasons: (1) a low internal financing capacity and/or poor access to external funds for a given innovation capacity, or (2) a high innovation capacity for a given amount of internal free cash flow and/or access to external funds.

More specifically, we take the information indicating the presence of funding gaps/financial needs (*fn*) from two survey questions revealing what the firms would do with exogenous additional funds. The first question reads: *Assuming your company had at its disposal an unexpected additional profit or additional equity capital of 10% of last year's turnover. Which possibilities of resource-allocation would your enterprise choose most probably?* A. *implementation of (additional) investment projects;* B. *implementation of (additional) innovation projects;* C. *accumulation/creation of reserves;* D. *distributions to owners (incl. repayment of shareholder loans);* E. *decrease of liabilities (for example, repayment of bank loans, accounts payables etc.);* F. *No assessment possible.*

The term "10% of the last annual turnover" means that the offered additional internal funds are clearly less expensive than external loans or equity. By choosing "implementation of (additional) innovation projects", the firm reveals that it expects the marginal profit to be higher from innovation projects than from the offered alternative applications of the funds.

The second question asks for the respondent's readiness to use external loans for innovation purposes: *Assuming, instead of the unexpected additional profit/additional equity capital mentioned above, your company had access to a credit of the same amount and with a comparatively attractive interest rate. Would your enterprise in this case implement the considered investments/innovation projects as well? A. yes, implementation of investments likely; B. yes, implementation of innovation projects likely; C. no, not likely; D. no assessment possible.*

Selecting the option "implementation of (additional) innovation projects" implies that this firm has a positive financial need for a cheap loan even though the offered borrowing alternative is, according to the pecking order theory, more expensive and less preferred than the own additional funds offered in the first question. We assume that revealed funding gaps for innovation projects persist over several periods.

Double selection of the option "implementation of (additional) innovation projects" implies that this firm has a positive financial need for a cheap loan even though the offered borrowing alternative is, according to the pecking order theory, more expensive and less preferred than the own additional funds offered in the first question. This is because the firm will double-select if, and only if, available innovation capabilities relative to own internal funds establish a funding gap, but available external bank loans are more expensive compared with the offered cheap loan. In contrast, firms with access to a cheaper loan than the one offered in question 2 have only a positive *fn* for additional internal funds (offered in question 1) but a zero financial need for the offered loan. Accordingly, we define three different levels of *fn*, ranging from zero (B neither selected in question 1 nor 2) to two (double selection of B): $fn \in [0,1,2]$.

The next subsection describes econometric estimations that we use in this study.

3.2 Econometric Estimations

We apply ordinal probit models to analyze whether environmental process (*Envinno1*) or environmental product (*Envinno2*) innovations cause funding gaps (*fn*). Consequently, the variable *fn* is used as the dependent variable. *fn* is a categorical variable with an ordinal scale, where *fn* is 1 when firms have financial need (cash), *fn* is 2 when firms have both cash and credit as financial need, and *fn* is 0 when firms have not indicated financial need. The two categorical variables *Envinno1* and *Envinno2* serve as our key variables of interest. The variable *Envinno1* takes a value of 1 if the firm has adopted an environmental process innovation with minor environmental benefits, and takes a value of 2 if the firm has launched a process innovation with significant environmental protection and 0 otherwise. Similarly, variable *Envinno2* describes product innovations with different degrees of environmental benefits. *Envinno2* equals 1 when the product innovation has minor environmental benefits, *Envinno2* takes a value of 2 when the new product or service has significant environmental benefits for the end user and 0 otherwise.[1]

1 Note that those values are defined when at least one of the benefits is significant.

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The ordinal probit regression is specified as follows,

(1) *P(fn) = f (Envinno1/Envinno2, Firm size, Industry)*

This basic model is extended by adding proxy variables for *innovation capability* and

Return on sales (RoS). Therefore, the extended model is specified as

(2) *P(fn) = f (Envinno1/Envinno2, Innovation capability, Return on sales, Size, Industry),*

where the *innovation capability* proxy variables are *R&D continuously/occasionally, R&D Intensity, Cost for further education (CE)*, and *share of employees with college/university degree*. In the second step of the analysis we address potential endogeneity concerns. For this purpose, and since the main equation of interest is an ordinal probit model, we specify a recursive system of two equations where environmental innovation itself (*Envinno1/Envinno2*) is explained by an ordinal probit model. The dependent variable of the first equation in this model (Equation (3)) is again financial need (*fn*), which is explained by variables from the 2014 wave, such as *Innovation capability*, control variables *RoS, Size, Industry*, and the key variables of interest, *Envinno1* and *Envinno2*.

(3) $\mathrm{P}(\mathrm{fn}_{2013i}) = \mathrm{f}\ (\mathrm{Envinno1/Envinno2}_{2014i}$, Innovation capability, Return on sales, Size, Industry) + ϵ_i

(4) $\mathrm{P}(\mathrm{Envinno1}_{2014i}/\mathrm{Envinno2}_{2014i})$ = f (Innovation capability, Return on sales, Size, Industry) + ν_i

Note that Equation (4) describes either *Envinno1* or *Envinno2* which are assumed to depend on *Innovation capability* and other control variables *RoS, Size, Industry*. The variables that explain *Envinno1* or *Envinno2* are taken from the 2015 survey and, since they are related in Equation (3) to the *fn* variable from one year earlier, we can assume that those variables from later years are exogenous to *fn*. We allow the error terms, ϵ_i and ν_i, of this system of two ordinal probit equations to be correlated with parameter ρ. The system of equations is estimated using Roodman (2011)'s cmp procedure[2] implemented for Stata. Note that *Envinno1* and *Envinno2* enter the equation for *fn* as predicted values, not as observed values.[3]

3.3 Descriptive Results

We start our empirical analysis by discussing some descriptive findings. Figure 1 illustrates how environmental innovation is distributed across industries. Environmental innovations are found in every industry. However, the number of firms active in environmental innovation differs widely. *EIF*s are especially frequent, both in terms of general and product innovation, in Metals, Electrical equipment and Machinery, but particularly rare in Mining, Wholesale, Banking and Insurance, Consulting/Advertisement and Firm-related services. In addition, based on Figure 1, we observe that the numbers of *EIF*s in some industries that are less energy intensive, e.g., Banking/Insurance, IT/Telecommunication, Media, have higher shares of *OIFs* than *EIF*s.

2 Version cmp 8.2.9 5 November 2018.

3 Using the cmp syntax, this can be accomplished by extending the variable name with #, see Stata's cmp help file.

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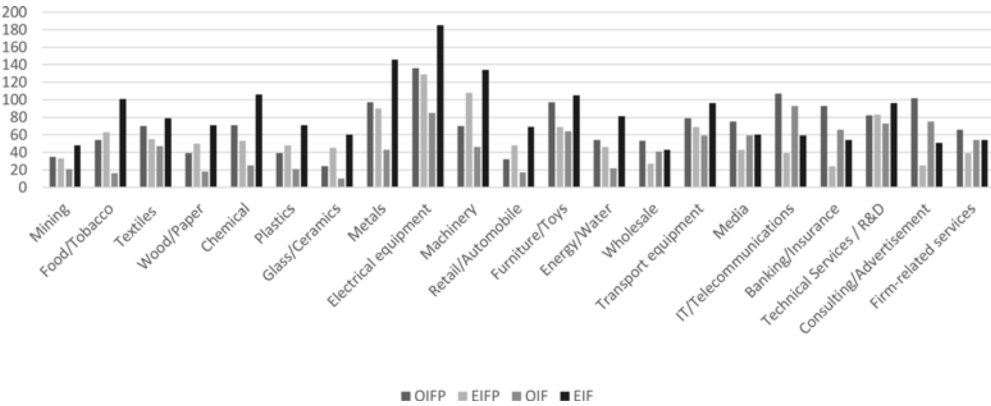
Figure 1

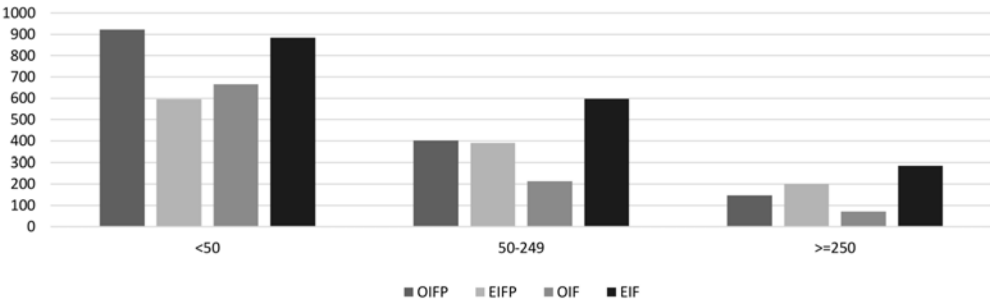
Firms' industry



Source: Mannheim-Innovation Panel, wave 2015, own calculation. *OIFP* (Other Innovator Firm-Product), *EIFP* (Environmental Innovator Firm-Product), *OIF* (Other Innovator Firm), *EIF* (Environmental Innovator Firm). Source: MIP, own calculations.

Figure 2

Firms' size



Source: Mannheim-Innovation Panel, wave 2015, own calculation. *OIFP* (Other Innovator Firm-Product), *EIFP* (Environmental Innovator Firm-Product), *OIF* (Other Innovator Firm), *EIF* (Environmental Innovator Firm). Source: MIP, own calculations.

Firm size matters for environmental innovation (Figure 2). The relative importance of environmental innovator firms is the lowest in the smallest size class. Figure 2 also shows that *EIF*s outnumber *OIF*s in all size classes while this is not the case for *EIFP*s vìs-à-vìs *OIFP*s.

Table 2 displays the menu of financing sources for the two types of innovator firms. With the exception of equity financing and bonds, *EIF*s declare more frequently than *OIF*s that they use specific financing sources for investment and innovation purposes. *EIF*s use cash flow more often to finance investment compared to *OIF*s. Similarly, cash flow is the most favored option for *EIF*s to finance innovation and subsidies are the second most used financing source for innovation projects. Furthermore, *EIF*s mainly use internal cash flow and, secondly, bank loans to finance their investments.

Table 2

Importance of financing sources for investment and innovation (%) of Environmental Innovator firms (EIFs) and Other Innovator firms (OIFs) during 2011 – 2013

Financing sources	Investment		T-test	Innovation		T-test
	OIF	*EIF*		*OIF*	*EIF*	
Cash flow	73.5	78.9	-1.92**	59.0	66.6	-2.30**
Equity financing	6.8	7.1	-0.10	3.4	3.2	0.16
Shareholders' loan	11.0	15.6	-1.73*	6.5	8.4	-0.90
Bonds	0.8	0.2	1.05	0.0	0.2	-0.77
Factoring or leasing	15.9	19.8	-1.32*	3.5	7.1	-1.98*
Overdraft	21.8	28.9	-2.12**	11.2	15.8	-1.69**
Bank loans	23.1	35.7	-3.64***	7.5	15.0	-2.97***
Public bank loans	11.2	18.5	-2.60***	6.8	11.0	-1.85**
Subsidy	16.1	24.3	-2.66***	24.6	29.4	-1.43*

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: MIP, own calculations.

Table 3 compares the importance of financing instruments for environmental product innovators (*EIFP*s) and other product innovators (*OIFPs*). This Table mirrors Table 2 to a large extent. The

Table 3

Importance of financing sources for investment and innovation (%) of Environmental product innovators (EIFPs) and non-environmental product innovators (OIFPs) during 2011 – 2013

Financing sources	Investment		T-test	Innovation		T-test
	OIFP	*EIFP*		*OIFP*	*EIFP*	
Cash flow	74.0	80.5	-2.35***	63.2	64.5	-0.39
Equity financing	6.4	8.0	-0.78	3.7	3.0	0.43
Shareholders' loan	12.0	17.1	-1.93**	6.9	9.1	-1.02
Bonds	0.0	1.0	-1.97*	0.0	0.3	-1.13
Factoring or leasing	18.3	17.8	0.18	5.9	5.0	0.50
Overdraft	19.5	35.6	-4.98***	12.1	16.7	-1.75**
Bank loans	25.6	37.4	-3.51***	11.1	13.8	-1.05
Public bank loans	12.2	20.2	-2.92***	8.0	11.3	-1.48*
Subsidy	16.3	27.7	-3.76***	22.8	33.5	-3.30***

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: MIP, own calculations.

share of firms declaring that they use a particular financing source is higher among environmental product innovators than it is among other product innovators. In particular, internal cash flow is an important financing source for *EIFP*s. They declare the use of cash flow as a funding source to finance their investment more frequently than *OIFP*s. However, based on the results of a t-test, the average share of *EIFP*s that choose cash flow as their financing source for innovation is not significantly different from the average share of *OIFP*s. Interestingly, the t-test result reveals that there is a significantly higher share of *EIFP*s than *OIFP*s relying on subsidies as a source for financing innovations.

Table 4 presents the descriptive statistics for the main obstacles to innovation as perceived by the responding firms.

Table 4

Share of firms (environmental innovators (EIFs & EIFPs) vs. non-environmental innovators (OIFs & OIFPs) facing innovation constraints, wave 2015

Innovation constraints	*OIF*	*EIF*	*t-test*	*#Obs*	*OIFP*	*EIFP*	*t-test*	*#Obs*
High economic risk	74.7	71.4	0.95	863	76.3	67.7	2.80***	850
High innovation cost	72.4	72.7	-0.07	905	75.2	68.8	2.15**	888
Lack of internal financing	72.5	70.9	0.38	584	77.0	64.4	3.32***	567
Lack of external financing	77.9	71.6	1.36*	441	79.1	67.1	2.81***	432
Lack of qualified employees	56.6	48.0	1.93**	628	57.1	43.9	3.32***	620

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Source: MIP, own calculations.

There is a significant difference between environmental innovators and non-environmental innovators in assessing different innovation constraints. *EIF*s are less likely to suffer from a lack of external financing and a lack of qualified employees. Furthermore, environmental innovation product innovators (*EIFP*s) and other innovation product innovators (*OIFP*s) differ significantly in the perception of innovation constraints. *EIFP*s suffer to a less extent than *OIFP*s from high economic risk, high innovation cost, a lack of internal financing, a lack of external financing and a lack of qualified employees.

Table 5 (process innovators) and Table 6 (product innovators) display differences in the importance of R&D activity for environmental and non-environmental innovators. Among those process innovators that occasionally or continuously conduct R&D the share of firms with either a “minor” or

Table 5

Innovation capability, R&D Engagements, of environmental innovators (EIFs) and other innovators (OIFs), wave 2014 & wave 2015

Innovation capability: R&D Continuously/Occasionally	*OIF*	*EIF*		Total
		Minor	*Significant*	
Never	533	393	313	1239
(%)	56,9	44,4	37,0	46,4
Continuously/Occasionally	404	493	532	1429
(%)	43,1	55,6	63,0	53,6
#obs	937	886	845	2668
Chi2(2)	72.6			
p-value	0			

Source: MIP, own calculations.

a “significant” environmental impact (*EIF*s) is much larger than the share of *OIF*s. Among those product innovators that conduct occasionally or continuously R&D, the combined share of envi-

Table 6

Innovation capability, R&D Engagements, of environmental innovation firms-products (EIFPs) and other innovators firms (OIFPs), wave 2015

Innovation capability: R&D Continually/Occasionally	*OIFP*	*EIFP* *Minor*	*Significant*	**Total**
Never	780	260	169	1209
(%)	54,1	39,9	32,9	46,4
Continuously	662	391	344	1397
(%)	45,9	60,1	67,1	53,6
#obs	1442	651	513	2606
Chi2(2)	82.6			
P-value	0.0			

Source: MIP, own calculations.

ronmental product innovators (*EIFPs*) is also larger than that of other product innovators (*OIFPs*) but the difference is smaller than in the case of process innovation.

The observed shares suggest that environmental innovators may primarily own ideas for non-product innovations while non-environmental innovators focus to a larger extent on product innovation. The fraction of *EIFs* that never engage in R&D is significantly lower than that of *OIFs* and the difference is more substantial between *EIFPs* and *OIFPs*. This may indicate that environmental innovators require more intellectual capacity than other innovators. R&D represents a cost to firms and environmental innovators seem to be more likely to invest in knowledge generation for innovation purposes than non-environmental innovators.

Table 7 displays another innovation capability measure, *R&D intensity*, and Innovation intensity measure, *IS*. *R&D intensity* represents the ratio of R&D expenditure over turnover and *IS* is the ratio of innovation expenditure over turnover. Environmental product innovator firms (*EIFPs*) have, on average, a higher R&D expenditure over turnover than other innovator firms. This might be

Table 7

R&D Intensity (%), and innovation intensity (IS) (%), of environmental innovators (EIF & EIFP) and non-environmental innovators (OIF & OIFP), wave 2015

	R&D Intensity *OIF*	*EIF*	*OIFP*	*EIFP*	*IS* *OIF*	*EIF*	*OIFP*	*EIFP*
Mean	1.9	2.2	1.6	2.6	5.0	6.1	4.4	6.6
SD	4.2	4.1	3.7	4.5	8.5	8.9	7.8	9.1
#Obs T-test	864	2399	1331	1076	1076	1527	1221	1047
	-1.59*		-5.98***		-3.07**		-5.71***	

Notes: *R&D Intensity* is the ratio of R & D expenditure over turnover (%). *IS* represents the ratio of innovation expenditure over turnover (%). * p <0.10, ** p <0.05, *** p <0.01. Source: MIP, own calculations.

explained by the fact that *EIFP*s has higher engagement in R&D compared to *OIFP*s, as shown in Table 6. Nevertheless, on average, *EIF*s and *OIF*s make slightly higher R&D expenditures over their turnover despite the fact that *EIF*s have significantly higher involvement in occasional and continuous R&D. Furthermore, both groups of environmental innovators spend, on average, a larger share of their turnover for innovation compared to other innovators.

Table 8 shows the share of graduate employees of environmental innovators and other innovators. *Graduate employees* reflect the innovation capabilities of both environmental innovators and other innovators. We observe that *EIF*s have a smaller share of graduate employees than *OIF*s. Nevertheless, the share of graduate employees does not differ between environmental product innovators and other product innovators. Taking into account all innovation capability variables used in this paper, the descriptive results show that there is no consistent finding that would indicate outperformance of environmental innovators with regard to their intellectual or innovation capacity.

Table 8

Innovation capability, Graduate employees (%), of environmental innovators (EIFs & EIFPs) and other innovators (OIFs & OIFPs), wave 2015

	Graduate employees			
	OIF	*EIF*	*OIFP*	*EIFP*
Mean	4.1	3.5	3.7	3.6
SD	2.8	2.4	2.7	2.4
#Obs	883	1638	1366	1101
T-test	6.07***		0.59	

Notes: *Graduate employees* is the share of graduate employees (%). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: MIP, own calculations.

Table 9 displays statistics on innovation outcomes for environmental and non-environmental innovators. Both types of environmental innovators achieve a higher share of turnover that stems from market novelties compared to non-environmental innovators. Horbach (2008), Cecere et al. (2014) argue that economic incentives for environmental innovators are low. However, given that *EIF*s and *OIF*s spend similar shares of their turnover on R&D and innovation, on average, as shown

Table 9

Innovation output of environmental innovators (EIFs & EIFPs) and non-environmental innovators (OIFs & OIFPs), wave 2015

	InnoNovel			
	OIF	*EIF*	*OIFP*	*EIFP*
Mean	0.85	1.15	0.74	1.41
SD	1.83	1.83	1.63	2.01
#Obs T-test	541	1632	832	779
	-3.27***		-7.39***	

Notes: *InnoNovel* is the share of turnover from market novelties (%). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: MIP, own calculations.

in Table 5, environmental innovators have higher shares of market novelties over turnover. This implies better performance of environmental innovators.

Table 10 shows return on sales for environmental innovators and other innovators over the last two years. The t-test reveals that environmental innovators earn, on average, a lower return on sales compared to other innovators. This implies that both environmental innovators (*EIF*s and *EIFP*s) are less efficient in turning sales into profit. This also suggests that other innovation firms are more profitable than environmental innovators.

Table 10

Return on Sales, RoS of environmental innovators (EIFs & EIFPs) and non-environmental innovators (OIFs & OIFPs), wave 2015

	RoS			
	OIF	*EIF*	*OIFP*	*EIFP*
Mean	6.40	6.15	6.33	6.04
SD	2.59	2.34	2.53	2.37
#Obs T-test	783	1485	267	261
	2.51***		2.79***	

Notes: *RoS* is the return on sales in the last two years. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: MIP, own calculations.

Table 11 reports the financial needs (*fn*) of *EIF*s vìs-à-vìs *OIF*s. The percentage of *EIF*s with no financial need is slightly higher than the percentage of *OIF*s without financial need. In addition, a higher percentage of *EIF*s than *OIF*s declares having financial needs or even higher financial needs. These results indicate that environmental innovators could be more financially constrained than other innovators. Furthermore, Table 11 reveals that the share of *EIFP*s with financial need

Table 11

Latent financial need for both environmental innovators (EIFs & EIFPs) and non-environmental innovators (OIFs & OIFPs) during 2012–2014

	OIF	*EIF*	*Total*	*OIFP*	*EIFP*	*Total*
No financial need, *fn=0*	104	137	241	151	87	238
(%)	44.1	30.2	34.9	41.6	27.6	35.1
Financial need (cash), *fn=1*	100	235	335	163	165	328
(%)	42.4	51.8	48.6	44.9	52.4	48.4
Financial need (cash and credit), *fn=2*	32	82	114	49	63	112
(%)	13.6	18.1	16.5	13.5	20	16.5
#Obs	236	454	690	363	315	678
Chi2(2)	13.3			15.7		
P-value	0.0			0.0		

Source: MIP, own calculations

(cash) is only slightly higher compared to *OIFP*s. Yet, the percentage of *EIFP*s that double select both cash and credit to finance innovation is significantly higher than that of *OIFP*s. In Subsection

3.4, we test whether environmental innovators are more constrained than non-environmental innovators in a multivariate framework.

3.4 Regression Analysis

To assess the association between the likelihood of financial constraints and environmental innovation in a multivariate framework, we estimate ordinal probit models. The first model describes how adoption of environmental innovations affect financial needs while the second model describes how the creation of environmental innovations for end users affect financial need. Based on the results displayed in Table 12, firms that adopt environmental process innovations are significantly more likely to have latent financial needs. The likelihood of being financially constrained is more evident for firms that adopt innovations with a substantial contribution to protecting the environment.

When we control for firms' innovation capability and return on sales (Column (3) and (4) in Table 12), while also including other controls, the effect becomes smaller, albeit still significant. This implies that *EIF*s are more likely than *OIF*s to have innovation projects that they could conduct if additional funds were available. In contrast, the funding gap for environmental product innovators (*Envinno2*) depends more on the significance of environmental benefit. Product innovations with minor environmental benefits are not affecting the funding gap, while innovations with substantial environmental benefits affect the financial need statistically significant at a 10% level.

The results also show that innovation capability variables, R&D engagement and R&D intensity, are important drivers of financial needs. Furthermore, higher returns on sales decrease the likelihood of having funding gaps because it implies higher internal funding possibilities.

Table 12

Ordinal probit regressions for the dependent variable financial constraints (fn)

Dependent variable: *fn*	(1)	(2)	(3)	(4)
Envinno1 (env process innovation) = 1	0.205*		0.308**	
	(1.88)		(2.22)	
Envinno1 (env process innovation) = 2	0.324***		0.291**	
	(2.84)		(1.97)	
Envinno2 (env product innovation) = 1		0.131		0.0747
		(1.21)		(0.55)
Envinno2 (env product innovation) = 2		0.372***		0.247*
		(3.19)		(1.68)
R&D ocassionally/continually			0.536***	0.589***
			(3.48)	(3.83)
R&D intensity			5.262***	4.875***
			(3.61)	(3.29)
Return on sales (RoS)			-0.0422*	-0.0419*
			(-1.72)	(-1.70)
Employees' training costs (TC)			5.365	4.928
			(1.45)	(1.33)
Graduated employees			-0.0251	-0.0348

Dependent variable: *fin*	(1)	(2)	(3)	(4)
			(-0.85)	(-1.18)
Size(*a*)				
50 – 249	0.0184	0.0265	-0.0612	-0.0640
	(0.18)	(0.26)	(-0.46)	(-0.48)
>=250	-0.190	-0.172	-0.301	-0.307
	(-1.35)	(-1.22)	(-1.59)	(-1.60)
Industry(*b*)				
Food/Tobacco	0.972**	1.203**	0.570	0.676
	(2.23)	(2.54)	(1.06)	(1.13)
Textiles	1.031**	1.160**	0.607	0.696
	(2.38)	(2.46)	(1.13)	(1.16)
Wood/Paper	0.703	0.884*	0.649	0.822
	(1.54)	(1.79)	(1.15)	(1.32)
Chemical	1.042**	1.223***	0.310	0.479
	(2.47)	(2.62)	(0.59)	(0.81)
Plastics	0.996**	1.181**	0.638	0.761
	(2.26)	(2.46)	(1.17)	(1.25)
Glass/Ceramics	1.049**	1.164**	0.527	0.638
	(2.16)	(2.23)	(0.93)	(1.02)
Metals	0.837**	1.003**	0.722	0.863
	(1.98)	(2.16)	(1.39)	(1.48)
Electrical equipment	0.956**	1.084**	0.269	0.409
	(2.37)	(2.44)	(0.54)	(0.72)
Machinery	1.057**	1.128**	0.494	0.541
	(2.52)	(2.45)	(0.95)	(0.92)
Retail/Automobile	1.264***	1.332***	1.173**	1.211*
	(2.72)	(2.66)	(2.03)	(1.91)
Furniture/Toys/Medical technology	0.738*	0.849*	0.374	0.514
	(1.76)	(1.85)	(0.73)	(0.89)
Energy/Water	-0.0374	0.244	-0.701	-0.270
	(-0.08)	(0.49)	(-1.17)	(-0.43)
Wholesale	0.548	0.694	0.910*	1.059*
	(1.21)	(1.42)	(1.67)	(1.75)
Transport equipment/Postal Service	0.625	0.810*	0.501	0.714
	(1.41)	(1.67)	(0.93)	(1.18)
Media services	0.651	0.815*	0.392	0.526
	(1.48)	(1.70)	(0.74)	(0.89)
IT/Telecommunications	0.696*	0.868*	0.142	0.290
	(1.66)	(1.89)	(0.27)	(0.49)
Banking/Insurance	-0.000108	0.190	-0.320	-0.137
	(-0.00)	(0.39)	(-0.55)	(-0.22)
Technical services/R&D services	0.747*	0.755*	0.160	0.209
	(1.81)	(1.67)	(0.30)	(0.35)
Consulting/Advertisement	0.510	0.672	0.230	0.388
	(1.10)	(1.34)	(0.39)	(0.60)

Dependent variable: *fn*	(1)	(2)	(3)	(4)
Firm-related services	0.711	0.774	1.008*	1.118*
	(1.51)	(1.53)	(1.71)	(1.73)
μ_1	0.528	0.612	0.278	0.254
	(1.34)	(1.42)	(0.54)	(0.45)
μ_2	1.958***	2.039***	1.796***	1.765***
	(4.92)	(4.69)	(3.45)	(3.12)
Observations	690	678	466	457

Notes: The sample contains only innovating firms. environmental process (Envinno1)/product innovation (Envinno2): 0=no (reference category), 1=yes, insignificant, 2=yes, significant, (*a*) reference category: <50 and (*b*) reference category: Mining. μ_1 and μ_2 represent the intercepts (thresholds) of the ordinal probit model. *t*-statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13

Ordinal probit IV estimations

Equation (3) with dependent variable: fn_{2013}	(1)	(2)
Environmental innovation$_{2014}$		
Envinno1 (env process innovation)	0.843***	
	(8.93)	
Envinno2 (env product innovation)		0.793***
		(7.52)
Size$^{(a)}$		
50–249	-0.181*	-0.0864
	(-1.84)	(-0.79)
>=250	-0.561***	-0.437***
	(-4.04)	(-2.75)
R&D continuously/occasionally$_{2013}$	0.111	0.201
	(0.93)	(1.44)
R&D intensity$_{2013}$	2.200*	0.810
	(1.68)	(0.56)
Return on sales$_{2013}$ (RoS)	-0.00729	-0.0198
	(-0.45)	(-1.07)
Share graduated employees$_{2013}$	0.0317	-0.00197
	(1.55)	(-0.09)
Industry$^{(b)}$		
Food/Tobacco	-0.110	0.290
	(-0.28)	(0.62)
Textiles	0.665*	0.775
	(1.69)	(1.62)
Wood/Paper	-0.183	0.351
	(-0.46)	(0.71)
Chemical	0.0747	0.589
	(0.20)	(1.28)
Plastics	0.00654	0.157

Equation (3) with dependent variable: fn_{2013}	(1)	(2)
	(0.02)	(0.32)
Glass/Ceramics	-0.0373	0.126
	(-0.09)	(0.26)
Metals	0.148	0.453
	(0.41)	(1.00)
Electrical equipment	0.160	0.254
	(0.47)	(0.59)
Machinery	0.249	0.167
	(0.71)	(0.37)
Retail/Automobile	0.664	0.888
	(1.59)	(1.58)
Furniture/Toys/Medical technology/Maintenance	0.283	0.503
	(0.82)	(1.14)
Energy/Water	-0.553	-0.230
	(-1.41)	(-0.49)
Wholesale	0.214	0.718
	(0.55)	(1.45)
Transport equipment/Postal Service	0.144	0.396
	(0.39)	(0.85)
Media services	0.145	0.320
	(0.39)	(0.70)
IT/Telecommunications	0.619*	0.763*
	(1.70)	(1.71)
Banking/Insurance	0.232	0.378
	(0.53)	(0.74)
Technical services/R&D services	0.0765	-0.104
	(0.21)	(-0.23)
Consulting/Advertisement	0.386	0.596
	(1.01)	(1.25)
Firm-related services	0.760*	0.863*
	(1.92)	(1.70)

Equation (4) with dependent variable: *Environmental innovation*$_{2014}$	(1)	(2)
R&D continuously or occasionally$_{2014}$	0.384***	0.348***
	(5.92)	(4.93)
R&D intensity$_{2014}$	0.796	3.089***
	(1.09)	(3.79)
Return on sales$_{2014}$ (RoS)	-0.0105	0.00182
	(-1.03)	(0.15)
Costs for further education$_{2014}$ (CE)		4.511***
		(2.68)
Graduated employees$_{2014}$	-0.0397***	-0.0113
	(-3.26)	(-0.79)
Size[a]		
50–249	0.218***	0.0839

Equation (4) with dependent variable: *Environmental innovation*$_{2014}$	(1)	(2)
	(3.58)	(1.22)
>=250	0.428***	0.210**
	(4.85)	(2.22)
Industry[1,8]		
Food/Tobacco	0.482**	0.120
(cont)		
	(1)	(2)
	(2.39)	(0.54)
Textiles	-0.145	-0.247
	(-0.75)	(-1.12)
Wood/Paper	0.441**	0.190
	(2.09)	(0.82)
Chemical	0.0593	-0.440*
	(0.30)	(-1.93)
Plastics	0.0918	0.210
	(0.42)	(0.89)
Glass/Ceramics	0.360	0.301
	(1.63)	(1.28)
Metals	0.163	-0.0178
	(0.90)	(-0.09)
Electrical equipment	-0.191	-0.186
	(-1.10)	(-0.94)
Machinery	-0.0907	0.0423
	(-0.50)	(0.20)
Retail/Automobile	-0.0540	0.106
	(-0.26)	(0.44)
Furniture/Toys/Medical technology/Maintenance	-0.196	-0.323
	(-1.08)	(-1.54)
Energy/Water	0.224	-0.0363
	(1.11)	(-0.16)
Wholesale	-0.0779	-0.280
	(-0.38)	(-1.17)
Transport equipment/Postal Service	-0.122	-0.0140
	(-0.66)	(-0.07)
Media services	-0.214	-0.266
	(-1.09)	(-1.19)
IT/Telecommunications	-0.853***	-0.841***
	(-4.42)	(-3.80)
Banking/Insurance	-0.765***	-0.919***
	(-3.72)	(-3.76)
Technical services/R&D services	-0.260	0.00709
	(-1.38)	(0.03)
Consulting/Advertisement	-0.475**	-0.840***
	(-2.46)	(-3.56)

Equation (4) with dependent variable: *Environmental innovation*$_{2014}$	(1)	(2)
Firm-related services	-0.415**	-0.146
	(-2.05)	(-0.63)
μ11	0.00402	0.119
	(0.01)	(0.30)
μ12	0.985***	1.137**
	(2.67)	(2.49)
μ21	-0.452***	0.257
	(-2.65)	(1.31)
μ22	0.503***	1.052***
	(2.94)	(5.31)
atanhρ_{12}	-1.021***	-0.951***
	(-3.87)	(-3.78)
Total observations used N	1910	1628
First equation N_1	444	382
Second equation N_2	1910	1628

Notes: The sample contains only innovating firms. (a) reference category: <50, (b) reference category: Mining, μ_{ij} indicates the ordinal probit model intercepts (threshold i) for equation j. t statistics in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 13 shows the results of the CMP estimation where environmental innovation variables, *Envinno1* and *Envinno2*, are instrumented. Based on Columns 1 and 2 of the first part of Table 13, *Envinno1* and *Envinno2* are positive and significant at the 1 % level. This strengthens the conclusions from the ordinal probit model, shown in Table 12, that environmental innovators (*EIF*s and *EIFP*s) vís-à-vìs non-environmental innovators (*OIF*s and *OIFP*s) have a higher likelihood to suffer from financing constraints. In other words, those firms have latent financial needs for their innovation and investment projects.

Larger firms have smaller funding gaps. The result is significant at the 1 % level for the size class ≥250 employees in both columns. Our innovation capability proxy variable, *R&D intensity*, is another important determinant of financing constraints. From the second part of Table 13, Equation (4), we infer that the innovation capability variable especially the variable *R&D continuously/occasionally* is an important driver for environmental innovation. This result supports the univariate analysis from Table 5 that environmental innovators are more engaged in R&D than other innovators. Furthermore, R&D continuously or occasionally, R&D intensity and cost for further education are innovation capability proxy variables that are associated with a higher likelihood of having developed environmental innovations products (*EIFP*s).

4 Conclusions

Investigating whether financing constraints matter for firms that adopt or create environmental innovations is crucial for identifying the relationship between environmental innovation and funding gaps. Using the Mannheim Innovation Panel, we identify firms that either have launched environmental product/service innovations or have adopted process innovations, such as cleaner production technologies or reduction of energy consumption. Furthermore, we use a methodology suggested by Hottenrott and Peters (2012) to determine latent financial needs of firms which innovate.

Our main finding is that firms with environmental innovations, especially those that are changing their processes to cleaner or more energy efficient production, are more likely to experience funding gaps. This result also holds when taking potential endogeneity of environmental innovation into account. Firms that launch environmental innovations in terms of new products or services for end users are also constrained, but to a lesser extent. The existence of funding gaps imply that firms have latent projects that would be pursued if funding was available.

To mitigate the consequences of funding gaps, one tentative conclusion from our study is that public subsidies could be an instrument that supports firms adopting environmental innovations. Another instrument to consider is promoting the accumulation of equity capital building of green innovator firms to strengthen their creditworthiness. One option could be granting public subsidies as equity capital for green innovators. Another option could be to introduce for green innovators a similar preferential tax treatment for the returns of retained earnings than for interest rates on debt (e. g. Ketzler and Schäfer 2009, Spengel, Heckemeyer, Bräutigam, Nicolay, Klar and Stutzenberger 2016). Of course, the latter measure requires profitability of firms to be effective. Whether financing constraints of environmental innovators are driven by a higher innovation capability of environmental innovators or by restrictions imposed by the financial sector is a question left for future studies.

References

— Aghion, P., R. Veugelers, D. Hemous et al. (2009): No green growth without innovation, Bruegel Policy Brief-2009/07.
— Alliance, G. G. A. (2013): The green investment report: The ways and means to unlock private finance for green growth, in 'World Economic Forum'.
— Almeida, H., P.-H. Hsu, and D. Li (2013): Less is more: Financial constraints and innovative efficiency, Available at SSRN 1831786.
— Bachelet, M. J., L. Becchetti, and S. Manfredonia (2019): The green bonds premium puzzle: The role of issuer characteristics and third-party verification, Sustainability 11(4), 1098.
— Beck, T., A. Demirgüç-Kunt, L. Laeven, and V. Maksimovic (2006): The determinants of financing obstacles, Journal of International Money and Finance 25(6), 932–952.
— Behrens, V., M. Berger, M. Hud, P. Hünermund, Y. Iferd, B. Peters, C. Rammer, and T. Schubert (2017): Innovation activities of firms in germany-results of the german cis 2012 and 2014: Background report on the surveys of the mannheim innovation panel conducted in the years 2013 to 2016, Technical report, ZEW-Dokumentation.
— Brouillat, E. (2009): Recycling and extending product-life: an evolutionary modelling, Journal of Evolutionary Economics 19(3), 437–461.
— Brown, J. R., G. Martinsson, and B. C. Petersen (2012): Do financing constraints matter for R&D?, European Economic Review 56(8), 1512–1529.
— Cecere, G., N. Corrocher, C. Gossart, and M. Ozman (2014): Lock-in and path dependence: an evolutionary approach to eco-innovations, Journal of Evolutionary Economics 24(5), 1037–1065.

— Cosci, S., V. Meliciani, and V. Sabato (2016): Relationship lending and innovation: empirical evidence on a sample of European firms, Economics of Innovation and New Technology 25(4), 335–357.
— Czarnitzki, D., and H. Hottenrott (2011): R&d investment and financing constraints of small and medium-sized firms, Small Business Economics 36(1), 65–83.
— De Marchi, V. (2012): Environmental innovation and r&d cooperation: Empirical evidence from spanish manufacturing firms, Research policy 41(3), 614–623.
— Demary, M., J. Hornik, and G. Watfe (2016): SME financing in the EU: Moving beyond one-size-fits-all, IW-Reports 11/2016, Institut der deutschen Wirtschaft (IW)/German Economic Institute. https://ideas.repec.org/p/zbw/iwkrep/112016.html.
— Doran, J., and G. Ryan (2016): The importance of the diverse drivers and types of environmental innovation for firm performance, Business strategy and the environment 25(2), 102–119.
— Fazzari, S., R. G. Hubbard, and B. C. Petersen (1987): Financing constraints and corporate investment.
— Ghisetti, C., S. Mancinelli, M. Mazzanti, and M. Zoli (2017): Financial barriers and environmental innovations: evidence from EU manufacturing firms, Climate Policy 17(sup1), pp. 131–147.
— Hall, B. H. (2005): The financing of innovation, The Handbook of Technology and Innovation Management pp. 409–430.
— Hall, B. H., P. Moncada-Paternò-Castello, S. Montresor, and A. Vezzani (2016): Financing constraints, R&D investments and innovative performances: new empirical evidence at the firm level for Europe.
— Horbach, J. (2008): Determinants of environmental innovation – new evidence from german panel data sources, Research policy 37(1), 163–173.
— Hottenrott, H., and B. Peters (2012): Innovative capability and financing constraints for innovation: more money, more innovation?, Review of Economics and Statistics 94(4), 1126–1142.
— ING (2018): From sustainability to business value, Technical report.
— Janssen, M. A., and W. Jager (2002): Stimulating diffusion of green products, Journal of Evolutionary Economics 12(3), 283–306.
— Kemp, R., and V. Oltra (2011): Research insights and challenges on eco-innovation dynamics, Industry and Innovation 18(03), 249–253.
— Kemp, R., and S. Pontoglio (2011): The innovation effects of environmental policy instruments – a typical case of the blind men and the elephant?, Ecological Economics 72, 28–36.
— Lahr, H., and A. Mina (2013): Dynamic financial constraints and innovation: Evidence from the UK innovation surveys, in 'European Conference on Corporate R&D and Innovation CONCORDi-2013 conference paper, Seville (Spain)'.
— Lööf, H., A. Stephan, and F. Wulandari (2018): New ventures in cleantech: opportunities, capabilities and innovation outcomes'. Business Strategy and the Environment, forthcoming.
— Mazzucato, M. (2015): Innovation systems: from fixing market failures to creating markets, Revista do Serviço Público 66(4), 627–640.
— Myers, S. C., and N. S. Majluf (1984): Corporate financing and investment decisions when firms have information that investors do not have, Journal of financial economics 13(2), 187–221.
— Olmos, L., S. Ruester, and S.-J. Liong (2012): On the selection of financing instruments to push the development of new technologies: Application to clean energy technologies, Energy Policy 43, 252–266.

DOI https://doi.org/10.3790/vjh.88.3.43

— Rammer, C., and B. Peters (2015): Dokumentation zur innovationserhebung 2014: Innovationen mit bezug zur energiewende, finanzierung von innovationen, Technical report, ZEW-Dokumentation.
— Rammer, C., A. Schmiele et al. (2008): Globalisation of innovation in smes: why they go abroad and what they bring back home, Applied Economics Quarterly (formerly: Konjunkturpolitik) 59(Supplement), 173–212.
— Rennings, K. (2000): Redefining innovation – eco-innovation research and the contribution from ecological economics, Ecological economics 32(2), 319–332.
— Rennings, K., P. Markewitz, and S. Vögele (2013): How clean is clean? incremental versus radical technological change in coal-fired power plants, Journal of Evolutionary Economics 23(2), 331–355.
— Roodman, D. (2011): Fitting fully observed recursive mixed-process models with cmp, Stata Journal 11(2), 159–206(48).
— Schäfer, D., and R. Ketzler (2009): Drohende Finanzierungsklemme bei Innovationen: rechtzeitig entgegensteuern. Wochenbericht. 76. 772–783.
— Schäfer, D., A. Stephan, and J. S. Mosquera (2017): Family ownership: does it matter for funding and success of corporate innovations?, Small Business Economics 48(4), 931–951. URL: https://doi.org/10.1007/s11187-016-9813-y.
— Spengel, C., J. H. Heckemeyer, R. Bräutigam, K. Nicolay, O. Klar, and K. Stutzenberger (2016): The effects of tax reforms to address the debt-equity bias on the cost of capital and on effective tax rates, ZEW Expertises, ZEW – Leibniz Centre for European Economic Research, volume 65, number 148156. https://ideas.repec.org/b/zbw/zewexp/148156.html.