SEEDS

Sustainability Environmental Economics
and Dynamics Studies

Working Paper Series

Do financial constraints make the environment worse off?
Understanding the effects of financial barriers on environmental
innovations

by

Claudia Ghisetti, Massimiliano Mazzanti, Susanna Mancinelli, Mariangela Zoli

1/2015

SEEDS is an interuniversity research centre. It develops research and higher education projects in the fields of ecological and environmental economics, with a special focus on the role of policy and innovation. Main fields of action are environmental policy, economics of innovation, energy economics and policy, economic evaluation by stated preference techniques, waste management and policy, climate change and development.

Do financial constraints make the environment worse off? Understanding the effects of financial barriers on environmental innovations

Claudia Ghisetti•, Massimiliano Mazzanti•, Susanna Mancinelli•, Mariangela Zoli•

Abstract

We analyse the role of financial barriers behind the adoption of environmental innovations with a focus on SMEs by using recent survey data at EU level. Finance is a key lever of innovation, especially relevant in the current phase of the economic cycle, and might play a critical role in defining green economy directions. Empirical analyses confirm financial barriers as a deterrent for the innovative capacity of EU firms. This is true for the economy as a whole, and for manufacturing firms taken alone. Being smaller and having a low amount of human capital in the firm also hampers environmental innovations . On the 'positive' side, we note that existing regulations and expected increasing demand for green products both support EI adoption. Financial barriers are perceived by firms and influenced by technological lock-ins, uncertainty in investments, non-competitive markets, and a lack of subsidies. We observe that the 'deterrent barrier hypothesis', alternative to the 'revealed barrier hypothesis', is not rejected here, as in recent analyses of traditional innovations: perceived financial constraints deter innovative strategies.

• Department of Economics and Management, University of Ferrara

• Department of Economics and Finance, University of Rome Tor Vergata

1. Introduction

The transition to a green economy passes through structural/composition effects and innovation, which also encompasses the different role of sectors and their relationships (Cainelli et al., 2012; Cainelli and Mazzanti, 2013; Corradini et al., 2014). Among sectors, finance and banking play a peculiar role since they may curb or drive the economy through the massive allocation of money. This is even more relevant in the current EU situation which is characterized by a liquidity trap risk: very low or even negative real interest rates, with harmful credit crunch in place. In this context, expectations on future growth matter to turn low interest rates into investments.

Even though considerable progress has been made in latest years in greening the economy (see World Economic Forum, 2013), the scale of green investments continues to be inadequate. The amount of financial investments needed globally to achieve a low carbon (LC) economy is enormous: estimates, which differ on the basis of the variables included in the analysis, range from USD 300-400 billion per year for 2010–2020 for reducing greenhouse gas emissions, with additional investments of 9.3 trillion between 2010 and 2050 for de-carbonizing the power sector, to USD 15-20 trillion for replacing existing fossil fuel and nuclear power infrastructure (EEA, 2014; p.77). In the European Union, the European Commission estimates that investments for the transition to a LC scenario would require an increase in public and private sources averaging around €270 billion a year over the coming 40 years. This represents an additional investment of around 1.5% of EU GDP per annum, on top of overall current investment representing 19% of GDP in 2009.

In view of these needs, there is a potential huge mass of liquidity that might be allocated to foster the LC economy in current and future years, through many different channels. Even though the public sector remains a crucial provider, an increasing role is expected to be played by private actors[1], as well as by hybrid solutions (mix of public and private lending through public-private partnerships, or other types of hybrid instruments, such as green bonds or project bond initiative, EEA, 2014).

The availability of financial resources is especially relevant to stimulate the adoption of environmental innovations (EI)[2], which, though being an essential force to drive economic growth while reducing greenhouse gas emissions and natural resource use, are still mildly diffused in many countries (see EEA, 2014). Schumpeter stressed the fundamental role played by finance in fostering innovation, defining banks credit as the 'monetary complement' of innovation, and entrusting banks the task of selecting 'in the name of society' the people authorized to innovate (Schumpeter, 1912, in Caiani et al., 2014).

---

[1] According to UNEP estimates, private capital sources are expected to supply 80% of the financial investments required for the transition to a LC economy (UNEP, 2013, 2011).

[2] We refer to environmental innovation (EI) as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives" (Kemp and Pearson, 2007: p.9). This is a consolidated definition, at least in the EU, which refers to EI adoption and diffusion.

The role played by finance and banking in boosting EI is perhaps even more relevant than for traditional innovations, even though the literature on EI adoptions has not touched upon it with sufficient depth and breadth. In this article, we take stock of the consolidated literature on EI and explore the issue of financial drivers/barriers for EI adoption, with a specific interest in manufacturing SMEs[3] organizations. We first investigate the main determinants of the entrepreneurs' perception of the stringency of financial constraints; as a second step, we analyse the impact of different factors that may facilitate or hamper firms' choices to eco-innovate, including the role of financial barriers. By considering that several factors that affect financial barriers may also affect firms' adoption of EI, we account for potential endogeneity of financial constraints and potential indirect effects. Our empirical investigation is based on data drawn from the 2011 Flash Eurobarometer Survey on Attitudes of European Entrepreneurs Towards Eco-innovation (315), representative for EU27 countries.

The article is organized as follows. Section 2 introduces some conceptual issues that are crucial to examine the relation between EI and financial barriers, while Section 3 presents the theoretical framework and lays out the main research hypotheses to be tested empirically. Section 4 describes the data and the empirical model, and Section 5 discusses estimation results.

2. Environmental innovations and financial constraints: some conceptual issues

EI 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). They are fundamental drivers for achieving the policy target of improving environmental performances, without giving up competitiveness. EI have also a central role for generating new job opportunities, as the new products or production processes can have the side-effect of boosting productivity, growth and reducing production costs.

EI, however, imply costly investments and risky returns, and the existence of financial constraints or difficulties in finding credit opportunities may reduce firms' possibilities to develop EI, even more than they do for other types of innovations. This is due to some peculiarities EI exhibit with respect to standard innovations, that motivate their investigation. There are at least three main conceptual issues that are worth highlighting.

One is adverse selection. Since investments in EI are characterised by high expected return and potential profitability, but also by high riskiness, problems of credit rationing may arise. Economic theory about imperfect information and adverse selection[4] suggests that in the presence of a high demand for credit, the banking system may prefer not to increase its interest rates, since high interest rates could attract only high-risk investments. In fact, this kind of investment is also

---

[3] It is worth noting that SMEs react with more difficulty, some of them 'exploiting' the challenge of financial barriers and (environmental) policies by turning costs into enhanced innovative and economic performances, others failing to innovate. Though this is a typical evolution of the economic cycle which depends upon firms' creation and destruction, policy makers should be aware of the possible increasing divergences between sectors, firms and regions in the EU.

[4] See, for instance, Stiglitz and Weiss (1981).

one that, if successful, gives investors such profit margins to offset the costs due to high interest rates. On the other hand, these investments may also increase the bank's costs due to their probability of default. Hence, in the presence of a high demand from the market, banks may find a credit rationing more profitable than an increase in interest rates. In the case of green investments, a similar situation may occur. Since investments in EI are expected to grow more and be more profitable than other more consolidated benchmarks, but are also more risky, due to initial market volatility and policy uncertainty, than other kinds of investment in innovation, banks could prefer to ration credit towards green investments, instead of asking higher interest rates on them, especially if they don't feel sufficiently protected by well designed, credible and stable environmental and fiscal policies. Following this reasoning, it might not be surprising to observe more financial constraints on more risky investments in EI, such as the ones related to CO_2 reduction. The second issue is complementarity among innovations. The strategy of investing in diverse innovations (process, product, marketing, organisational innovations, human resource management as well, etc..) is costly for firms, but can produce increasing returns to scale. The integration of different innovation strategies may deliver irreproducible returns, which have often characterised the competitiveness of SMEs. Financial support given to innovations should recognise the intangible value of complementarity among innovation practices (in the form of higher economic and environmental effects), especially by considering that the multiple adoption of innovation can be constrained by credit limits, especially for SMEs. The third issue of relevance is that there is long-term discounting of LC investments. Financial markets usually operate under high opportunity costs determined by the return of invested capital. A market discounting of 10-15% shrinks the time dimension within a period definable as short-term for environmental targets and EI related returns. Over at least 10-20 years, the present value difference determined by 10% or 2-3% social discount rates is considerable.

But there are other reasons behind short-termism in financial markets. Green investments are generally perceived as more risky; eco-investments tend to have a higher perceived risk for potential investors when compared with fossil-based investments for several reasons (Kapoor and Oksnes, 2011). First, in several cases, LC technologies are still in an early stage of development, and uncertainties related to their durability, performance, etc., contribute to increasing their higher perceived risk; further, they often have high capital costs, making their payback period longer than for many dirty investments (WEF, 2013). On the contrary, the perception of risk for dirty investments is still too low. This is mainly due to carbon prices, which are excessively low, as well as uncertain and volatile. As a consequence, the private return of LC investments continues to be lower than the return of fossil fuel-based investments, leading to excessively high (and inefficient) investments allocated towards high carbon (HC) alternatives. It is more profitable, then, to continue to rely on dirty energy infrastructure than to make new EI, or to change energy use patterns and make efficiency investments.

However, we can expect the risk/return trade-off between LC and HC investments to be reversed in the near future. This may happen through the increase of the prices for GHG emissions, which are relatively low at present, but expected to increase significantly[5], and increases in fossil fuel prices and their volatility as well. Further, it cannot be excluded that government requirements

---

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

could become stricter and that certain polluting technologies could be banned in the future. In other words, there is the possibility that a company currently adopting HC technologies will be not allowed to use them, or that permits to produce/emit will be withdrawn because the company's environmental impact does not fulfil the new, stricter requirements.

Another risk that is generally not accounted for by investors is represented by climate changes that result from the increased GHG effect, in terms of both the impact of catastrophic events on firms' physical assets and the impact that stricter climate regulations may have on producers' activities. It is clear that all previous types of risks concur to reduce the value of the investments financed by banks and credit institutions, increasing HC companies' environmental risks and translating into new credit risks for financial institutions (the so-called "indirect risks" for banks, i.e. financial risks deriving from the client's continuity problems caused, for instance, by changing environmental regulations and changing market conditions; Jeucken, 2004).

Strictly related to the previous argument, it is clear that when financial institutions tend to privilege short-term goals in their lending operations and financial transactions, they indirectly discourage EI. Companies and financial institutions continue to underestimate the consequences of the introduction of more stringent climate regulations, increases in carbon prices and penalties for GHG emissions, in terms of the investments' risk/return trade-off. Accordingly, they continue to provide credit to polluting investments that are currently profitable but exposed to serious risks due to all considerations made above. This short termism in financial markets is one of the main factors that deter financial institutions from providing credit to environmentally innovative projects.

3. Theoretical background and research hypotheses

Firms' investments in EI may be seriously hampered by the existence of financial and credit constraints; the strictness of these constraints in turn depends on several factors that can affect the perception of the risk/return trade-off which characterizes EI. In order to investigate the effect of financial barriers on the adoption of EI by firms, we first start reviewing the main factors that can have a role in determining the stringency of financial constraints; secondly, we identify, in the relevant literature, the main determinants of firms' decisions about EI development, besides financial constraints.

3.1 Financial barriers to environmental innovations: the main determinants of financial constraints

Innovation literature has devoted much attention to the impact of barriers of a financial nature on firms' likelihood to undertake innovations (e.g. Hall, 2002; Savignac, 2008; Mancusi and Vezzulli, 2010; Hottenrott and Peters, 2012, among others). Such literature highlights 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). Still lacking to our knowledge is an extension of this literature to the role played by financial barriers on

a peculiar typology of innovation, environmental innovations (EI), that have been defined as "special" kind of innovations (Rennings, 2000) and whose related literature has demonstrated some peculiarities in their nature, drivers and determinants (De Marchi, 2012; Horbach et al. 2012).

Given the relevance of financial constraints as obstacles to the development of EI, in this Section we identify factors that can affect financial institutions' decisions to grant credit to eco-innovative firms, or, in other terms, the main determinants of financial constraints to EI. This is relevant because these elements, by affecting the firm's probability of experiencing liquidity constraints, can be an indirect source of barriers to the diffusion of EI practices among firms.

It is worth noting that financial constraints are not only relevant for those green investments which currently have a negative net present value, and need additional funds from governments in the form of public subsidies or tax credits to become competitive. Constraints are also relevant for green investments which have a positive net present value so that in principle they do not need public subsidies. In this case, investments can be self-financing in the long run, but as they often entail higher upfront costs compared to traditional investments, they are perceived as more risky than conventional ones (Kapoor and Oksnes, 2011).

Building on the literature reviewed in Section 2, we can identify a set of factors that can contribute to explaining why financial institutions provide insufficient credit to EI. All of these factors operate by affecting the risk/return trade-off between investments in green technologies and investments in dirty projects, contributing to increasing the riskiness/decreasing the profitability of EI compared to conventional ones.

A first factor is represented by the 'current regulatory context': existing regulations not providing incentives to eco-innovate, the existence of perverse incentives for carbon-intensive technologies (e.g. fossil-fuel subsidies[6]) as well as the removal of incentives for clean energy production have the effect of preventing investments in EI from gaining competitive advantage. The lack of a consistent and predictable policy framework is also responsible for increased uncertainties in eco-investment profitability and results in new financial risks. An example in this respect is represented by financial incentives (e.g. credits and fixed prices) offered to stimulate investment in renewables. 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[7].

Secondly, by considering that EI generally have higher costs at the outset than conventional alternatives and that, on the other hand, the currently low prices of carbon and energy still make investments in traditional innovation more profitable, it can be easily understood why financial actors (banks as well as capital markets) continue to provide credit to conventional investments with short payback periods, and under-finance green alternatives with a longer payback horizon. This short-termism of financial institutions implies that energy intensive investments continue to be

---

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

granted credit, even though they are exposed to serious downside risks in the long-term due, for instance, to expected increases in energy/carbon prices and more stringent regulations and standards on carbon emissions.

Another factor that may contribute to explain restrictions in credit provision is represented by prevailing 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.

We can therefore formulate the following research hypothesis:

Hypothesis 1 (firms' perception of the stringency of financial constraints): *Existing regulations and the lack of financial incentives to EI, market conditions characterized by dominating firms and technological lock-ins, as well as the adoption of short-term perspective in finance concur to increase firms' perception of the stringency of financial constraints as a barrier to EI. On the contrary, it can be expected that future increases in energy prices and stricter carbon regulations will relax financial constraints by increasing the relative profitability of EI.*

3.2 Other barriers to EI adoption

In this Section, we elaborate on those elements that may facilitate or hamper a firm's choices to adopt EI, i.e. the factors correlated with EI. Previous contributions have mainly aimed at understanding the drivers of EI (e.g. Brunnermeier and Cohen, 2003; Horbach et al., 2012; Cainelli et al., 2012) and their economic implications (e.g. Cainelli et al., 2013; Hart and Ahuja, 1996).

Since Rennings's (2000) contribution, the unique features of EI with respect to standard innovations have been outlined and refined. A key fact is that EI are characterised as having a "double externality" nature: on the one hand, they reduce negative environmental externalities and, on the other hand, they are themselves subject to externalities, which are driven by knowledge spillovers that could potentially lead to sub-optimal investments. Further, EI are characterized by the 'regulatory push-pull effect', as they are strongly regulation driven, and regulation might act both on the supply (push) and on the demand side (pull) (Cleff and Rennings 1999; Rennings and Rammer 2009). Finally, EI adoption depends on social and institutional innovations as well (Rennings 2000).

Given these specificities, the literature on EI has mainly focused on four clusters of determinants (Horbach et al., 2012): "Market-pull", including turnover expectations, new demand for eco-products, past economic performances and customer benefits; "Technology-push", related to firms technological and organizational capabilities; "Firm specific factors", such as sector, location, size, mainly captured by the number of employees (Horbach, 2008), as well as market conditions, i.e. the structure of the market, the existing demand for green products or past economic

performance (Rehfeld et al., 2007); and "Regulation". Specifically much literature on EI determinants highlights the core role of regulation in spurring EI adoption (Brunnermeier and Cohen, 2003; Veugelers, 2012, among others): regulation may affect EI investments both indirectly, by providing fiscal incentives and public subsidies, and directly, by imposing technological standards and limits to emissions. Nevertheless, a number of elements - e.g. strictness, enforcement, predictability, sectoral differences, credibility of the commitment to standards, and combination with other policies – have made this regulatory push difficult to be measured and estimated (Kemp and Pontoglio, 2010). Further, empirical findings show a not unequivocal role played by policy intervention (e.g. Cuerva et al 2014; Jaffe and Palmer 1997; Ghisetti and Quatraro 2013)

Besides market conditions, also technological knowledge might spur EI adoption, and thus behave as EI determinant. This may be available within the boundaries of the firm or can be acquired from outside firms' boundaries. Relying upon external knowledge sourcing is indeed a relevant driver both for standard innovations (Laursen and Salter, 2006) and for EI (De Marchi, 2012; Ghisetti et al., 2015). In particular, the complexity and the multiplicity of capabilities required by EI (e.g. technological, organization and institutional) make the eco-innovator even more reliant on numerous, external knowledge sources and on repeated interaction over time.

While the recent literature has widely investigated the drivers of EI, very few contributions have explored the role of barriers to EI, contrary to the literature on "standard" technological innovation, which has explored both the determinants that affect the perception of barriers and the impact of barriers on innovation propensity and intensity (Iammarino et al., 2009; D'Este et al., 2012). Among the few contributions in the EI field, Foxon and Pearson (2008) borrow from the literature on systems of innovation some categories of 'system failures', i.e. failure in infrastructure provision and investment, transition failure, lock-in failures and institutional failures, but do not consider within-firm barriers. On the contrary, Marin et al. (2014) consider a wide set of potential obstacles to the EI activities of firms, and propose a taxonomy of EU SMEs identifying six clusters based on the combination of different types of perceived barriers (cost, market, knowledge) and the declared engagement in EI investment. However, they do not focus on the role that perceived financial barriers can have in deterring the eco-innovative decisions by firms. In this work, we also focus on barriers rather than drivers to EI, but, differently from previous work, we investigate specifically the impact of financial constraints.

We can now formulate our second research hypothesis:

Hypothesis 2 (Financial constraints and EI): *Once we control for the main EI determinants, we still expect that financial constraints are a relevant barrier to EI adoption.*

In other words, we expect financial constraints to prevent EI adoption also when we control for a set of non-financial barriers suggested by the literature reviewed in this Section.

4. Data and Empirical Model

We ground our empirical analysis on the 2011 Flash Eurobarometer Survey number 315 on Attitudes of European Entrepreneurs Towards Eco-innovation[8]. It is representative for EU27 countries and refers to Small (10-49 employees) and Medium (50-249 employees) Enterprises (SMEs) in the following sectors: Agriculture, Manufacturing, Water supply and waste management, Construction and Food services. Given their innovation potential and their environmental pressure we have chosen to focus on manufacturing firms and, as a robustness test, on all sectors. Data were collected in January 2011 by the Gallup Organisation for the DG Communication Public Opinion Analysis Sector of the European Commission.

The use of this survey gives us the opportunity to focus on a direct measure that captures innovations which have actually been adopted by firms, instead of an indirect measure, such as patent data, which only counts inventions. EI is defined in the survey 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 resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle of the product'. Specifically, respondents are asked whether in the previous 24 months their firm has introduced any EI that fits this definition. We consequently built a variable *EI* as a dummy equal to one when at least one EI has been introduced by the firm in the previous 24 months and to zero otherwise.

The financial barrier variable (*eFIN*) was extracted from a question asking firms to report, on a scale ranging from 1 (not relevant) to 4 (relevant), how strongly they perceive the lack of external financing as an obstacle to accelerated eco-innovation uptake (for a detailed description of variables see Table 1).

These two variables have been used to understand if and how weak access to financial resources constitutes a barrier for the development of EI, through a two-stage procedure. A two-step structural model is necessary given the potential endogeneity of those variables that jointly determine both the lack of financial barriers and the likelihood to adopt an EI. Further, variables that are significant in explaining firms' attitude to EI can have also an indirect effect by influencing the stringency of financial constraints. Given the binary nature of the two dependent variables, both models are estimated through Logit regressions in a cross-section environment.

At the first stage, we model what determines entrepreneurs' perceptions of the stringency of external financing as a barrier to EI, coherently with our Hypothesis 1:

$$eFIN = \alpha + \beta 0 TEC\_LOCK + \beta 1 UNCERTRETURN + \beta 2 UNCERTDEMAND + \beta 3 MARKET + \beta 4 \, REG + \beta 5 INC + \beta 6 \, FUT\_ENPRICE + \beta 6 \, FUT\_REG + \delta dstate* + \gamma size* + \epsilon$$

(1)

In Eq.(1), the 'perception of financial barriers' depends on the existence of technological lock-ins (*TEC_LOCK*), of uncertainties related to market demand (*UNCERTDEMAND*) and return

---

of the investment (*UNCERTRETURN*), on market conditions, such as the presence of established enterprises that dominate the market (*MARKET*), as well as on the regulatory framework, mainly existing rules and structures (*REG*) and the lack of incentives for EI (*INC*). Further, we suppose that even expectations about future increases in energy prices (*FUT_ENPRICE*) and in the regulatory stringency (*FUT_REG*) may affect the seriousness of the financial barrier. We control for country fixed effects by including country dummies (*dstate*) and for the size of the firms in terms of number of employees (*size*).

We then exploit the *predicted values* for *eFIN* to explain the likelihood of introducing any EI, by considering also a set of other, non-financial factors that have been acknowledged by the literature to strongly affect innovation activities, in line with our Hypothesis 2:

EI= α+ β1eFIN + β2MARKET + β3 DEMAND + β4EXT_KNOW + β5 INT_KNOW + β6 REG + β7 INC + β8 TURNLOW + δdstate* + γsize* + ϵ

(2)

In Eq.(2), the probability of introducing EI is supposed to be affected by existing market conditions (*MARKET*) and market demand for green products (*DEMAND*), as well as access to knowledge, defined both as presence of technological and management capabilities within the enterprise (*INT_KNOW*) and access to information and external knowledge sources, not only from business partners but also from universities or research institutes (*EXT_KNOW*). The regulatory framework, that is supposed to affect EI also directly, and not only through the availability of financial resources, is captured again by *REG* and *INC*. Finally, we include firm specific characteristics such as their turnover, which can be lower than 2 million € or larger (*TURNLOW*). As for Eq.(1), we control for country fixed effects and for firm size.

To account for the different perceptions of barriers to innovation that arise between innovative and non-innovative firms, we follow Pellegrino and Savona (2013[9]); Eq. (1) and (2) are estimated on a "filtered" sample of firms, where firms 'that do not innovate and do not perceive any financial barrier' are excluded by the analysis. This is justified by considering that barriers to innovation are perceived as stronger for firms which are actually innovating (Mohen and Roeller, 2005), and that obstacles to innovation should be more properly interpreted as a measure of how firms are able to overcome them rather than as 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' barriers: in the first case barriers negatively impact on innovation, while in the second case a positive effect is ascertainable: firms overcome the barrier and innovate.

The tetrachoric correlation matrix among variables is shown in Table 2.

---

[9] Pellegrino and Savona (2013) outlined a potential bias in estimating the role of barriers to innovation on a whole sample of innovative and non-innovative firms.

Table 1. Descriptive statistics of variables

Stats	Description	N	Mean	SD	min	max
EI	Takes value 1 when at least one EI has been introduced by the firm in the previous 24 months, 0 otherwise.	2526	0.4592	0.4984	0	1
eFIN	Takes value 1 when the lack of external financing is perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.5507	0.4975	0	1
UNCERTRETURN	Takes value 1 when uncertain return on investment is perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.6667	0.4715	0	1
UNCERTDEMAND	Takes value 1 when uncertain demand from the market is perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.6706	0.4701	0	1
FUT_ENPRICE	Takes value 1 when expected future increases in energy prices are perceived as *very important/somewhat important* driver, 0 *otherwise*.	2526	0.8432	0.3637	0	1
FUT_REG	Takes value 1 when expected future regulations imposing new standards are perceived as *very important/somewhat important* driver, 0 *otherwise*.	2526	0.7146	0.4517	0	1
SIZE_SMALL	Takes value 1 when the number of employees is between 10 and 49, 0 otherwise.	2526	0.7652	0.4239	0	1
SIZE_MEDIUM	Takes value 1 when the number of employees is between 50 and 249, 0 otherwise.	2526	0.2348	0.4239	0	1
TURNLOW	Takes value 1 when turnover is *lower than 2 million €,* 0 *when higher*.	2526	0.4790	0.4997	0	1
TEC_LOCK	Takes value 1 when technical and technological lock-ins in economy are perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.5325	0.4990	0	1
INT_KNOW	Takes value 1 when the lack of qualified personnel or technological capabilities in the firm is perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.5103	0.4999	0	1
MARKET	Takes value 1 when market dominated by established enterprises is perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.4964	0.5001	0	1
DEMAND	Takes value 1 when increasing demand for green products is perceived a *very important/somewhat important* driver, 0 *otherwise*.	2526	0.6777	0.4674	0	1
EXT_KNOW	Takes value 1 when limited access to external information and knowledge and lack of collaboration with research institutes and universities are perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.5348	0.4989	0	1
REG	Takes value 1 when existing regulations and structures not providing incentives to eco-innovate are perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.5891	0.4921	0	1
INC	Takes value 1 when insufficient access to existing subsidies and fiscal incentives is perceived as a *very serious/somewhat serious* barrier, 0 *otherwise*.	2526	0.5950	0.4909	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	0.0686*	1												
3	TEC_LOCK	0.0636*	0.3874*	1											
4	UNCERTRETURN	0.1089*	0.4130*	0.4393*	1										
5	UNCERTDEMAND	0.0940*	0.3655*	0.3339*	0.3912*	1									
6	SIZE_MEDIUM	0.2172*	-0.1022*	0.0625	0.0596	-0.0867*	1								
7	TURNLOW	-0.2326*	0.1841*	0.0692*	0.031	0.0674*	-0.6597*	1							
8	MARKET	0.0628*	0.3616*	0.3919*	0.3800*	0.4025*	-0.0820*	0.1052*	1						
9	EXT_KNOW	0.1018*	0.4303*	0.4569*	0.4564*	0.3130*	-0.0005	0.0471	0.3967*	1					
10	INT_KNOW	0.0077	0.3207*	0.3811*	0.2953*	0.2779*	-0.0343	0.0909*	0.3299*	0.4780*	1				
11	INC	0.1203*	0.5595*	0.3672*	0.4427*	0.3436*	0.0005	0.1357*	0.3607*	0.5085*	0.3099*	1			
12	REG	0.0940*	0.4115*	0.3825*	0.4637*	0.3378*	-0.0044	0.0976*	0.3605*	0.4532*	0.2885*	0.5115*	1		
13	FUT_REG	0.1062*	0.2605*	0.3299*	0.2698*	0.2467*	0.0703	0.0274	0.2694*	0.2984*	0.2088*	0.2862*	0.6520*	1	
14	FUT_ENPRICE	0.1798*	0.3107*	0.2336*	0.2775*	0.2483*	0.0943*	0.0526	0.3423*	0.2495*	0.2929*	0.3137*	0.3856*	0.4398*	1

5.   **Discussion of econometric results**

We now move to a description of our results: Table 3 outlines the results of the first step (Eq. (1)) and Table 4 those of the second step (Eq. (2)). In both Tables (3 and 4), Column (1) reports results for manufacturing firms and Column (2) those on all sectors[10].

On the basis of our estimations, the 'first part' of Hypothesis 1 cannot be rejected: as expected, the existence of regulations and structures not providing incentives to eco-innovate as well as insufficient access to subsidies and fiscal incentives increase firms' perception of the stringency of financial constraints as a barrier to EI. Similarly, the presence of established enterprises that dominate the market and of technical/technological lock-ins, such as old technical infrastructures, may restrict firms' access to credit, worsening the perception of the barrier. External credit opportunities are perceived as more difficult also when the return on the investment in EI is perceived as uncertain or the payback period as too long, confirming the presumption that short-termism of financial institutions can be a strong determinant of the perceived stringency of the lack of funding.

On the contrary, expectations about future increases in energy prices and about stricter future regulations imposing new standards are not significant in explaining financial barriers for firms that eco-innovate: these factors are still not perceived as serious risks for both entrepreneurs and financial institutions. Uncertain demand does not affect EI decisions of manufacturing firms but it turns out to be significant for the whole sample; this different result may reflect the existence of sector specificities to this respect and deserves further investigation. Finally, and most importantly, smaller firms are more likely to perceive external financial constraints as strong barriers compared to medium firms, confirming that small firms have to face major difficulties in getting credit for their innovative activities compared to large firms that often access equity and long term loans, and possess more developed 'eco-literacy' (Hoogendoorn et al., 2014).

Moving to H2 and Table 4, evidence suggests that financial barriers have a negative and significant impact on decisions about EI adoption, both for manufacturing firms and for the whole sample. This strongly supports Hypothesis 2, highlighting the need of relaxing the strictness of financial constraints in order to spur EI adoption by firms.

As far as the remaining explanatory variables are concerned, we note that medium sized firms are more likely to adopt EI, but only with respect to the whole sample. This is compatible with a Schumpeter Mark II scenario (Schumpeter, 1942). Higher turnover increases the probability to adopt EI. For manufacturing firms, environmental innovativeness does not seem to be related to the size of the firm in terms of employees, even though having low economic performance significantly decreases the likelihood to adopt EI (the coefficient of *TURNLOW* is negative and significant). In this case, we can also note that firms' dimension and turnover have both a direct and indirect effect on the probability of developing EI, through the financial barrier constraint.

---

[10] We must stress that the nature of the dataset we are exploiting only allows us to comment on correlations among variables rather than causations.

Table 3: Results on Equation (1)		
	(1) Manufacturing firms	(2) All firms
TEC_LOCK	0.4145***	0.3343***
	(0.1240)	(0.0923)
UNCERTRETURN	0.5361***	0.5069***
	(0.1331)	(0.0974)
UNCERTDEMAND	0.1736	0.2268**
	(0.1327)	(0.0970)
MARKET	0.3212**	0.2798***
	(0.1257)	(0.0922)
SIZE_MEDIUM	-0.6494***	-0.5316***
	(0.1325)	(0.1010)
REG	0.2314*	0.2748***
	(0.1281)	(0.0948)
INC	0.9608***	0.8532***
	(0.1248)	(0.0932)
FUT_ENPRICE	0.2821	0.1582
	(0.1816)	(0.1321)
FUT_REG	-0.0561	-0.0793
	(0.1376)	(0.1042)
Constant	-0.3649	-0.3589
	(0.3806)	(0.3254)
N	1878	3506
pseudo R^2	0.177	0.158
D State	Included	Included
D Sector	No	Included
D State	Included	Included
AIC	1850.1681	3385.9614
BIC	2043.9968	3632.4506

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

Table 4: Results on Equation (2)		
	(1) Manufacturing firms	(2) All firms
$\widehat{eFIN}$	-1.6624**	-1.5523***
	(0.7556)	(0.5900)
SIZE_MEDIUM	0.2198	0.2271**
	(0.1555)	(0.1120)
TURNLOW	-0.6000***	-0.5116***
	(0.1186)	(0.0849)
MARKET	-0.1121	-0.0918
	(0.1209)	(0.0859)
INT_KNOW	-0.3093***	-0.1743**
	(0.1090)	(0.0777)
EXT_KNOW	-0.0689	-0.0784
	(0.1174)	(0.0848)
DEMAND	0.3611***	0.4116***
	(0.1196)	(0.0867)
REG	0.0194	0.0632
	(0.1257)	(0.0928)
INC	-0.0450	-0.0451
	(0.1834)	(0.1335)
Constant	1.8037***	1.4349***
	(0.5293)	(0.4204)
N	1878	3506
pseudo R^2	0.086	0.062
D State	Included	Included
D Sector	No	Included
D State	Included	Included
AIC	2357.9304	4512.5880
BIC	2551.7591	4759.0772

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

Market conditions only partially affect EI adoption: the existence of established firms that dominate the market does not play any significant direct effect on EI (even though the indirect effect through *eFIN* may be relevant), while a higher market demand for green products (*DEMAND*) positively affect the probability of adopting EI.

Current regulations not providing incentives to eco-innovate and insufficient access to incentives are not a significant direct barrier to EI; this is coherent with some previous findings (as explained in Section 3.2) and can be related to the fact that the policy instruments here are general and not specific (e.g. Borghesi et al., 2014). Future works may contribute to investigate the

(complementary) effect of financial barriers and specific policy tools (taxes, subsidies, emission trading).

Technological know-how can help to determine EI as well: the lack of internal knowledge and capabilities is a factor that hampers EI adoption, while the lack of external knowledge sourcing does not seem to play any significant role in this context.

6. Conclusions

We enriched the literature on firms behaviour towards environmental practices by focusing on financial issues and eco innovation adoption. According to our two stages empirical investigation, the perception of financial barriers is a deterrent for the eco-innovative capacity of EU firms. This is true for the economy as a whole, and for manufacturing firms taken alone. Being smaller and having a low amount of human capital within the firm also hamper environmental innovations. Further, even though the lack of proper regulations stimulating EI through the provision of incentives and tax credits does not seem to affect firms' propensity to eco-innovate, they may have an indirect negative effect, acting through the increased strictness of financial constraints. We do highlight the necessity of assessing and understanding direct and indirect effects. This extends the policy reasoning around firm's environmental practices.

The main policy implication from this is that policy interventions mitigating imperfections in capital market and facilitating firms' access to credit could spur the adoption of EI anyway. In other words, properly designed policies can stimulate financial institutions to grant credit for green investments, by reversing their risk/return trade-off, and as a consequence reduce the risk perceived by firms, or they can help firms in seeing the positive economic returns of their investment. Financial support to environmental innovations is specifically crucial to set the pre-condition to integrate short term (2020) and medium term (2030) environmental targets. Targeting manufacturing financial conditions is additionally relevant to mitigate the trade-off between EU remanufacturing strategies and climate change abatement scenarios.

Another interesting policy suggestion is provided by the stimulating effect that can be related to improved market conditions: the removal of technological lock-ins and old technical infrastructures, increasing competitiveness in the market and growing demand for green products can have strong positive effects in supporting EI adoption, especially favouring SMEs. All these factors will in turn help reaching the broader policy target of improving Europe's environmental performances without giving up its competitiveness, highly centred on SMEs' role, as the Europe 2020 Strategy puts forth.

References

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P. (2005) Competition and Innovation: An Inverted-U Relationship. *Quarterly Journal of Economics* 120(2), 701-728.

Baldwin, J. and Lin, Z. (2002) Impediments to Advanced Technology Adoption for Canadian Manufacturers. *Research Policy* 31, 1–18.

Borghesi, S., Cainelli, G., and Mazzanti, M. (2014), Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry. *Research Policy*, in press

Brunnermeier, S. and Cohen, M. (2003) Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management* 45, 278–293.

Caiani, A., Godin, A., and Lucarelli, S. (2014) Innovation and finance: a stock flow consistent analysis of great surges of development. *Journal of Evolutionary Economics* 24(2), 421–448.

Cainelli, G., and Mazzanti, M. (2013) Environmental innovations in services: integration and policy transmissions. *Research Policy* 42(9), 1595-1604.

Cainelli, G., Mazzanti, M., and Montresor, S. (2012) Environmental Innovations, Local Networks and Internationalization. *Industry and Innovation* 19(8), 697–734.

Cainelli, G., Mazzanti, M. and Zoboli, R. (2013) Environmental performance, manufacturing sectors and firm growth: structural factors and dynamic relationships. *Environmental Economics and Policy Studies* 15, 367-387

Canepa, A., and Stoneman, P. (2007) Financial constraints to innovation in the UK: evidence from CIS2 and CIS3. *Oxford Economic Papers* 60, 711–730.

Cleff, T., and Rennings, K. (1999) Determinants of environmental product and process innovation. *European Environment* 9, 191–201.

Corradini, M., Costantini, V., Mancinelli, S., Mazzanti, M. (2014) Unveiling the dynamic relation between R&D and emission abatement, *Ecological Economics* 102, pp. 48-59

Cuerva, M.C., Triguero-Cano, Á. & Córcoles, D., 2014. Drivers of green and non-green innovation: empirical evidence in Low-Tech SMEs. Journal of Cleaner Production, 68, pp.104–113.

D'Este, P., Iammarino, S., Savona, M., and von Tunzelmann, N. (2012) What hampers innovation ? Revealed barriers versus deterring barriers. *Research Policy* 41(2), 482–488.

De Marchi, V. (2012) Environmental innovation and R and D cooperation : Empirical evidence from Spanish manufacturing firms. *Research Policy* 41(3), 614–623.

EEA (2014) Resource-efficient green economy and EU policies. European Environment Agency Report n 2- 2014, Copenaghen.

Foxon, T. and Pearson, P. (2008) Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime, Journal of Cleaner Production, 16 (1), 148-161.

Ghisetti, C., Marzucchi, A., and Montresor, S. (2015) The open eco-innovation mode. An empirical investigation of eleven European countries. *Research Policy*, forthcoming. Doi: http://dx.doi.org/10.1016/j.respol.2014.12.001

Ghisetti, C. and Quatraro, F., 2013. Beyond inducement in climate change : Does environmental performance spur environmental technologies ? A regional analysis of cross-sectoral differences. Ecological Economics, 96, pp.99–113.

Hall, B. (2002) The assessment: Technology policy. *Oxford Review of Economic Policy* 18(1), 1–9.

Hart, S., and Ahuja, G. (1996) Does it pay to be green? An empirical examination of the relationship between emission reduction and firm performance. *Business Strategy and the Environment* 5, 30–37.

Hoogendoorn, B., Guerra, D., and Van der Zwan, P. (2014), What drives environmental practices of SME's? *Small Business Economics*, in press.

Horbach, J. (2008) Determinants of environmental innovation—new evidence from German panel data sources. *Research Policy*, 37, 163–173.

Horbach, J., Rammer, C., and Rennings, K. (2012) Determinants of eco-innovations by type of environmental impact — The role of regulatory push / pull , technology push and market pull. *Ecological Economics*, 78, 112–122.

Hottenrott, H., and Peters, B. (2012) Innovative capability and financing constraints for innovation: More money, more innovation? *Review of Economics and Statistics* 94(4), 1126–1142.

Iammarino, S., Sanna-Randaccio, F., and Savona, M. (2009) The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. *Revue d'économie industrielle*, 0(1), 75-104.

IEA (2013) World Energy Outlook Special Report, Redrawing the Energy-Climate Map, Paris; France.

Jaffe, A. and Palmer, K., (1997). Environmental regulation and innovation: a panel data study. Review of economics and statistics, 79(4), 610-619.

Jeucken, M. (2004) Sustainability in Finance. Banking on the Planet, Eburon Academic Publishers, The Netherlands.

Kapoor, S. and Oksnes, L. (2011) Funding the Green New Deal: Building a Green Financial System. Green European Foundation. Green New Deal Series Vol. 6.

Kemp, R. and Pearson, P. (2007) Final report MEI project about measuring eco- innovation. European Environment. Retrieved from http://www.oecd.org/env/consumption-innovation/43960830.pdf

Kemp, R. and Pontoglio, S. (2011) The innovation effects of environmental policy instruments - A typical case of the blind men and the elephant? *Ecological Economics* 72, 28–36.

Laursen, K., and Salter, A. (2006) Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal* 27, 131–150.

Mancusi, M.L. and Vezzulli, A. (2010) R&D, Innovation, and Liquidity Constraints, KITeS Working Papers 30/2010, Bocconi University, Milan.

Marin, G., Marzucchi, A., and Zoboli, R. (2014). SMEs and Barriers to Eco-Innovation in EU: A Diverse Palette of Greens. SEEDS Working Paper Series n. 6.

Mohnen, P. and Röller, L. (2005) Complementarities in innovation policy. *European Economic Review* 49, 1431–1450.

Pellegrino, G. and Savona, M. (2013). Financing versus knowledge and demand constraints to innovation. UNU-MERIT Working Paper Series No. 29-2013.

Rehfeld, K.-M., Rennings, K., and Ziegler, A. (2007) Integrated product policy and environmental product innovations: an empirical analysis. *Ecological Economics* 1, 91–100.

Rennings, K. (2000) Redefining innovation—eco-innovation research and the contribution from ecological economics. *Ecological Economics* 32, 319–332.

Rennings, K., and Rammer, C. (2009) Increasing energy and resource efficiency through innovation: an explorative analysis using innovation survey data. *Czech Journal of Economics and Finance* 5, 442–459.

Savignac, F. (2008) Impact of Financial Constraints on Innovation: What Can Be Learned From a Direct Measure? *Economics of Innovation and New Technology*, 17(6), 553–569

Sawin, J. L. (2004) National Policy Instruments. Policy Lessons for the Advancement and Diffusion of Renewable Energy Technologies Around the World. Thematic Background Paper International Conference for Renewable Energies, Bonn; reprinted in Assmann, D., Laumanns, U., & Uh, D. (Eds.) (2006) Renewable energy: a global review of technologies, policies and markets, Routledge.

Schumpeter, J. A. (1942) Capitalism socialism, and democracy. Harper and Row: New York

Stiglitz, J. E., and Weiss, A. (1981) Credit rationing in markets with imperfect information. *The American Economic Review*, 393-410.

Tourigny, D., and Le, C.D. (2004) Impediments to Innovation Faced by Canadian Manufacturing Firms. *Economics of Innovation and New Technology* 13, 217–250.

Unruh, G. C. (2000) Understanding carbon lock-in. *Energy policy* 28(12), 817-830.

UNEP (2011) Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers, www.unep.org/greeneconomy.

UNEP (2013) UNEP, 2013, Green economy and trade. Trends, Challenges and Opportunities, Geneva.

Veugelers, R. (2012) Which policy instruments to induce clean innovating ? *Research Policy* 41(10), 1770–1778.

World Economic Forum (2013) The Green Investment Report. The ways and means to unlock private finance for green growth, Geneva .