Financial barriers and Environmental Innovations. Evidence from EU manufacturing firms

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Abstract

We analyse the role of financial barriers in affecting the adoption of environmental innovations with a focus on manufacturing SMEs in Europe. In taking stock of the consolidated literature on environmental innovations, we find that the role of financial barriers is substantially neglected, although crucial, even more relevant in the current phase of the economic cycle. Our empirical analysis confirms the existence of direct negative effects of financial barriers on environmental innovation investment decisions. It furthermore sheds more light on the determinants of financial barriers that shape firms' cleaner production choices. Our findings have the following policy implications: properly designed policies can play a critical role, not only by stimulating environmental innovations through their determinants, but also by acting on the financial obstacles to eco-innovation.

Policy relevance

Environmental innovations (EI) are essential to achieve economic growth and environmental protection goals. Technological development is one of the key factors that can counterbalance the growth and population emission-augmenting effects. EI are a priority in major EU policy strategies and a prerequisite for the development of a "Resource efficient Europe", one of the flagship initiatives of Europe 2020. The existence of financial barriers can constitute a serious deterrent for the eco-innovative capacity of firms, even more than for "traditional" innovations, as EI are characterized by high technical risk, long payback period and uncertainty on the appropriability of private rents. This article analyses in depth whether barriers related to external financing affect EI investments and whether the stringency of financial constraints to investments in EI is affected by factors related to EI specificities. We show that when both direct and indirect effects on EI investments are considered, the role of the policy framework appears to be as particularly crucial in order to reverse the risk/return trade-off of eco-innovative investments. Targeting policy interventions to facilitate access to credit and to mitigate capital markets' imperfections is essential to mitigate the apparent contradiction between EU industrial policies and climate abatement scenarios.

JEL: Q55; O31

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1. Introduction

Environmental innovations (EI henceforth) are essential to achieve environmental and economic goals. Green growth processes can witness an absolute decoupling of environmental pressure and economic growth thanks to innovation effects (Brock and Taylor, 2010) which continuously increase the value added per unit of environmental resources used. Within the specific climate policy debate, the Stern review recognizes the role of technological and environmental innovations as key factors towards decarbonisation.

The current macroeconomic setting is slowly moving towards financing the low carbon economy through diversified private and public oriented sources (EEA, 2014). Nevertheless, when compared to the mass of potential liquidity and high decarbonisation targets, this development is still in its infancy. The funding of both long-term and short-term environmental investments is central. Regarding the former, private capital sources as well as hybrid initiatives mixing public and private lending (as green bonds or sovereign wealth funds) should complement public actions. For short-term investments, asset allocation of banking and finance is a key driver. In the current EU liquidity trap situation, with very low or even negative real interest rates, financial constraints co-exist with extensive and structural excess of savings that can be potentially allocated to low carbon investments, and equilibrate the observed decreasing investment dynamics.

It is worth noting that even though access to finance is a classical barrier to innovations in general, financial constraints are especially relevant for EI, defined as innovations that contribute to economic and environmental sustainability[1] (Rennings, 2000). This happens because EI are characterized by higher technical risk and uncertainty compared to "standard" innovations. Despite the fundamental role played by finance and banking in boosting EI, however, the literature on this particular type of innovation has not touched upon it with sufficient depth and breadth.

In this article, the role of financial barriers on firms' EI investment choices is explored, by controlling for the determinants that the economic literature identifies relevant for EI decisions. As several factors related to EI specificities can affect the firms' probability of experiencing liquidity constraints, we also control for the influence of these factors on the stringency of financial constraints.

EI are "special" innovations and their specificities in terms of drivers and barriers have been largely empirically analysed, attributing a crucial role to environmental policies (for a review, see Barbieri et al., 2016; Del Río et al., 2015). Kemp (2000) and Kemp and Pontoglio (2011) conclude that different policy instruments can favour or disfavour particular types of innovation and that radical innovations can be stimulated by well-designed and fine-tuned policy instruments. Foxon and Pearson (2008) focus on barriers in terms of 'system failures': failure in infrastructure provision and

[1] As noted by Carrillo-Hermosilla et al. (2010), the literature provides several attempts to define EI. In general, all definitions agree that EI are such when reduce the environmental impact of consumption and production activities, independently of the explicit environmental motivation for their development or deployment.

investment, transition failure, lock-in failures and institutional failures. Marin et al. (2015) enlarge the picture and propose a taxonomy of SMEs in EU based on their engagement in EI and their innovation barriers in terms of costs, market and knowledge. Other studies emphasize the peculiar features of EI with respect to general innovation in terms of their determinants (Horbach et al., 2012; Ghisetti et al., 2015, among others).

Very few contributions, however, explicitly address the relevance of financial constraints as potential barriers to the eco-innovative activity of firms. Among them, Cuerva et al. (2014) find that, even though financial constraints do not seem to have an effect on the probability of introducing conventional innovation, they turn out to have a significant and negative effect on EI. This suggests the opportunity of providing a deeper investigation of financial issues faced by eco-innovative firms, by analysing the main driving forces behind them, in order to suggest potential policy improvements to support EI.

In particular, this paper investigates the following two issues: i) whether the stringency of financial constraints to EI investments is affected by factors related to EI specificities, and ii) whether barriers related to external financing affect EI investments. These issues are empirically analysed by using a recursive bivariate probit model that takes into account the existence of interdependencies between the experience of financial constraints and the decision to invest in EI.

To perform our empirical investigation, we use data for 27 European countries, drawn from a specific Eurobarometer survey (Flash Eurobarometer survey #315), which contains valuable information on EI activities of small and medium-sized enterprises (SMEs) in the EU. The focus is on SMEs and it is justified by considering that difficulties to get external finance are one of the most pressing problems to the development and investments of SMEs. Indeed, differently from large-scale enterprises, which have direct access to capital markets, SMEs are financially more constrained and are less likely to have access to formal finance (EC, 2015; Beck and Demirguc-Kunt, 2006). Further, many of the most eco-innovative solutions are developed by SMEs (EC, 2011), as recognized also by the recent policy initiatives at the EU level, especially the Eco-Innovation Action Plan (EcoAP), which aims at reducing environmental pressure through innovation within the framework of the Europe 2020 strategy. Specifically, the plan includes a series of actions to foster the uptake of EI, including the mobilisation of financial instruments and support services for SMEs[2] (EC, 2011).

Our analysis is explicitly devoted to the manufacturing sector. This sector contributes to 18.8 % of all greenhouse gas emissions in EU (Eurostat, data refer to 2013) and it is at centre of the current European policy framework, in which strategies towards a decarbonized and resource efficient economy should be integrated with industrial policies calling for manufacturing to achieve a 20 % share of GDP by 2020, from about 16 % in 2011 (EEA, 2014). As the manufacturing sector is "heavy" for the environment, but with a huge innovative (and also eco-innovative) potential (Borghesi et al. 2015), it is extremely important to investigate the role of financial barriers to EI on this sector.[3]

[2] The EcoAP (Action 4) recognizes that access to finance is especially difficult for SMEs engaging in ecoinnovation because their perceived commercial risk is greater (EC, 2011).

[3] Own elaboration on WIOD data (available upon request) show the heaviness but also the dynamic innovation potential of manufacturing firms, as the share of CO_2 emissions over the value added in EU28 is higher for manufacturing firms, but it has improved over time through innovation.

The article is organized as follows. Section 2 introduces the conceptual background to examine the main determinants of financial barriers to EI, while Section 3 describes the data and the empirical model, and Section 4 discusses estimation results. Section 5 concludes.

2. Financial barriers to EI: conceptual background

Innovation studies have devoted much attention to the impact of barriers of a financial nature on firms' innovations (e.g. Hall, 2002; Savignac, 2008; Mancusi and Vezzulli, 2010; Hottenrott and Peters, 2012, among others). These studies highlight that the high degree of uncertainty that characterises innovation projects, together with their complexity and specificity, makes firms less prone to investing in innovation in the presence of a lack of financial availability (Hottenrott and Peters, 2012). The presence of financial constraints and weak access to credit significantly reduces the likelihood of firms to innovate (Savignac, 2008), although with heterogeneities depending on firms' sectors and dimension (Canepa and Stoneman, 2007).

All these features are shared also by EI, that are crucial to improve the sustainability of production processes, either when innovations are integrated in the production process (Cleaner Production measures), or when innovations are add-on measures which reduce the negative externalities in the last stage of the production process (End of Pipe technologies). EI, however, imply costly investments and risky returns, even more than other types of innovations. The higher riskiness compared to traditional innovations is mainly related to the relatively longer payback period, the lower maturity of green markets and the heterogeneous "appropriability" of innovation rents, related to the 'mixed' public good nature of EI (Corradini et al. 2014) which produce private and public benefits. EI are riskier even compared to other environmental practices, because they require greater financial commitment and usually returns are enjoyed in the long term (Berrone et al. 2013); moreover, due to their explicit aim of reducing pollution, EI face positive knowledge externalities (Rennings, 2000) which may possibly lead to suboptimal investment levels.

These considerations suggest that the probability of experiencing barriers to access external financing can be higher for EI, especially for the more breakthrough ones that are characterized by a high technical risk/uncertainty (Aghion et al., 2009; Cuerva et al., 2014; EC, 2011). In this respect, low carbon innovations are a special kind of EI facing even higher risks, because for this type of innovations the characteristics of relative immaturity, capital intensity (Bolton et al., 2015), policy dependence and mixed public good nature are even more pronounced. Further, path dependence and lock-in effects are likely to arise because of network effects and high switching costs[4] (Aghion, et al., 2014), so that the lack of external private sources of funding is especially relevant (Polzin, et al., 2015; Leete et al., 2013; Olmos et al., 2012).

Despite their relevance, the literature on EI has not extensively investigated the role of financial barriers. In filling this research gap, we not only estimate the effect of financial barriers on firms' investments in EI but also identify factors that can affect the stringency of financial constraints for EI. This additional analysis is relevant because factors that affect firm's probability of

[4] As an example of the difficulties in overcoming lock-ins in traditional polluting technologies, Aghion et al. (2014) report the challenge of stimulating research and development on electric cars.

experiencing liquidity constraints can be an indirect source of barriers to the diffusion of EI practices among firms and this leads to additional policy implications.

In the following, we provide a concise overview of the main elements that affect the stringency of liquidity constraints to EI. All of these elements operate by affecting the risk/return trade-off of investments in EI, contributing to increase the riskiness and/or decreasing the profitability of EI.

Financial constraints are not only relevant for those “green investments” which currently have a negative net present value and need additional public funds (subsidies or tax credits) to become competitive. Constraints are instead relevant also for “green” investments that have a positive net present value and that - in principle - do not need any public support. In the latter case, investments can be self-financing in the long run, but they often entail higher upfront costs compared to traditional investments, and are thus perceived as riskier than conventional ones (Kapoor and Oksnes, 2011). With a specific reference to energy technologies investments, given the longer time horizon required to draw profit, significant changes in the institutional context, policies and regulations, technology alternatives, financial vehicles and social preferences may occur. These considerations suggest the need to conceptualize energy finance as an adaptive market (Hall et al., 2015; Bolton et al., 2015).

Among the factors that contribute to explaining why financial institutions provide insufficient credit to EI, a relevant role is played by the institutional context, often characterized by regulations not focused on providing incentives to green innovations. The existence of perverse incentives for carbon-intensive technologies (e.g. fossil-fuel subsidies[5]) as well as the instability of incentives for clean energy production, for instance, have the effect of preventing investments in EI from gaining competitive advantage. The lack of a consistent and predictable policy framework is responsible for increased uncertainties in eco-investment profitability and it results in new financial risks. As argued by Sawin (2004), the implementation of an “on-and-off” policy approach to renewables caused negative effects in terms of uncertainties, bankruptcies, suspension of projects and worker lay-offs in the U.S. and Denmark[6].

On the other hand, especially for low-carbon innovations, climate related policies are a crucial driver, particularly in the energy sector (among others, Kerr and Newell, 2003; for a review, see Dechezleprêtre et al., 2016). The adoption of more stringent regulations on carbon emissions in response to climate change challenges, determining future increases in energy/carbon prices[7], can reduce the profitability of dirty existing technologies, while stimulating EI (Acemoglu et al., 2012; Aghion et al., 2009; Newell et al., 1999; Popp, 2002). Aghion et al. (2016), with specific reference to low-carbon innovation activities in the car industry, show that firms tend to innovate more in green technologies than in grey technologies, when facing higher fuel prices. This in turn contributes to reduce the stringency of financial barriers to EI.

[5] According to IEA, fossil-fuel subsidies amounted to $544 billion in 2012, and over half of the total corresponded to subsidies on oil products. As a result, 15% of global CO_2 emissions currently receive financial incentives corresponding to $110 per tonne, while only 8% are subject to a carbon price (IEA, 2013).

[6] Chart 3 in Sawin (2004: p.39) shows the impact of policy inconsistencies on annual wind installations in Germany, the United States and Spain.

[7] Under some mitigation scenarios, carbon price is expected to be € 60-100/tonne of carbon dioxide (Kapoor and Oksnes, 2011; p. 54).

Another factor behind such under-provision of credit for EI is the short-termism in financial markets. Green investments tend to have a higher perceived risk for potential investors when compared with traditional investments (Kapoor and Oksnes, 2011). In several cases, innovative clean investments are characterised by uncertainties related to features as their durability or performance, which contribute to increase their perceived risk. They further have high capital costs at the outset and it takes a longer time to get a new solution to the market, making their payback period longer than many traditional investments (WEF, 2013). EI is still perceived by investors as an immature arena with unknown markets and business models, compared to other sectors deemed as more mature, such as ICT, biotech, or life science, and whose financial returns have been already experienced[8] (EC, 2011). As noted by Mazzucato (2015) with specific reference to the short-termist perspective of venture capital, private funding generally requires very short lifespans ("an exit in three years", p.123), compared to 15-20 years required by innovation processes[9]. EI time spans can well go beyond 20 years.

Another source of restrictions in credit provision is represented by market conditions. The existence of well-established firms that dominate the market, as well as the lock-in effect of carbon intensive technologies (Unruh, 2000) may act as barriers to EI not only directly, but also by inducing restrictions of financial credit for SMEs. Monopolistic markets may either support innovations through rents or deter innovations through a lack of competitive pressures. Non-linear innovation-market structure relationships might exist in theory and practice (Aghion et al., 2005). In this article where we focus on SMEs, we take into account this kind of barriers, as those firms could operate in markets with big players that reduce competition and extract rents.

3. Data and Empirical Model

The empirical analysis is based on data collected by the Gallup Organisation in the Flash Eurobarometer Survey number 315 (Attitudes of European Entrepreneurs towards Eco-innovation)[10]. In this survey, information is drawn from interviews to 5222 managers of SMEs, realized between January and February 2011[11] (EC, 2011). The survey is representative for 27 EU Member States and refers to small (10-49 employees) and medium (50-249 employees) enterprises in agriculture, manufacturing, water supply and waste management, construction and food services sectors. As it was previously motivated, the focus is only on the subset of manufacturing firms, amounting to 2775 respondents. Our operative sample shrinks to 1885 firms due to missing values in some variables of interest.

The questionnaire defines EI as 'the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural

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[8] These features clearly do not characterize only eco-innovation markets but they are more pronounced than for most other sectors (EC, 2011).

[9] Mazzucato (2015) suggests, as an example of innovative high-risk projects requiring financial support, investments made by the greentech company Tesla Motors.

[10] To the best of our knowledge, this is the only source that presents both EI and financial barriers information (e.g. Community Innovation Survey CIS 4 presents only barriers, CIS5 EI but not barriers; CIS surveys are the main source of information on EI, but at the moment they do not allow for analyses on EI and financial barriers).

[11] The cross-sectional structure of the data constitutes a limitation in the scope of the current analysis and requires the need to make explicit that it allows us to assess only correlations rather than proper causations among the variables.

resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle of the product'. As the paper investigates the potential impact of financial barriers on EI, we consider the share of innovation investments related to EI over the last five years as our dependent variable (*EI*). This allows us to focus on an "input" proxy of innovation (namely innovation investments) rather than on alternative proxies (e.g. EI adoption counts) as financial barriers are likely to affect directly the amount of resources devoted to EI investments first.

The variable for financial barriers (*eFIN*) is elicited through a question, which asks entrepreneurs to report, on a scale ranging from 1 (not relevant) to 4 (relevant), how serious they consider the lack of external financing as an obstacle to EI uptake. It has then been dichotomized: it equals 1 when the lack of external financing is considered as a very serious/somewhat serious barrier (values 3 or 4) and 0 otherwise (values 1 and 2). A detailed description of the variables included in the analysis is provided in Table 1[12]. The mean values of the variables are reported for the full sample and for the subgroups of non eco-innovative and eco-innovative firms to compare the values in the two groups. The tetrachoric correlation matrix is shown in Table 2.

To investigate both factors affecting the stringency of financial constraints to EI investments and factors affecting EI investments, including financial barriers, a simultaneous-equations model has been chosen: the recursive bivariate probit model (Greene, 2008). This empirical strategy explicitly takes into account that the experience of difficulties in getting external financing and firms' investments in EI can be correlated. Specifically, two equations are jointly estimated, Equation 2 on EI investment decisions (with *EI* as dependent variable) and Equation 1 for financial constraints (with *eFIN* as dependent variable). Further, *eFIN* is included as explanatory variable into Equation 2, to evaluate whether a direct correlation between the two variables exists, besides the indirect correlation exerted through the error terms. The two equations are presented below.

The determinants of external financing constraints suggested by the literature and summarized in Section 2 are chosen as explanatory variables in Equation (1). Accordingly, the experience of financial barrier is expected to be affected by the existence of technological lock-ins (*TEC_LOCK*), uncertainties related to the market demand (*UNCERTDEMAND*) and return of the investment (*UNCERTRETURN*), market conditions, such as the presence of established enterprises that dominate the market (*MARKET*) and expectations about future increases[13] in energy prices (*FUT_ENPRICE*) and in regulatory stringency (*FUT_REG*):

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[12] Even though the self-reported nature of variables in the survey can be considered as a limitation, it is worth to note that, given the aim of our analysis, it is extremely relevant to have the entrepreneurs' opinion on the relevance of the barriers they experience in their EI investments. The choice of considering binary variables is motivated because we are not interested in assessing the degree of seriousness of the barriers, but if entrepreneurs consider the specific factor as a barrier to EI or not. The lack of multiple continuous variables can however constitute a limit to the current empirical analysis that needs to be made explicit.

[13] We are currently facing a contingent situation where energy prices have sharply decreased due to excess of supply in oil markets, the discovery of new fossil fuel sources in North America and stagnating economic growth in the EU and emerging countries (except for India). A reduction in energy use resulting from energy efficiency improvements and investments in renewables might also contribute to reduce energy prices. Nevertheless, it is reasonable to assume that in the medium-long run, prices will tend to increase due to scarcity of cheap fossil fuels and especially for the increasing stringency of climate policy targets. In the EU, for instance, the decreasing cap of the EU ETS and the introduction of new energy/carbon taxes (EU Energy Directive) will sustain increasing prices for energy deriving from fossils. Markandya et al. (2014) estimate carbon values in the EU27 about 100-200 €/ton for the period 2020-2030 and about

$$eFIN = \alpha + \beta_0 TEC\_LOCK + \beta_1 UNCERTRETURN + \beta_2 UNCERTDEMAND + \beta_3 MARKET + \beta_4 FUT\_REG + \beta_5 FUT\_ENPRICE + \delta DCountry + \gamma SIZE\_MEDIUM + \epsilon$$

(1)

where we control for country fixed effects (with the dummy *DCountry*) and size of the firm (*SIZE_MEDIUM)*.

Among the covariates affecting EI investment decisions, we draw on existing literature to select relevant drivers and barriers besides the financial barriers. EI are affected by four categories of determinants (Horbach et al., 2012): market-pull, technology-push, firm specific factors and regulation. Within the first category, we include the firm's turnover (*TURNLOW*) and the demand for eco-products (*DEMAND*), while as a proxy for technology-push factors we consider the presence of technological and management capabilities within the enterprise (*INT_KNOW*). Firm's specific factors could be captured by the number of employees as in Horbach (2008). Nevertheless, given the high correlation between *TURNLOW* and *SIZE_MEDIUM* (Table 2), and its not significant coefficient, *SIZE_MEDIUM* was excluded from Equation 2. The regulatory framework is accounted for by *REG*. As noted above, technological knowledge may be a relevant element to spur EI adoption. In addition to the availability of internal knowledge inside the firm, considered above, the company can obtain technological information and capabilities from outside (*EXT_KNOW*). Relying upon external knowledge sourcing is a relevant driver for EI (De Marchi, 2012; Ghisetti et al., 2015): the complexity and the multiplicity of capabilities required by EI (e.g. technological, organization and institutional) make the eco-innovator even more reliant on several external knowledge sources and on repeated interaction over time, compared to traditional innovation.

On the basis of previous considerations, Equation (2) is defined as it follows:

$$EI= \alpha + \beta_1 eFIN + \beta_2 DEMAND + \beta_3 EXT\_KNOW + \beta_4 INT\_KNOW + \beta_5 REG + \beta_6 TURNLOW + \delta DCountry + \eta \qquad (2)$$

As for Eq.(1), country fixed effects are introduced.

It is important to note that, in order to account for the different experience of barriers to EI between innovative and non-innovative firms, Eq. (1) and (2) are estimated on a "filtered" sample of firms, where firms that jointly do not innovate and do not perceive any financial barrier are excluded by the analysis. In doing so, we follow Pellegrino and Savona (2013) that highlight the existence of a potential bias in estimating the role of barriers to innovation on the whole sample of innovative and non-innovative firms. This is justified in that barriers to innovation are perceived as stronger for firms which are actually innovating or have tried to innovate (Mohnen and Röller, 2005). Obstacles to innovation should then be more properly interpreted as a measure of how firms are able to overcome them rather than as barriers preventing innovation (Baldwin and Lin, 2002; Tourigny and Le, 2004). In the same line, D'Este et al. (2012), proposed a distinction between 'deterring' and 'revealed'

400-600 €/ton in 2050. The dynamics of carbon prices, which is coherent with the achievement of climate change mitigation targets (25% in 2020 and 80% in 2050), is expected to be exponential: prices sharply increase after 2025-30.

barriers: in the first case, barriers negatively impact on innovation, while in the second case a positive effect is ascertainable when firms overcome the barrier and innovate.

4. Results and Discussion

Table 3 presents the results of the bivariate probit model with reference to Equations (1) and (2). Average marginal effects are reported in column (2).

The use of the recursive bivariate probit model is supported by the reported Wald test on the correlation coefficient ρ: the null hypothesis of zero correlation between the error terms (ε and η) of the two equations is not accepted. The hypothesized relationship between the experience of external financing barriers and investment decisions in EI is thus confirmed. Disturbances in the equations are capturing unobserved omitted factors which affect both EI investment strategies and the experience of financial constraints.

Estimation results (Eq. 1) suggest that the experience of difficulties in getting external sources of finance is strongly correlated to the short-termism perspective of financial institutions and actors, proxied by the perception of uncertainties related to EI investment returns, mainly related to their too long payback period. These results confirm that the characteristics of EI as still an immature kind of innovation increase the perception of their risk and consequently the difficulties for firms to exploit external credit opportunities.

Similarly, market conditions, as the presence of established enterprises that dominate the market (*MARKET*), and of technical/technological lock-ins (*TEC_LOCK*), such as old technical infrastructures, may restrict firms' access to credit, increasing the stringency of the financial barrier. These results confirm that the characteristics of EI as a perceived uncertain innovation increase the perception of their risk and consequently the difficulties for firms to exploit external credit opportunities.

On the contrary, expectations about future increases in energy prices (*FUT_ENPRICE* - that is only slightly significant) and about stricter future regulations imposing new standards (*FUT_REG*) do not seem to be associated to the existence of financial barriers for firms that eco-innovate. These results suggest that both entrepreneurs and financial institutions have not perceived yet these factors as serious threats for the profitability of dirty projects (and, at the opposite, as an opportunity for EI). This result, from a firm level perspective, is coherent with the freezing expectations on energy prices occurred after the recession, and with the uncertain environmental regulatory setting related to the "recovery" of the EU ETS and the proposals for new and increased carbon taxes.

Finally, medium-sized firms are less likely to perceive external financial constraints as strong barriers, relatively to small firms. This confirms that small firms have to face major difficulties in getting credit for their EI investments compared to large firms that often access equity and long term loans, and possess more developed 'eco-literacy' (Hoogendoorn et al., 2014). It is also in line with previous studies, suggesting that smaller firms tend to face larger financial obstacles compared to medium-sized ones (Beck et al., 2006).

Moving to decisions about EI investments (Eq. 2), our estimates indicate that financial barriers have a negative and significant impact, highlighting the need of relaxing the strictness of financial constraints in order to spur EI investments by firms. Given the recursive nature of our estimates, it is interesting to note that the perception of external financing constraints - as a barrier on EI investments - is highly significant, even when we account for a set of potential determinants explaining the relevance of the financial barrier. This also suggests that variables affecting the financial barrier exert an indirect (and negative) impact on EI investments. This opens interesting questions about the importance of loosening the stringency of constraints in obtaining external sources of funding for eco-innovative firms, by reducing uncertainties related to perceived high riskiness and low profitability of EI investments.

As far as the remaining explanatory variables are concerned, our results are generally in line with previous findings of the literature. Firms assigning a high value to the market demand for green products are more likely to invest in EI (*DEMAND* positive and significant), in line with Kammerer (2009).

Higher turnover increases the probability to invest in EI: having low economic performance significantly decreases the likelihood to adopt EI (the coefficient of *TURNLOW* is negative and significant).

The presence of technological and managerial capabilities within the firm (*INT_KNOW*) surprisingly do not seem to affect EI investments, while the presence of external knowledge sourcing (*EXT_KNOW*) is positive and significant, confirming that an “open eco-innovation mode” allows overcoming the complexity of the knowledge required for EI (Ghisetti et al. 2015).

Current regulations are not relevant for EI investments. Though, in principle, the regulatory framework pushes and pulls EI’s uptake, empirical analyses – mainly cross sectional ones as the current study – often fail in finding a significant effect, as discussed in Ghisetti and Pontoni (2015).

5. Conclusions

This paper enriches the literature on firms’ behaviour towards environmental practices by focusing on financial constraints and EI investments.

According to our empirical investigation, the existence of financial barriers, namely difficulties in access to external sources of funding, constitute a serious deterrent for the eco-innovative capacity of EU manufacturing SMEs. Indeed, the absence of stable and competitive markets, as well as the lack of a credible institutional context increase uncertainties and risks related to EI investments, reinforcing the strictness of external financing constraints.

This evidence, obtained on very recent (and post downturn) EU data, raises concerns given the relevance of manufacturing SMEs for economic and environmental performances in the EU. If EU has to decarbonize, EI investments should increase. Both public and climate policies should thus draw on the current economic situation of high savings, low interest rates but low investments and direct such excess of liquidity towards EI investments in order to achieve the EU 2030 and 2050 goals.

Increasing public spending on R&D devoted to environmental practices would also be coherent with the Lisbon agenda; by complementing private R&D investments, public policy makers would become ‘market activators’ and ‘investors’, as low interest rates alone are not enough to spur investments. Furthermore, climate policies aimed at reducing emissions should be coherent with such (innovation-oriented) public policies but also with the development of financial markets as well as to their regulations. The recent Prospectus Directive, within the framework of the Capital Market Union and aimed at expanding long-term private funds, venture capital and crowdfunding may be an example of support to SMEs' access to credit. In a nutshell, the financial sector can provide a multiplier effect to the already acknowledged policy induced innovation effect, once the full set of barriers and specificities is understood.

If it is true that "standard" innovations are potentially affected by difficulties in credit access from financial institutions, EI are characterized by an even higher stringency and probability of experiencing external financial constraints, due to their high technical risk, longer time span and larger uncertainty on the appropriability of private rents. Understanding the impact of factors affecting the perception of financial barrier is crucial, because they indirectly affect firms' decisions to invest in EI, thus giving a crucial role to the policy setting.

Changing initial market conditions and expectations in order to decrease the risks of investments in EI could not only directly spur firms' investments, but also increase the availability of external credit opportunities, whose absence constitutes an additional deterrent to EI investments and to the achievement of low-emissions targets. Policies can stimulate green innovations by reversing their risk/return trade-off, or, in other terms, by reducing the perceived risk of EI and making more evident the positive economic returns of their investments. Targeting policy interventions to facilitate access to credit and to mitigate capital market imperfections, especially for the manufacturing sector, is crucial to mitigate the apparent contradiction between EU industrial policies and climate abatement scenarios.

Finally, there is a stimulating effect related to improved market conditions: the removal of technological lock-ins and old technical infrastructures, the increased competitiveness in the market and growing demand for green products can have strong positive, indirect and direct effects in supporting EI investments.

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Table 1. Descriptive statistics of variables

Stats	Description	Mean	Mean EI=0, n=990	Mean EI=1 N=895	SD	min	max
EI	Takes value 1 when, over the last 5 years, the share of innovation investments related to eco-innovation ranges from 10 to more than 50% , 0 *otherwise*.	0.4748	-	-	0.4994	0	1
eFIN	Takes value 1 when the lack of external financing is considered as a *very serious/somewhat serious* barrier, 0 *otherwise*.	0.7379	0.8070	0.6614	0.4398	0	1
UNCERTRETURN	Takes value 1 when uncertain return on investment is considered as a *very serious/somewhat serious* barrier, 0 *otherwise*.	0.7294	0.7494	0.7073	0.4443	0	1
UNCERTDEMAND	Takes value 1 when uncertain demand from the market is considered as a *very serious/somewhat serious* barrier, 0 *otherwise*.	0.7315	0.7404	0.7218	0.4432	0	1
FUT_ENPRICE	Takes value 1 when expected future increases in energy prices are considered as *very important*/*somewhat important* driver, 0 *otherwise*.	0.8811	0.8616	0.9027	0.3236	0	1
FUT_REG	Takes value 1 when expected future regulations imposing new standards are considered as *very important*/*somewhat important* driver, 0 *otherwise*.	0.7549	0.7292	0.7832	0.4302	0	1
SIZE_MEDIUM	Takes value 1 when the number of employees is between 50 and 249, 0 otherwise.	0.2456	0.2111	0.2838	0.4305	0	1
TURNLOW	Takes value 1 when turnover is *lower than 2 million €,* 0 *when higher*.	0.4758	0.5202	0.4268	0.4995	0	1
TEC_LOCK	Takes value 1 when technical and technological lock-ins in economy are considered as a *very serious/somewhat serious* barrier, 0 *otherwise*.	0.5325	0.6171	0.4990	0.4990	0	1
INT_KNOW	Takes value 1 when the presence of managerial or technological capabilities in the firm are considered as *very important*/*somewhat important* driver, 0 *otherwise.*	0.8122	0.7909	0.8357	0.3906	0	1
MARKET	Takes value 1 when market dominated by established enterprises is considered as a *very serious/somewhat serious* barrier, 0 *otherwise*.	0.5506	0.5505	0.4975	0.4975	0	1
DEMAND	Takes value 1 when increasing demand for green products is considered a *very important*/*somewhat important* driver, 0 *otherwise*.	0.7400	0.6959	0.7888	0.4387	0	1
EXT_KNOW	Takes value 1 when access to external information sources and knowledge and collaboration with research institutes and universities are considered as a *very serious/somewhat serious* driver, 0 *otherwise*.	0.8493	0.8222	0.8793	0.3578	0	1
REG	Takes value 1 when existing regulations and standards are considered as a *very important/somewhat important* driver to eco-innovate , 0 *otherwise*.	0.7310	0.7131	0.7508	0.4435	0	1

Table 2. Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	EI	1													
2	eFIN	-0.2763*	1												
3	TEC_LOCK	-0.0870*	0.3093*	1											
4	UNCERTRETURN	-0.0797*	0.3141*	0.3520*	1										
5	UNCERTDEMAND	-0.0353	0.2412*	0.2518*	0.3099*	1									
6	MARKET	0.005	0.2904*	0.3787*	0.3197*	0.3393*	1								
7	SIZE_MEDIUM	0.1439*	-0.2290*	-0.0081	0.0321	-0.1423*	-0.0973*	1							
8	FUT_ENPRICE	0.1306*	0.1790*	0.1318*	0.1917*	0.1156*	0.2615*	0.1254*	1						
9	FUT_REG	0.1076*	0.1691*	0.2551*	0.2000*	0.1818*	0.1872*	0.0569	0.3691*	1					
10	TURNLOW	-0.1464*	0.3182*	0.0837*	0.0390	0.0906*	0.0943*	-0.6496*	0.0510	0.0205	1				
11	INT_KNOW	0.1045*	0.1183*	0.3147*	0.0941*	0.2401*	0.2685*	0.0249	0.3425*	0.3086*	0.0815	1			
12	EXT_KNOW	0.1538*	0.1243*	0.2605*	0.2068*	0.1178*	0.2393*	0.0722	0.4235*	0.3866*	0.0065	0.5436*	1		
13	REG	0.0716	0.1116*	0.1346*	0.1363*	0.1963*	0.1856*	0.0649	0.2843*	0.6183*	-0.0433	0.3695*	0.3598*	1	
14	DEMAND	0.1794*	0.0477	0.1530*	0.1598*	0.1836*	0.2434*	0.0866	0.3277*	0.3655*	-0.0608	0.3054*	0.4156*	0.3067*	1

* reports a correlation significant at a 95% confidence

Table 3: Bivariate probit results

	(1)	(2)
	Equation 1	Average marginal effects
TEC_LOCK	0.3037***	0.0837***
	(0.0694)	(0.0189)
UNCERTRETURN	0.4264***	0.1176***
	(0.0739)	(0.0199)
UNCERTDEMAND	0.1675**	0.0461**
	(0.0740)	(0.0203)
MARKET	0.2233***	0.0616***
	(0.0702)	(0.0192)
SIZE_MEDIUM	-0.3700***	-0.1020***
	(0.0752)	(0.0204)
FUT_ENPRICE	0.1795*	0.0495*
	(0.1030)	(0.0283)
FUT_REG	-0.0297	-0.008
	(0.0793)	(0.0218)
Constant	0.1597	-
	(0.2163)	
	Equation 2	
TURNLOW	-0.1587**	-0.0548**
	(0.0657)	(0.0230)
INT_KNOW	0.1078	-0.0372
	(0.0812)	(0.0279)
EXT_KNOW	0.1850**	0.0639**
	(0.0893)	(0.0307)
REG	0.0783	0.0271
	(0.0690)	(0.0238)
DEMAND	0.2559***	0.0884***
	(0.0707)	(0.0244)
eFIN	-1.0218***	-0.3643***
	(0.2307)	(0.0735)
Constant	0.0124	-
	(0.2584)	
Rho	0.3551	
	(0.1488)	
N	1885	
McFadden's adjusted R^2	0.093	
Log Likelihood	-2129.84	
Wald test of rho=0:		
Chi R^2	4.75187	
p-value	0.0293	
Country dummies	Included	

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$