CECILIA 2050
OPTIMAL EU CLIMATE POLICY

Choosing Efficient Combinations of Policy Instruments for Low-carbon development and Innovation to Achieve Europe's 2050 climate targets

The availability of finance for the low carbon economy

Evidence on eco innovation diffusion from sector analyses

Funded by the European Union

This project has received funding from the European Union's Seventh Programme for Research, Technological Development and Demonstration under Grant Agreement no. 308680.

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Project coordination and editing provided by Ecologic Institute.

Manuscript completed in [November, 2014]

Document title	The availability of finance for the low carbon economy. Evidence on Eco innovation diffusion from sector analyses
Work Package	WP4
Document Type	Deliverable 4.4
Date	25 November 2014
Document Status	Final
Please Cite As	Mazzanti, Massimiliano et al., 2014. The availability of finance for the low carbon economy. Evidence on Eco innovation diffusion from sector analyses. WP4 Deliverable 4.4. Ferrara, University of Ferrara.

ACKNOWLEDGEMENT & DISCLAIMER

The research leading to these results has received funding from the European Union FP7 ENV.2012.6.1-4: Exploiting the full potential of economic instruments to achieve the EU's key greenhouse gas emissions reductions targets for 2020 and 2050 under the grant agreement n° 308680.

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LIST OF ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIS	Community Innovation Survey
CSR	Corporate Social Responsibility
EC	European Commission
EEA	European Environmental Agency
EI	Environmental Innovation
EU	European Union
GDP	Gross Domestical Product
GHG	Greenhouse Gas Emissions
HC	High Carbon
HRM	Human resource management
IEA	International Energy Agency
LC	Low Carbon
MEI	Measuring Eco-Innovation Project
MNEs	Multinational enterprises
RAN	Rainforest Action Network
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
SMEs	Small and Medium Enterprises
UNEP	United Nations Environment Programme

1 Executive summary

The current macroeconomic setting is slowly moving towards financing the green/low carbon economy through diversified private and public oriented sources. Nevertheless, when compared to the mass of potential liquidity that current markets witness and high decarbonisation targets, this development is still in its infancy. Complementary fiscal and monetary policies, as well as private and public investments are needed. One key issue is the funding of short and long term (radical) innovations: regarding the former, the asset allocation of banking and finance is a key driver; as for the latter, institutional investors and wealth funds should complement state actions to look into a distant future which risks being heavily discounted by markets.

In a present EU situation which is heavily affected by a Keynesian liquidity trap, financial constraints co-exist with huge savings to be potentially allocated to low carbon (LC) investments, including environmental innovations of technological and organisational flavours. A key difference is the role of banking and finance with respect to the potentially diverse financial needs of SMEs and MNEs[1].

Our empirical analyses, which are based on cases studies, direct interviews with managers and experts and survey data-based econometrics, highlight three key findings. First, MNEs seem to play a different game, where internal resources partially or fully compensate the financial needs of firms to invest in the low carbon economy. While this is potentially effective for 2020 and 2030 EU targets, it is unlikely that 2050 targets will be achieved without the support of external sources. At the very least, cooperation among corporate firms will be needed to cope with radical and not just incremental innovations. The situation with SMEs differs.

Overall, evidence could suggest a different scenario, where MNEs proactively react to the recession shock and LC economy targets, and find ways to bring together competitiveness and sustainability. 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. If 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; some of these could possess irreversible features and create 'hot spots', namely structurally underperforming regions/sectors.

The second key finding confirms financial barriers as a deterrent for the innovative capacity of EU firms in the current situation, if we observe the overall quantitative and qualitative evidence. This is true for the economy as a whole, and for manufacturing or construction firms taken alone. Being smaller and having a low amount of human capital in the firm also hampers environmental innovations (EI). On the 'positive' side, we note that existing regulations and expected increasing demand for green products both support EI adoption. Financial barriers are

[1] See Figure 1.

perceived by firms and influenced by several factors (such as technological lock-in, uncertainty in investments, non-competitive markets, and lack of subsidies).

While policies are driving innovations to some extent, 'external knowledge sourcing' does not seem to play any significant role in this context. This highlights a highly critical issue: external finance elements deter EI and external knowledge is not acting as a potential substitute; firms are currently isolated islands in the green economy with respect to other firms and financial institutions.

As a corollary, 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. This might suggest that the routes through which firms implement EI and innovations are not parallel but inter-wined. The lack of 'separation' between EI and traditional innovation strategies is confirmed by interviews with managers. On a positive note, complementarity exists (see also below), while one possibly more problematic aspect is the lack of specific attention paid to specific EI that could drive the way towards 2030-2050 CO2 abatement. The challenge of abating 20-40% of emissions is likely to be milder compared to the needed radical cuts of about 80-90%. Strong complementarity among all innovation actions (and market/policy drivers) is necessary to achieve those targets. The two are clearly interconnected in these dynamics; this highlights the need of understanding innovation through evolutionary thinking.

Nevertheless, our third key finding, shown by the analysis in section 3.2, is that a possible way out is the complementarity among actions that tends to relax 'barriers'. Namely, EI is stimulated where (i) financial barriers are (perceived) as low and (ii) other policies help to increase collaboration with research institutes and universities, to reduce technical and technological lock-ins, to enhance competition on markets dominated by established enterprises and to improve existing regulations and structures providing incentives to eco-innovate. The transition to the LC economy is then a pathway constituted by different elements that play synergic roles. Finance and banking as sources external to the firm are one of these. Policies, regulations and a firm's cooperation activities are among the others.[2]

[2] The report analyses have benefited from insights that originated during the 15 May 2014 workshop: '*Finance and the environment – The role of finance behind the adoption of eco innovations and firm's 'green competitiveness*' held at UCL London as a specific milestone of task 4.4 WP4. The various experts who participated and presented papers stimulated the analyses and provided useful insights. Presentations by Elia Rossi, Maria Savona, Jens Horbach, Nick Silver, James McGregor, Valeria Miceli, Mariangela Zoli are available upon request. The Report is a complement to deliverable 2.7 WP2. Some insights and analyses follow the outcomes and evidence that deliverable 2.7 provided. Section 3.3. has largely benefited from the collaboration of italian industry associations, mainly Confindustria Emilia-Romagna and Assolombarda Lombardy, which allowed us to contact and interview selected firms. We wish to acknowledge their help as well as to thank respondent firms for precious information.

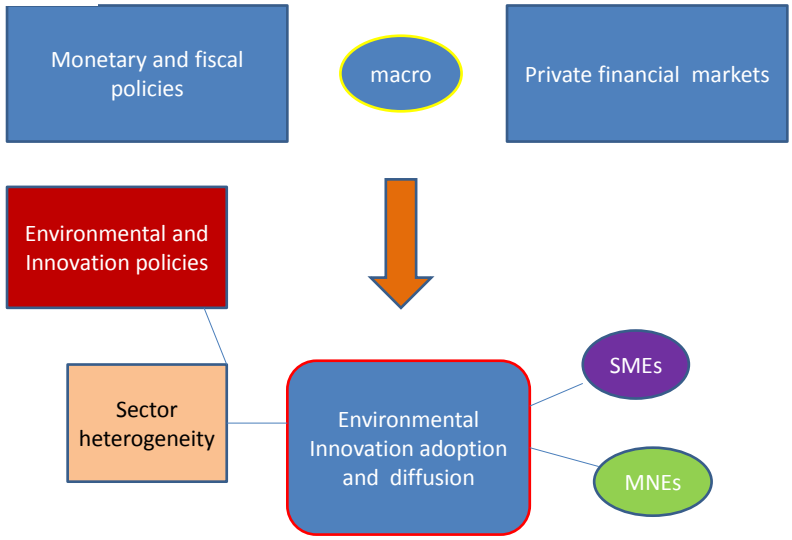

Figure 1 – Analysis Framework

2. Introduction

2.1 The setting: banking/financial barriers and the low carbon economy

The transition to a low carbon (LC) 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, but presence of credit crunch. 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 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 , 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), which are an essential force to drive economic growth while reducing greenhouse gas emissions and natural resource use. Among others, 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, cited in Caiani et al., 2014).

Institutional and policy attention on the role of finance has gained momentum since the 2009 downturn posed questions on how public and private financial flows may support the ‘green

recovery' and a future transition to a green LC society. With reference to the green low carbon economy transition, the EEA (2014)[3] stresses that investing in a low-carbon future encompassing smart grids, passive housing, carbon capture and storage, advanced industrial processes, and electrification of transport (including energy storage technologies) will require major and sustained investment. Over the coming 40 years, the EC estimates that this would require an increase in public and private investment averaging around €270billion a year. 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. The EEA explicitly states, which is of relevance to our discourse: "There are opportunities for creating and directing financial resources to the green economy through many different alternative channels. Some of them are publicly-driven (including specific initiatives undertaken by the EU and its financial institutions), while some others are to be found in the private domain (for example pension funds and socially responsible investments). We also considered a third category made up by hybrid players (sovereign wealth funds) and hybrid instruments (green bonds, project bond initiative)", and "Among the positive trends emerging, some novel approaches to green (and socially sustainable) finance, as in the case of 'socially responsible investments', can become mainstream, and they are already in some European countries. This selectiveness of funding based on sustainability criteria can be a powerful mechanism to re-direct resources towards the green economy in a competitive financial market".

We may summarise by saying that from a macroeconomic point of view: There is a significant gap between current investments and what is needed to meet EU energy and climate policy targets at 2020; The financial crisis has impaired governments in financing the transition to the green economy; Eco-innovation requires 'patient' capital: investments are long-term and risky.

We analyse here in specific terms the role of finance and banking among the factors that support the adoption of eco innovation in the realms of energy efficiency and CO2 abatement. We address this by contextualising the eco innovation adoption by firms (SME, large firms, clusters of firms) in the broader macroeconomic framework that touches the role of 'green finance' to achieve green economy patterns. We thus take a meso / micro approach which lies within the macroeconomic setting.

We take stock of the consolidated literature on environmental innovation adoptions, which has nevertheless not touched upon with sufficient depth and breadth, if any, the role of finance and banking to support eco innovations as in the innovation counterpart. Given the public nature of some innovation benefits (e.g. CO2 reduction) and the presence of double externality, it is of main interest to analyse the interactions (complementarity or trade off) between policies and financial levers. The analysis of complementarity/trade off effects is consolidated in the innovation literature (Mohnen and Roller, 2005).

Our analysis is thus aimed at discussing the issue of 'financial drivers and barriers for eco innovation adoption', with a specific interest in manufacturing SME organisations and sector heterogeneity. The increasing integration between services and manufacturing will be under

[3] EEA (2014), Resource efficient green economy and EU policies, chapter 8.

scrutiny. The complementary role of financial drivers, environmental policy and industrial policy will be addressed.

The most significant **barriers** to financing the low carbon economy (discussed in depth in section 2.2) are in fact:

- current fiscal deficits and debts;
- deleveraging by banks
- not coherent risk-return profile;
- lack of specialist teams in clean technology investments with experience
- political risks/regulatory instability.

The investigation is based upon case studies, in field interviews and econometric exercises on EU innovation data. We fully integrate different exercise to offer a richer and more effective analysis based on complement methods. Case studies cannot provide EU wide representative evidence, econometric analysis difficultly delivers very detailed insights on specific firms and sector based idiosyncratic elements.

Environmental innovations[4] have a leading role in driving economic growth while reducing greenhouse gas emissions and natural resource use. As far as eco-investments are concerned, considerable progress has been made in latest years in greening industrial activities. By limiting attention to renewable energy, for instance, global investments in 2011 were equal to US$ 257 billion, representing a six-fold increase from 2004 and 93% higher than in 2007, the year before the financial crisis (World Economic Forum, 2013). Nevertheless the scale of green investments continues to be inadequate, outpaced by polluting investments in fossil-fuel intensive technologies and infrastructures. On the basis of existing estimates, the amount of green investments that are needed globally to achieve climate stabilization goals (such as the IEA's Blue Map scenario of halving worldwide energy-related CO2 emissions by 2050) are approximately equal to US$ 750 billion per year from 2010 to 2030 and US$ 1.6 trillion per year from 2030 to 2050. According to the World Economic Forum and Bloomberg New Energy Finance estimates, a rise in clean energy investment equal to US$ 500 billion per year by 2020 is needed to limit global warming to less than 2°C, while according to HSBC the transition to a low-carbon energy market will require US$ 10 trillion between 2010 and 2020 (UNEP, 2011).

The sources of financing are multiple and diversified. Among them, institutional investors (i) such as insurances and pension funds, manages today €13.8tn of assets, more than 100% of EU GDP. It might be plausible to assume that up to 1% may be devoted to climate change related assets (EEA, 2014). Venture capital (ii) accounts for 2% of clean energy investments. Though decreasing in recent years, low carbon technologies attracted 2.1 billion $ in 2013 and solar half a

[4] We refer to Environmental Innovation (EI) as defined into MEI project, i.e. 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 & Pearson, 2007:9).

billion. Wealth sovereign funds (iii) also may have a relevant role, as they may operate over long term scenarios, can be counter cyclical and may compensate short termism of private financial actors. As an example, the Norwegian fund invested 3.5% in environmentally friendly companies in 2013 and may jump to 5% or more. Finally, socially responsible investments (iv) accounted 6.8B€ in 2011 in the EU, as well as green bonds (v), whose issuance was 11$ billion in 2013 (expected 20B$ in 2014).

2.2 Finance, banking and the transition to a low carbon economy: Additional conceptual issues

There are at least three main conceptual issues that are of relevance to this work and link it to the aforementioned discussion. One is **Complementarity among innovations.** The strategy of investing in diverse innovations (eco innovation, process, product, marketing, organisational innovations, HRM as well, etc..) is costly for firms. It is an investment as R&D and can produce returns through increasing returns to scale. The integration of different innovation strategies may deliver irreproducible returns (thus implicitly 'patented'), which have often characterised the competitiveness of SME. Financial support given to innovations should recognise the intangible value of complementarity among innovation practices (in the form of higher economic and environmental effects). The multiple adoption of innovation can be constrained by credit limits, especially for SME. Thus, the 'complementarity' issue is relevant both for policies (policies and financial instruments) and innovation adoption.

The second issue is **Adverse selection.** Since investments in eco innovation are characterised by high expected growth and potential profitability, but also by high riskiness, problems of credit rationing may arise. Within the economic theory about imperfect information and adverse selection[5], 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 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 eco innovations are expected to grow more and be more profitable than other more consolidated benchmarks, but are also more risky 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

[5] See, for instance, Stiglitz-Weiss (1981), Credit Rationing in Markets with Imperfect Information, *American Economic Review.*

observe more financial constraints on more risky investments in eco innovations, such as the ones related to CO_2 reduction.

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. Even without accounting for other reasons behind short-termism in financial markets, a market discounting of 10-15% shrinks the time dimension within a period definable as short-term for environmental targets and eco innovation related returns. Over at least 10-20 years, the present value difference determined by 10% or 2-3% social discount rates is considerable. This reasoning is made more complex by the introduction of declining discount rates that give more value to the future and are justified by uncertainty in future interest rates. The issue is to some extent well known: which discount factor should be applied to private and public components of an investment. For our purposes, it is worth noting that the interdependencies between financial tools and environmental policy instruments, as factors that correlate to eco innovation, lie on the grounds of the interaction between fiscal policies and the 'financial world' (including policies and regulations on finance and banking), as well as on the grounds of cost benefit analysis implementation, which might include 'social elements'. If and how the market can integrate such elements (through public actions) is a relevant issue.

Deepening the conceptual discussion, we outline in the following some **specific key constraints** to eco-investments (including EI). The conceptualisation of some 'flag' issues introduces the analyses we will carry out in section 3, where we test the role of financial and other barriers as factors that affect eco innovation diffusion in EU firms.

It is worth noting that 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, dirty, incremental investments, they need to be supported (Kapoor and Oksnes, 2011). The scale of required investments makes green projects more risky than conventional ones.

The main barriers to eco-investments can be identified in the following.

Existing regulations - Carbon-intensive energy sources continue to be financially supported through perverse incentives (e.g. inefficient fossil-fuel subsidies), which prevent green alternatives from gaining competitive advantage. 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 CO2 emissions currently receive financial incentives corresponding to $110 per tonne, while only 8% are subject to a carbon price (IEA, 2013). The revolutions in shale gas and tight oil, which are expected to account for almost one fifth of the increase in global energy supply to 2030 (BP, 2013), but whose environmental impact is still debated, also place downward pressure on the use of carbon-intensive energy sources. All these factors have the effect of making renewables comparatively more costly and less attractive for investments. At the same time,

policy incentives provided by governments for clean energy development in several cases have been removed, leading to new policy risks for green-technology investments. The lack of a consistent and predictable policy framework also undermines investor confidence.

Risk perceptions – Green investments are perceived as more risky than dirty investments: the supposed risk/return trade-off favours dirty investments over green. 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):

1 – in several cases, LC technologies are still in an early stage of development; uncertainties related to their durability, performance, etc., contribute to increasing their higher perceived risk;

2- the payback period of many green investments is longer than for many dirty investments; green technologies often have higher capital costs, especially in the earlier stages of development (WEF, 2013);

3 - due to their recent introduction, data series on the performance of green technologies are still lacking. This absence has put eco-investments at a disadvantage compared to traditional investments that have a long record of high returns. As lenders and investors use historical performance time series, the absence of these means that they attach a higher risk premium to green investments.

On the contrary, the perception of risk for dirty investments is too low. This is mainly due to carbon prices, which are still 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 (HI) alternatives. It is more profitable, then, to continue to rely on dirty energy infrastructure than to make new green investments, 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 several channels.

Firstly, even though the prices for GHG emissions are relatively low at present, they are expected to increase significantly: under some mitigation scenarios, carbon price is expected to be € 60-100/tonne of carbon dioxide (Kapoor and Oksnes, 2011; p. 54).

At the same time, increases in fossil fuel prices and their volatility also tend to reduce the profitability of dirty investments based on the use of fossil fuels. Further, it cannot be excluded that government requirements 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 – see below).

Short-termism in finance – 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 green investments. Even though it can be expected that governments will introduce more stringent climate regulations, causing serious increases in carbon prices and penalties for GHG emissions, both companies and financial institutions continue to underestimate the consequences of these developments in terms of the investments' risk/return trade-off. There is evidence that financial markets, rather than stimulating long-term profitable and more sustainable investments, 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 causes of the small amount of green investments currently financed (Kapoor and Oksnes, 2011).

Banks' 'environmental risks' – Every type of financial transaction (credit provision or equity investment) may involve environmental risks for banks. The existence of these risks may deter financial institutions from providing credit to environmentally innovative projects.

Environmental risks can develop in several ways (Jeucken, 2004):

1. They can result from a reduced repayment capacity of the borrowers or a reduction in the value of their collateral due to stricter environmental legislation or different market conditions ("indirect risks").

2. They can be related to a bank's direct liability for environmental damages caused by its borrowers. This may happen when regulations introduce the so-called "financial responsibility" (a sort of ex post liability policy extended to fund providers) for the environmental costs related to the project that has been financed by the bank. In other terms, financial and credit institutions can be sued for negligence if they do not consider potential environmental and social impact of the investment and can be held directly accountable for the environmental damages caused by the activities of their client.

In the U.S., for instance, environmental policy requires financial responsibility for the owners and operators of landfills and underground petroleum storage tanks, offshore rigs and oil tankers under the RCRA (Resource Conservation and Recovery Act) and the CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act). Accordingly, in order to operate, these actors must demonstrate the existence of adequate levels of capital to compensate society for pollution costs generated by their activities. Since their investment may imply potential environmental costs in the future, making the firm financially responsible for the environmental damage created increases the relevance of these costs to the firm's decision-making. In the US, financial responsibility can be demonstrated either through self- or third-party insurance (Boyd,

1996). If a firm can self-insure, this implies the possibility of internalising directly expected environmental costs. But in several cases firms cannot self-insure and must be guaranteed by acquiring rights to financial assets from third parties (i.e. banks and insurers). When third parties are involved in providing capital to this end they are obviously interested in calculating the probability that their capital will be consumed by future liabilities. Accordingly, financial institutions have a strong incentive to acquire environmental information and to monitor the environmental safety of the firm. Obviously, financial coverage and capital costs will be strictly related to environmental risk and credit may be denied to firms which fail to demonstrate acceptable levels of safety.

Clearly, the introduction of financial liability regulation may lead both firms and financial institutions to bankruptcy; in the U.S., for example, this type of regulation caused some banks to go bankrupt. In the EU, environmental liability with regards to the prevention and remedying of environmental damage (ELD) was introduced in 2004, with the Directive 2004/35/EC. One issue is, in fact, the creation of trusts (through charges or taxes) that compensate victims in case of a polluter's bankruptcy.

In contrast, banks can be encouraged to provide credit to eco-innovations and projects in order to build a **green reputation** and attract funding from environmentally concerned consumers and investors. Reputation is very important for the banking sector, because services provided are largely intangible and financial operations are mainly based on trust (Trotta and Cavallaro, 2012). Trust is considered as both a prerequisite and a consequence of the relationship between the bank and the customer (Stansfield, 2006). Even though reputational risks are difficult to estimate in financial terms, they can seriously impact on the bank's activities, involving not only the specific investment that can create environmental damage, but the entire lending portfolio (Jeucken, 2004). As the vast literature on the CSR of banks testifies, banks have an interest in developing a positive social and environmental report and disclosing their CSR policies, because this has a positive influence on bank customer loyalty. It may be difficult to attract funding for a financial institution considered to be "dirty": for example, in 2008 the Rainforest Action Network (RAN) published a report on the climate exposure of seven important Canadian banks, and encouraged clients to move their deposits to "greener" banks (Kapoor and Oksnes, 2011; p.56).

3 Empirical evidence

3.1 Financial barriers, policy and eco innovation adoption. EU evidence from firm data

Environmental Innovations (EI) may be considered as fundamental drivers for an economic growth that cares about the reduction of greenhouse gas emissions and natural resource use, a necessary condition to reach the policy target of improving Europe's environmental performances, without giving up its competitiveness. The importance of policy instruments that incentivise EI by firms is straightforward. A leading role in firms' investments in EI is played by the availability of financial resources, 80% of which is expected to come from private capital (UNEP, 2011). Private financing, however, remains strongly dependent on public policy initiatives and incentives to achieve economic viability and profitability.

What we aim to investigate in the current section is if and how financial barriers have a detrimental effect on environmental innovations (EI) adoption by firms and sectors.

Specifically, we perform an empirical analysis aimed at discussing the issue of 'financial drivers and barriers for eco innovation adoption', with a specific interest in SME and on sector heterogeneity.

Key policy implications may derive from this analysis. If the presence of under-investment in environmental-innovative activities due to financial barriers emerges in the empirical analysis, the main policy implication would be that policy mitigating imperfections in capital market and facilitating firms' access to credit could spur the adoption of EI. In other words, the scarcity of financial resources is an exogenous constraint in our analysis that limits firms' investment in EI. A properly designed policy can, for instance, stimulate financial institutions to provide loans for green investments and, therefore, reduce the risk perceived by firms, or it can help firms in seeing the positive economic returns on their investment, as postulated by the Porter Hypothesis (Porter and van der Linde, 1995). This will in turn help reach the broader policy target of improving Europe's environmental performances without giving up its competitiveness, as the Europe 2020 Strategy puts forth.

3.1.1 The role of financial constraints as a barrier to eco-innovation

As mentioned in section 2.2, a leading role in providing financial resources for required EI and green investments could be played by private capital sources, which are expected to supply 80% of the amount required to transition to a low carbon economy (UNEP, 2011); private financing, however, remains strongly dependent on public policy initiatives and incentives to achieve economic viability and profitability. Public intervention also remains essential in financially

supporting green investments, as recently testified by the green components of the fiscal stimulus packages launched by G20 countries in response to the financial and economic crisis of 2008.[6]

Notwithstanding their huge financial potential, there continues to be a significant gap between the amount of eco-investments needed and the amount of eco-investments currently being made. This is due to the existence of several different barriers to eco-innovative projects (surveyed in the following section), among which financial constraints play a relevant role.

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 characterizes 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 & 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, Rammer, & Rennings, 2012).

Given the relevance of financial constraints as obstacles to the development of eco-innovations, 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.

Building on the literature reviewed in section 2.2, we can identify a set of factors that can contribute to explaining why financial institutions provide insufficient credit to eco-innovations:

- current regulations;
- financial incentives;
- market practices;
- short termism in finance;
- risk perceptions.

All of these factors operate by affecting the risk/return trade-off between green investments and dirty investments, contributing to increasing the riskiness/decreasing the profitability of green innovations compared to traditional ones.

[6] Barbier, E., (2010) A Global Green New Deal: Rethinking the Economic Recovery. University Press, Cambridge, UK.

Current regulations not providing incentives to eco-innovate, the existence of perverse incentives for carbon-intensive technologies (e.g. fossil-fuel subsidies) as well as the removal of incentives for clean energy production have the effect of preventing green investments 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, while inconsistent state policies acted as barriers to renewables development in India[7].

Further, by considering that green investments 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 dirty investments more profitable, it can be easily understood why financial actors (banks as well as capital markets) continue to provide cheap finance for 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 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 justify 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 eco-innovations not only directly, but also by inducing restrictions of financial credit for SMEs[8].

Summing up previous considerations we can formulate the following research hypothesis:

Hypothesis 1: *Existing regulations and the lack of financial incentives to EI, as well as market conditions and short-termism 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.*

[7] See also Chart 3 in Sawin (2004), p. 39, for an analysis of the impact of policy inconsistencies on annual wind installations in Germany, the United States and Spain.

[8] 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). Here we focus on cases where firms (SMEs) could operate in markets with big players in actions that reduce competition and extract rents.

3.1.2. Determinants of EI

Having clarified the conditions that are influencing financial barriers' presence and perception, wet now elaborate on those elements that facilitate or hamper a firm's choices to adopt EI, i.e. EI's determinants. EI have recently been at the centre of the analysis of a multitude of contributions, given their potential key role in spurring both environmental improvements and economic competitiveness. Within this framework, previous contributions have mainly aimed at understanding the determinants of EI (e.g. Brunnermeier and Cohen, 2003; Horbach et al., 2012; Mazzanti and Zoboli, 2005) and their economic implications (e.g. Cainelli et al., 2013; Hart and Ahuja, 1996).

Since Rennings's contribution, the unique features of EI with respect to standard innovations have been outlined. EIs are characterised as having a "double externality" nature: they reduce negative environmental externalities and are affected by knowledge spillovers. EI are strongly regulation driven, the 'regulatory push-pull effect' (Cleff & Rennings 1999; Rennings & Rammer 2009) and depend on social and institutional innovations as well (Rennings 2000).

Specific literature on EI determinants highlights the core role of "regulation" in spurring EI adoption (Brunnermeier & Cohen, 2003; Veugelers, 2012), which may take the form of either incentives or subsidies (inc) or existing regulation (reg).

A firm's "specific characteristics" in terms of sector and size, mainly captured by the number of employees, have to be accounted for (Horbach, 2008), as well as "market" conditions such as the structure of the market (market), the existing demand for green products (demand) or past economic performance (turnover) (Rehfeld, Rennings, & Ziegler, 2007). Not only market but also "technological" conditions might spur EI adoption, and thus behave as EI determinants. These may be available within the boundaries of the firm (int_knowledge) or can be acquired from outside firms' boundaries (ext_knowledge). Relying upon external knowledge sourcing is indeed a relevant source both for standard innovations (Laursen & Salter, 2006) and for EI (De Marchi, 2012; Ghisetti et al. 2014) . Moving from EI's special characteristics and from the consideration that they require knowledge that is far from firms' traditional knowledge base (De Marchi, 2012), we hypothesise that financial constraints might be a strong limitation to EI adoption.

We can now formulate our second research hypothesis, in the awareness that a set of non-financial barriers exists which is as important as any financial barriers, such as market and knowledge conditions and regulation (Este, Iammarino, Savona, & Tunzelmann, 2012)**,** and that EI adoption can be affected by firms' characteristics as well (Horbach et al., 2012) - which we control for in the empirical strategy.

Hypothesis 2: *Once we control for EI determinants and other relevant barriers, we still expect to find empirical evidence that financial constraints act as a relevant barrier to EI adoption by firms. The hypothesis is that perceived financial barriers are a deterrent to EI adoption.*

3.1.3 Empirical investigation

3.1.3.1 Data and Model

We ground our empirical analysis on the 2011 Flash Eurobarometer Survey number 315 on Attitudes of European Entrepreneurs towards Eco-innovation, which is the only existent source that presents both EI and financial barriers information.

To analyse the role that financial barriers play on EI we decided to focus on a direct measure of innovation extracted from the survey. This measure captures innovations, which have actually been adopted by firms, instead of an indirect measure such as patent data, which only counts inventions, without having the certainty that those inventions will enter the market to become innovations.

The Community Innovation Survey CIS5 2006-2008 and the Flash Eurobarometer 315, 342 and 381 are the available recent surveys that provide EU-wide data on environmental innovations.

Among these available surveys, we chose to focus on the Flash Eurobarometer 315, as it is an EU-wide survey providing data both on EI and on financial constraints. With respect to the Flash Eurobarometer 342 “Small and Medium Enterprises, Resource Efficiency and Green Markets”, the 315 has a more comprehensive definition of EI. The first conceives EI only in terms of innovations leading to resource efficiency, thus excluding all the remaining innovations that should also be accounted for as EI, mainly externality reducing innovations (Ghisetti & Rennings, 2014) and organisational innovations.

The CIS 2006-2008 has the drawback that it provides information on EI, but data on financial barriers was only sampled in previous waves of the survey.

Whereas in principle a merge of the two waves would be possible to link the information we need, a set of problems arise that make this choice unfeasible. First of all, the survey is representative for the population of firms in each wave. When we merge two waves it is very likely that only firms with similar structural characteristics survive in the sample, i.e. were surveyed twice and would thus be included in the merge. This would definitely lead to a potential selection problem and the sample may no longer be representative for the whole population. Secondly, the anonymisation requirements of many EU countries will not allow for any firm identifiers that might be used to merge data of the two waves. This ‘panel’ option, which uses two or more waves, is pursued in a few national studies (UK, France). At any rate, it would be unfeasible if one wants to consider EI in a panel fashion.

These considerations lead us to exclude CIS from our dataset choice.

The Flash Eurobarometer 315 survey represents 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 on construction sectors. We will provide results for all the sectors in the survey, as a robustness test.

Data was collected in January 2011 by the Gallup Organisation for the DG Communication Public Opinion Analysis Sector of the European Commission.

We aim to understand how (and if) weak access to financial resources constitutes a barrier for the development of EI. In testing for this, we rely on a two-stage procedure.

At the first stage, we model what determines entrepreneurs' perceptions of the stringency of external financing as a barrier to EI (eFIN), as described in Equation (1) (See section 3.1.3.2 for the variables description).

$$eFIN = \alpha + \beta 0 TEC\_LOCK + \beta 1 UNCERTRETURN + \beta 2 UNCERTDEMAND + \beta 3 MARKET + \beta 4 REG + \beta 5 INC + \beta 6 FUT\_ENPRICE + \beta 6 FUT\_REG + \delta dstate^* + \gamma size^* + \epsilon \quad (1)$$[9]

At the second stage, we analyse drivers and barriers for EI, by including the predicted values of the external financing variable modelled into Eq. (1) and a set of non-financial barriers that may be detrimental on EI, such as market and knowledge conditions, according to the model described in Equation (2).

$$EI = \alpha + \beta 1 eFIN + \beta 2 MARKET + \beta 3\ DEMAND + \beta 4 EXT\_KNOW + \beta 5\ INT\_KNOW + \beta 6\ REG + \beta 7\ INC + \beta 8\ TURNLOW + \delta dstate^* + \gamma size^* + \epsilon \quad (2)$$

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 (see figure 2).

Given the binary nature of the two dependent variables, both models are estimated through LOGIT regressions.

Barriers to innovation are perceived as stronger for firms which are actually innovating (Mohen and Roeller, 2005). Baldwin and Lin (2002) and Tourigny and Le (2004) suggest that the

[9] (eFIN=Lack of external financing; tec_lock= Technical and technological lock-ins (e.g. old technical infrastructures); uncertreturn= Uncertain return on investment or too long a payback period for eco-innovation; uncertdeman= Uncertain demand from the market; market= Market dominated by established enterprises; reg= Existing regulations and structures not providing incentives to eco-innovate; inc= Insufficient access to existing subsidies and fiscal incentives; futen_price= Expected future increases in energy prices; fut_reg= Expected future regulations imposing new standards.)

obstacles to innovation cannot be interpreted as preventing innovation but rather as a measure of how firms are able to overcome them. D'Este et al. (2008, 2012), proposed a distinction between deterring and revealed barriers in translating innovative input into actual output. 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.

We thus draw on this literature and account for the different perceptions of barriers to innovation that arise between innovative and non-innovative firms, as the latter are less sensitive to obstacles to innovation simply because their propensity to innovate is lower (Mohen and Roller, 2005).

We estimate equations (1) and (2) on the whole sample and on a "filtered" sample.

We created a filter which excludes those firms 'that do not innovate and do not perceive any financial barrier' and estimated equations (1) and (2) on the whole sample and on the filtered sample. It is worth noting that main results are related to the filtered analysis: firms 'that do not innovate and do not perceive any financial barrier' distort the evidence if introduced. The filter is thus methodological in nature: it is not similar to filtering for 'innovative/non innovative firms'. It is aimed at enhancing the quality of the dataset.

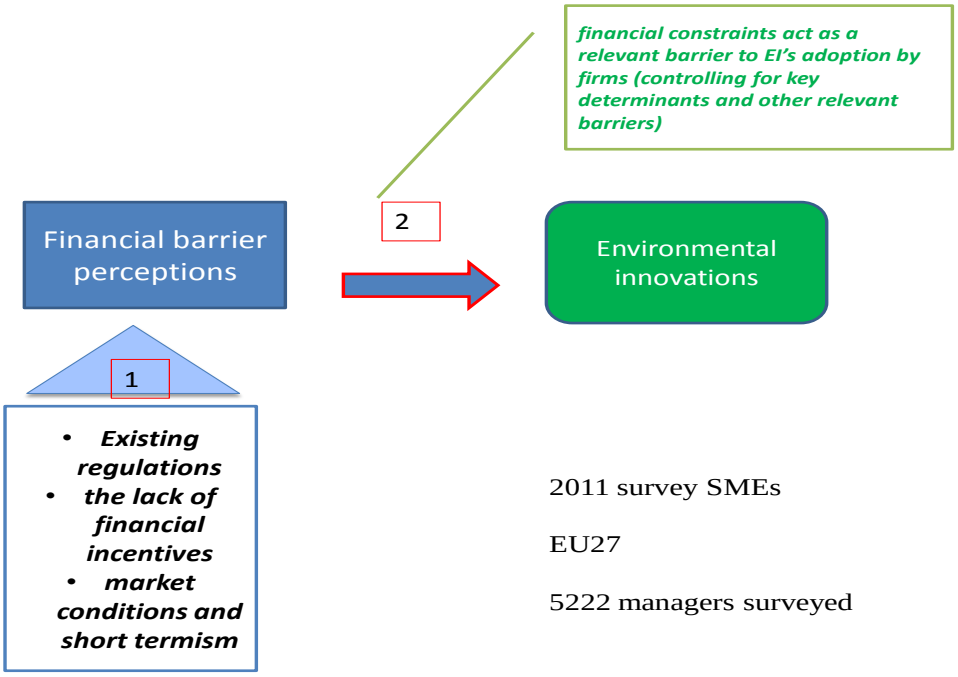

Figure 2 – The econometric strategy – a diagram

3.1.3.2 Description of variables

EI is defined in the survey adopted 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'.

Respondents are asked to state whether in *the previous 24 months* their firm has introduced any EI that fits this definition. We consequently built *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. EI constitutes the dependent variable of the model in Eq.(2).

We then extracted the financial barrier variable (eFIN) as well as our main explanatory variables from a set of questions asking firms to report, on a scale ranging from 1 and 2 (not relevant) to 3 and 4 (relevant), how strongly they perceive the presence of an obstacle to accelerated eco-innovation uptake.

Specifically, eFIN takes value one when the lack of external financing is perceived as relevant, i.e. for values equal to 3 or 4.

In Eq.(1), the perception of financial barriers depends on the existence of technological lock-ins (*TEC_LOCK*), 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*), 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 in Eq.(2). The other explanatory variables we exploit are those that have been recently acknowledged to strongly affect innovation activities together with financial constraint, such as market conditions and demand, regulatory framework and access to knowledge (D'Este et al., 2012).

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.

Descriptive statistics can be found in Table 1. The tetrachoric correlation matrix among variables is expressed in Table 2.

Table 1. Descriptive statistics of variables (Manufacturing sectors[10])

Variables	Description	N	Mean	Sd	min	max
EI	D equal to one when at least one EI has been introduced by the firm in the previous 24 months	2526	0.459224	0.498433	0	1
eFIN	D takes value one when the lack of external financing is perceived as relevant, i.e. for values equal to 3 or 4.	2526	0.550673	0.497524	0	1
UNCERTRETURN	D takes value one when return of investment is uncertain	2526	0.666667	0.471498	0	1
UNCERTDEMAND	D takes value one when demand is uncertain	2526	0.670626	0.470079	0	1
FUT_ENPRICE	D equal to one when future energy prices are expected to increase	2526	0.84323	0.363655	0	1
FUT_REG	D equal to one when future regulation is expected to create incentives for EI	2526	0.714569	0.451709	0	1
SIZE_SMALL	Dummy equal to one when the number of employees is between 10 and 49	2526	0.765242	0.423932	0	1
SIZE_MEDIUM	Dummy equal to one when the number of employees is between 50 and 249	2526	0.234759	0.423932	0	1
TURNLOW	Dummy equal to one when turnover is lower than 2 million €, 0 when higher	2526	0.479018	0.499659	0	1
TEC_LOCK	Dummy equal to one in the presence of technological lock ins	2526	0.532462	0.499044	0	1
INT_KNOW	D equal to one when there is lack of qualified personnel or technological capabilities in the firm	2526	0.510293	0.499993	0	1
MARKET	D equal to one when the market is dominated by established enterprises	2526	0.496437	0.500086	0	1
DEMAND	D equal to one when increasing demand for green products is perceived as a driver for EI	2526	0.677751	0.467430	0	1
EXT_KNOW	D equal to one when access to information and external knowledge is weak and there is lack of collaboration with universities or research institutes	2526	0.534838	0.498884	0	1
REG	D equal to one when existing regulations and structures do not provide incentives to eco-innovate	2526	0.589074	0.492099	0	1
INC	D equal to one when access to existing subsidies and fiscal incentives is insufficient	2526	0.595012	0.490987	0	1

[10] Descriptive statistics for all firms are available in the appendix, Table A3.

Table 2. Correlation matrix (* means significant)

		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

3.1.3.3 Econometric results

We now move to a description of our results: Table 3 outlines the results of the first step (Equation (1)) and Table 4 those of the second step (Equation (2)).

In both Tables (3 and 4), Column (1) reports results for not filtered manufacturing firms, while Column (2) contains the results of filtered manufacturing firms. Column (3) reports results on construction sectors' filtered firms. Column (4) reports estimation on the whole sample of firms (all sectors) while column (5) reports filtered firms for all sectors.

Table 3: Results of Equation (1)

	(1) eFIN_man	**(2) eFIN_manfil**	**(3) eFIN_filCON**	(4) eFIN	**(5) eFIN_fil**
TEC_LOCK	0.4474***	**0.4145*** **	**0.1998**	0.4281***	**0.3343*** **
	(0.0988)	**(0.1240)**	**(0.1931)**	(0.0725)	**(0.0923)**
UNCERTRETURN	0.5306***	**0.5361*** **	**0.5772*** **	0.5541***	**0.5069*** **
	(0.1065)	**(0.1331)**	**(0.1979)**	(0.0772)	**(0.0974)**
UNCERTDEMAND	0.3988***	**0.1736**	**0.4509** **	0.3562***	**0.2268** **
	(0.1041)	**(0.1327)**	**(0.1986)**	(0.0760)	**(0.0970)**
MARKET	0.3306***	**0.3212** **	**0.1585**	0.3354***	**0.2798*** **
	(0.1000)	**(0.1257)**	**(0.1859)**	(0.0721)	**(0.0922)**
SIZE_MEDIUM	-0.3093***	**-0.6494*** **	**-0.3196**	-0.2176***	**-0.5316*** **
	(0.1108)	**(0.1325)**	**(0.2250)**	(0.0842)	**(0.1010)**
REG	0.3025***	**0.2314** *	**0.1621**	0.3618***	**0.2748*** **
	(0.1019)	**(0.1281)**	**(0.2010)**	(0.0744)	**(0.0948)**
INC	1.0816***	**0.9608*** **	**0.6269*** **	1.0123***	**0.8532*** **
	(0.0999)	**(0.1248)**	**(0.1951)**	(0.0737)	**(0.0932)**
FUT_ENPRICE	0.4790***	**0.2821**	**0.1563**	0.4307***	**0.1582**
	(0.1402)	**(0.1816)**	**(0.2502)**	(0.0996)	**(0.1321)**
FUT_REG	0.0307	**-0.0561**	**0.1932**	0.0222	**-0.0793**
	(0.1091)	**(0.1376)**	**(0.2137)**	(0.0815)	**(0.1042)**
_cons	-2.0743***	**-0.3649**	**-0.3495**	-2.0057***	**-0.3589**
	(0.2781)	**(0.3806)**	**(0.5104)**	(0.2461)	**(0.3254)**
N	2526	**1878**	**948**	4737	**3506**
pseudo R^2	0.208	**0.177**	**0.159**	0.203	**0.158**
D State	Included	**Included**	**Included**	Included	**Included**
D Sector	no	**No**	**no**	Included	**Included**
Sample	Manufacturing	**Manufacturing only filtered firms**	**Construction only filtered firms**	All sectors	**All sectors filtered**
D State	Included	**Included**	**Included**	Included	**Included**
AIC	2825.5485	**1850.1681**	**902.2683**	5268.3278	**3385.9614**
BIC	3035.5866	**2043.9968**	**1072.1707**	5526.8542	**3632.4506**

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Results of the second step

	(1)	**(2)**	**(3)**	(4)	**(5)**
	EI	**EI**	**EI**	EI	**EI**
$\widehat{\text{eFIN}}$	1.0259**	**-1.6624****	**-2.0350****	1.3925***	**-1.5523*****
	(0.4741)	**(0.7556)**	**(1.0151)**	(0.3571)	**(0.5900)**
SIZE_MEDIUM	0.3970***	**0.2198**	**0.2680**	0.4002***	**0.2271****
	(0.1114)	**(0.1555)**	**(0.2083)**	(0.0834)	**(0.1120)**
TURNLOW	-0.5535***	**-0.6000*****	**-0.3657****	-0.3973***	**-0.5116*****
	(0.0996)	**(0.1186)**	**(0.1590)**	(0.0720)	**(0.0849)**
MARKET	-0.1099	**-0.1121**	**0.0773**	-0.1046	**-0.0918**
	(0.1032)	**(0.1209)**	**(0.1535)**	(0.0750)	**(0.0859)**
INT_KNOW	-0.1370	**-0.3093*****	**-0.0423**	-0.0126	**-0.1743****
	(0.0912)	**(0.1090)**	**(0.1488)**	(0.0661)	**(0.0777)**
EXT_KNOW	0.0686	**-0.0689**	**-0.1116**	0.0251	**-0.0784**
	(0.0972)	**(0.1174)**	**(0.1676)**	(0.0715)	**(0.0848)**
DEMAND	0.6168***	**0.3611*****	**0.4492*****	0.5907***	**0.4116*****
	(0.0967)	**(0.1196)**	**(0.1686)**	(0.0714)	**(0.0867)**
REG	0.0019	**0.0194**	**0.1451**	0.0013	**0.0632**
	(0.1058)	**(0.1257)**	**(0.1712)**	(0.0798)	**(0.0928)**
INC	-0.0231	**-0.0450**	**0.1165**	-0.0892	**-0.0451**
	(0.1564)	**(0.1834)**	**(0.2230)**	(0.1148)	**(0.1335)**
_cons	-1.2083***	**1.8037*****	**1.5721****	-1.4734***	**1.4349*****
	(0.2706)	**(0.5293)**	**(0.7337)**	(0.2375)	**(0.4204)**
N	2526	**1878**	**948**	4737	**3506**
pseudo R^2	0.061	**0.086**	**0.045**	0.053	**0.062**
D State	Included	**Included**	**Included**	Included	**Included**
D Sector	no	**No**	**no**	Included	**Included**
Sample	Manufacturing	**Manufacturing only filtered firms**	**Construction only filtered firms**	All sectors	**All sectors filtered**
D State	Included	**Included**	**Included**	Included	**Included**
AIC	3344.4943	**2357.9304**	**1305.5826**	6236.1880	**4512.5880**
BIC	3554.5324	**2551.7591**	**1475.4851**	6494.7144	**4759.0772**

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We must stress that the nature of the dataset we are exploiting only allows us to comment on correlations among variables rather than causations. To properly test for the latter, a panel database that would allow us to answer our research question and also to lag the explanatory variables with respect to the dependent variable would be required but to our knowledge it is not available.

Thus, the first part of H1 is not 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 eco-innovation 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.

Quite surprisingly, 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, suggesting that perhaps 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.

Comments on financial barriers are the following. Results on manufacturing sectors and on all sample sectors column (1) and (3) outline a positive and highly significant correlation between the adoption of EI and the presence of financial barriers. Though some scholars (Baldwin and Lin (2002) and Tourigny and Le (2004), D'Este et al. (2008, 2012)) suggest that the obstacles to innovation cannot be interpreted as preventing innovation (as a negative sign would have suggested) but rather as a measure of how firms are able to overcome them, we here interpret the evidence as driven by a distortion. When we do not filter '00' firms (no EI, no perceived barrier), results are distorted.

When we exclude those firms that do not innovate and do not perceive any barrier to innovation from our empirical analysis as reported in column (2) for manufacturing sectors and in column (4) for all sampled sectors, results greatly change as we expected. The coefficient for the financial barrier variables turns negative and significant, coherently with

our expectations. This is true for the whole sample, as well as for manufacturing and construction specifically11.

Results on the second equation strongly support the phrasing of our second research hypothesis, which is thus not rejected: financial constraints do limit the adoption of EI by firms, 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 as well as firms with higher turnover, coherently with a Schumpeter Mark I scenario, but only with respect to the whole sample. 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. 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. 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.

According to our empirical investigation, then, financial barriers confirm to be a deterrent for the innovative capacity of EU firms in the current situation overall. 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 (EI). 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. 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, as postulated by the Porter Hypothesis (Porter and van der Linde, 1995). 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

[11] Results are not significant for other sectors, partly due to lower number of observations. See the appendix.

demand for green products can have strong positive effects in supporting EI adoption. All these factors will in turn help reach the broader policy target of improving Europe's environmental performances without giving up to its competitiveness, as the Europe 2020 Strategy puts forth.

3.2 The complementarity of financial and policy barriers

The aim of this analysis is to investigate whether the probability of the adoption of EI by firms is significantly influenced by the presence of complementarities between access to external financing and other innovation policies.

The relevance of investigating this issue is that whenever a relationship of complementarity is found between two policies, this implies that if one of the two is implemented, it is also necessary (or effective) to implement the other complementary policy.

This has obvious implications on a country's strategic decisions about environmental innovation. In fact, changing one policy may have little effect if complementary policies about external financing remain unchanged.

As for the previous econometric exercise, we ground our empirical analysis in the Flash Eurobarometer Survey number 315 on 'Attitudes of European Entrepreneurs Towards Eco-innovation' for manufacturing firms in 27 European Countries. We perform complementarity tests on a set of selected barriers to environmental innovation adoption to analyse if the policies potentially related to the different types of barriers jointly affect environmental innovation dynamics.

Essentially, our research hypothesis is the following:

Hypothesis: "policies oriented toward relaxing Financial constraints to EI" and other kinds of innovation policies may be complementary when the firm's objective function is the adoption of EI.

In this case, changing one policy may have little effect if the complementary policy on financial constraints remains unchanged.

In fact, when the objective function of the firm is its adoption of EI, and a relationship of complementarity between two policies is found, this implies that if one of the two policies is increased, an increase in the other complementary policy is more attractive for the firm as well. On the other hand, an increase in only one policy may have little effect if other complementary policy remains unchanged.

We study complementarity among these policies through the properties of supermodular functions (Topkis, 1995, 1998; Milgrom and Roberts, 1990, 1995; Milgrom and Shannon, 1994).

We begin by assuming that firms' *EI* are affected by a policy which is specifically oriented toward relaxing financial constraints to EI (that we call FP_j), and by other *K* national environmental innovation policies, $EP_j = (EP_{1j}, EP_{2j}, ..., EP_{Kj})$, where the subscript *j* indicates the country.

In our specific case, we consider the 'Environmental Innovation function' of the firm as represented by the following function: $EI = EI(EP_j, FP_j)$.

The challenge of the government of country *j* is to choose a set of national policies, $EFP_j = (EP_{1j}, EP_{2j}, ..., EP_{Kj}, FP_j)$, which maximise Environmental Innovation adoption by firms.

Complementarity between EP_{kj} and FP_j may be analysed by testing whether $EI = EI(EP_j, FP_j)$ is supermodular in EP_{kj} and FP_j.

If we consider, for example, two binary decision variables (EP_{1j}, FP_j), there are four elements in the set EFP_j. If, for instance, a country chooses not to adopt either of the two policies, namely $EP_{1j} = 0, FP_j = 0$, the element of the set EFP_j is $EP_{1j} \wedge FP_j = \{00\}$. If a country chooses to adopt both policies, we have $EP_{1j} = 1, FP_j = 1$ and the element of the set is EFP_j is $EP_{1j} \vee FP_j = \{11\}$. Including mixed cases as well, we have four elements in the set EFP_j that form a lattice: $EFP_j = \{\{00\}, \{01\}, \{10\}, \{11\}\}$.

We can assert that the two policies (EP_{1j}, FP_j) are complements and hence that the function EI_j is supermodular, if and only if:

(3) $$EI_j(11) + EI_j(00) \geq EI_j(10) + EI_j(01),$$

or:

(4) $$EI_j(11) - EI_j(00) \geq \left[EI_j(10) - EI_j(00)\right] + \left[EI_j(01) - EI_j(00)\right],$$

that is, changes in firms' environmental innovation function when both forms of policies (to relax obstacles) are increased together are more than the changes resulting from the sum of the separate increases of the two kinds of policies.

To sum up, complementarity between *"policies oriented toward relaxing Financial constraints to EI"* and one of the *K "environmental innovation policies"* exists if the EI_j

function is shown to be supermodular in these two variables and this happens when either inequality (1), inequality (2) or other derived inequalities are satisfied[12].

More specifically, through the supermodularity approach we analyse whether the probability of firms' EI adoption is significantly influenced by the presence of complementarities between *"policies oriented toward relaxing Financial constraints to EI"* and one of the *K "innovation policies"*.

Our aim is to derive a set of inequalities (such as those explicated in equations (1) and (2)), that are tested in the empirical analysis.

3.2.1 Data and empirical strategy

We test our hypothesis on an EU-wide dataset, the Flash Eurobarometer 315 survey on 'Attitudes of European Entrepreneurs towards Eco-innovation'. Our focus is specifically on manufacturing firms, given innovation potential and the environmental pressure on this sector.

As explained in section 3.1.3.2, our dependent variable, EI, captures the adoption of environmental innovations by the respondent firm in the last 2 years.

We test the complementarity among barriers to innovation as in Equation (3).

Since direct measures of government policies to firms' EI are not currently available, but we do have a number of measures of obstacles to firms' EI, we measure complementarity in policies using the information on a perceived lack of obstacles. We refer to the absence of perceived obstacles because reverting the score assigned to each obstacle in the questionnaire, which increases as the perception of the obstacles becomes more and more stringent, is functional to the creation of binary variables in which the value 1 is associated to the absence of obstacles, and 0 otherwise. Since policies are an instrument that can be adopted in order to mitigate, and in extreme cases eliminate, the obstacles faced by firms, we can assume that the favourable situation in which an obstacle is not perceived can be 'equated' to the most favourable case in which a policy is effective in eliminating the perception of obstacles.

Thus, in our empirical framework, the binary variables measuring the absence of obstacles perceived regarding the six dimensions taken into consideration (external financial resources, collaboration with research institutes and universities, technical and technological lock-ins, markets dominated by established enterprises, existing regulations and structures not providing incentives to eco-innovate and subsidies to stimulate innovation activity) are

[12] Since the substitutability relationship is the opposite of that of complementarity, we can test if a substitutability relationship exists if the *EI* function is shown to be submodular, that is if: $EI_j(11,\theta_j) + EI_j(00,\theta_j) \leq EI_j(10,\theta_j) + EI_j(01,\theta_j)$

interacted in couples of variables, in order to create bi-dimensional interactions, providing four states of the world for each couple: the firm does not perceive either of the two obstacles {1,1}, it perceives one but not the other {0,1} or {1,0} and it perceives both of the obstacles {0,0}.

To limit a reverse causality problem, we drew on innovation literature, as in the previous econometric analysis, and constructed a filter to be used to exclude firms that would create a bias in our estimations from the sample.

The distribution of firms in our working sample, which is a sample filtered in order to get rid of the previously outlined problem of reverse causality, for the states of the world is reported in Tab.5. We can notice that a small proportion of firms does not jointly perceive barriers, indicated by the state of the world (1,1)[13], while the large majority perceive some kind of obstacles to the EI activity. In particular, a large proportion of firms declare they perceive both external financial obstacles and other types of obstacles (state of the world (00)).

Table 5: Distribution of firms in each state of the world (%)

	States of the world	(1,1)	(1,0)	(0,1)	(0,0)
Obstacles					
EXT-FIN	COOP	18.58	8.61	33.50	39.30
EXT-FIN	LOCK-IN	13.33	13.54	22.85	50.28
EXT-FIN	MARKET	14.74	12.16	26.55	46.56
EXT-FIN	REGULATION	11.47	15.34	18.18	55.01
EXT-FIN	SUBSIDIES	13.68	12.87	14.75	58.70

Manufacturing firms perceiving barriers and implementing EI activities

The econometric test for complementarity passes through an auxiliary set of probit 'regressions' in which the EI variable is the dependent variable and the states of the world are the main covariates of interest:

(5) $Pr(EI=1|X)_i = \Phi\{(Controls_i\ ;$ [LACK _OBS$_t$(1); LACK _OBS$_s$(1)]; [LACK _OBS$_t$(1); LACK _OBS$_s$(0)]; [LACK _OBS$_t$(0); LACK _OBS$_s$(1)]; [LACK _OBS$_t$(0); LACK _OBS$_s$(0)]}

Where *X* is the full set of explicative variables, i denotes the single firm, t,s= {EXT_FIN; COOP; LOCK-IN; MARKET, REGULATION; SUBSIDIES} where t is EXT_FIN and $t \neq s$

[13] 1 conventionally indicates here 'barrier'.

In equation (3) the *Controls* vector includes a set of explicative variables which emerged in the previous literature as relevant as determinants of the propensity to innovate and eco-innovate and the set of the four states of the world [LACK _OBS$_t$(1); LACK _OBS$_s$(1)]; [LACK _OBS$_t$(1); LACK _OBS$_s$(0)]; [LACK _OBS$_t$(0); LACK _OBS$_s$(1)]; [LACK _OBS$_t$(0); LACK _OBS$_s$(0)] represents a lattice $LACK\_OBS_j = \{\{00\},\{01\},\{10\},\{11\}\} \cong EFP_j$, that is to say the lattice of lack-of-obstacles state of the world can be considered as an approximation of the *EFP* lattice, given the inversion we used to 'equate' the lack of obstacles to the virtual adoption of 'obstacle relaxing' policies.

The EI function is supermodular in the policies, that is policies are complements, if the following inequality is satisfied:

$$EI_j(11, Controls) - EI_j(00, Controls) \geq \left[EI_j(10, Controls) - EI_j(00, Controls)\right] + \left[EI_j(01, Controls) - EI_j(00, Controls)\right] \quad (6)$$

The operationalisation of the procedure to test for the complementarities among policies is based on the estimation of equation (3), in which all the four states of the world for each couple of policies are included, in order to arrive at the coefficients associated to each state of the world: b1 for {1,1}; b2 for {1,0}; b3 for {0,1} and b4 for {0,0}. It is thus necessary to run several Wald tests. These latter allow us to test the following linear restriction, under the null hypothesis, on the state-of-the-world-dummies coefficients: b1+b4=b2+b3. The test is distributed as a Chi2 statistic with one degree of freedom, since we are testing a single linear restriction at a time, so we can apply the appropriate procedure for the p-value adjustment in testing inequalities[14]. We are interested in the following inequalities, namely the sign of the scalar linear combination of our parameters of interest: b1+b4-b2-b3≥0; b1+b4-b2-b3≤0. If we combine the information provided by the standard Wald test, by the adjusted p-values for inequality tests and by the sign of the linear combination of the coefficients, we can state whether we are in the presence of complementarity (b1+b4-b2-b3≥0) between a couple of two policies or if we are instead in the presence of substitutability (b1+b4-b2-b3≤0).

Among the CONTROLS, we capture country specificities through proper dichotomous country variables, the size of the firm, which can either be small (less than 50 employees) or medium (50-250 employees) and a firm's turnover, which can either be low (TURNLOW) or medium high (benchmark).

Table 6 reports descriptive statistics of the variables of interest and Table 7 their tetrachoric correlation.

Table 6: Descriptive statistics of main variables

Stats	N	mean	Sd	Min	max
EI	1451	0.097	0.296	0	1

[14] For an appropriate reference see http://www.stata.com/support/faqs/statistics/one-sided-tests-for-coefficients/.

SIZE	1451	0.239	0.427	0	1
TURNLOW	1451	0.479	0.500	0	1
EXT_FIN	1451	0.271	0.445	0	1
COOP	1451	0.520	0.500	0	1
LOCK_IN	1451	0.356	0.479	0	1
MARKET	1451	0.423	0.494	0	1
REGULATION	1451	0.291	0.454	0	1
SUBSIDIES	1451	0.292	0.455	0	1

Table 7: Tetrachoric correlations

		1	2	3	4	5	6	7	8	9
1	EI	1								
2	SIZE	0.1487	1							
3	TURNLOW	-0.0559	-0.6797	1						
4	EXT_FIN	0.0913	0.1177	-0.1632	1					
5	COOP	-0.1041	-0.0365	-0.0288	0.3042	1				
6	LOCK_IN	0.0082	-0.0398	-0.0633	0.2532	0.3164	1			
7	MARKET	0.0238	0.1022	-0.0843	0.2583	0.2945	0.3879	1		
8	REGULATION	0.0116	0.0263	-0.1167	0.3018	0.3618	0.3759	0.3116	1	
9	SUBSIDIES	-0.0488	0.0119	-0.1542	0.473	0.4264	0.2718	0.2852	0.459	1

3.2.2 Main results

We firstly report (Table 8) the results of an explorative probit which has among its covariates the dummy variables we have created to denote the lack-of-obstacles: EXT_FIN; COOP; LOCK-IN; MARKET, REGULATION; SUBSIDIES. The main result we notice is the relation, positive and significant, between the lack of external financial constraints and the propensity to innovate. The absence of financial constraint emerges as the most relevant among the set of lack-of-obstacles variables we are analysing. The lack of significance of the other variables makes the scope for a complementarity analysis even more relevant, because in this way we can capture the role of the joint perception of lack-of-obstacles on the EI, when the external financial obstacle remains.

Table 8 – Probit results on EI as a dependent variable

	EI
COUNTRY DUMMIES	Yes
SIZE	0.041**
	(0.019)
TURNLOW	-0.018
	(0.019)
EXT_FIN	0.039**

	(0.019)
COOP	-0.027
	(0.017)
LOCK-IN	0.003
	(0.018)
MARKET	0.013
	(0.017)
REGULATION	0.008
	(0.019)
SUBSIDIES	-0.009
	(0.019)
N	1426
PseudoR2	0.070
Chi2(d.f.)	64.542(33)
p-value	0.001
Multicollinearity tests	
VIF	1.22
Condition number	6.05

Marginal effects; Standard errors in parentheses; (d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results of the complementarity tests are based on a set of 5 different probit specifications, each of which have the 4 states of the world, and the associated coefficients stemming from each couple of lack-of-obstacles dummy variables, as main covariates (Table 9).

Table 9 – Probit analysis to retrieve the states of the world coefficients: b1, b2, b3 and b4

	EI				
COUNTRY DUMMIES	Yes	Yes	Yes	Yes	Yes
SIZE	0.242**	0.196*	0.195*	0.180*	0.194*
	(0.111)	(0.108)	(0.106)	(0.107)	(0.107)
TURNLOW	-0.096	-0.151	-0.207**	-0.170*	-0.197*
	(0.104)	(0.100)	(0.099)	(0.100)	(0.101)
EXT_FIN_COOP11	-0.689***				
	(0.239)				
EXT_FIN _COOP10	-0.766***				
	(0.260)				
EXT_FIN _COOP01	-1.097***				
	(0.234)				
EXT_FIN _COOP00	-0.804***				
	(0.224)				
EXT_FIN _LOCK_IN11		-0.593**			
		(0.232)			
EXT_FIN _ LOCK_IN 10		-0.757***			
		(0.228)			
EXT_FIN _ LOCK_IN 01		-0.944***			

		(0.224)			
EXT_FIN _ LOCK_IN 00		-0.921***			
		(0.206)			
EXT_FIN _MARKET11			-0.509**		
			(0.221)		
EXT_FIN _MARKET10			-0.586**		
			(0.229)		
EXT_FIN _MARKET01			-0.816***		
			(0.202)		
EXT_FIN _MARKET00			-0.808***		
			(0.206)		
EXT_FIN _REGULATION11				-0.559**	
				(0.241)	
EXT_FIN _ REGULATION 10				-0.739***	
				(0.225)	
EXT_FIN _ REGULATION 01				-0.875***	
				(0.227)	
EXT_FIN _ REGULATION 00				-0.890***	
				(0.208)	
EXT_FIN _SUBSIDIES11					-0.665***
					(0.234)
EXT_FIN _SUBSIDIES10					-0.573**
					(0.226)
EXT_FIN _SUBIDIESS01					-0.932***
					(0.229)
EXT_FIN _SUBIDIESS00					-0.838***
					(0.206)
N	1641	1797	1826	1788	1822
Chi2(d.f.)	830.872(32)	926.897(32)	932.609(32)	922.877(32)	936.287(32)

Standard errors in parentheses; (d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Probit analysis without the constant variable, in order to get the full set of 4 coefficients for the states of the world.

The complementarity tests are reported in Table 10 and they show the existence of complementarity among several couples of 'lack-of-obstacles variables'. This evidence suggests that the various policies which might be introduced to relax the perception of obstacles are complements. Increases in the probability to eco-innovate seem to strongly depend on the joint adoption of couples of policies aiming at relaxing external financial obstacles and other specific typologies of barriers.

Table 10 - Complementarity tests: lack of Financial Barriers and Policy-Relevant Barriers.

		Wald test§ (Adj. p-vale for: H_0: coeff. 11+00 >= coeff.10+01)^	Sign of the linear combination (b1+b4)+(-b2-b3)
EXT-FIN	COOP	**3.23***	**> 0**
		(.963)	
EXT-FIN	LOCK-IN	**6.17****	**> 0**
		(.993)	
EXT-FIN	MARKET	**4.99****	**> 0**

		(.987)	
EXT-FIN	REGULATION	**4.17****	**> 0**
		(.979)	
EXT-FIN	SUBSIDIES	2.63	> 0
		(.947)	

§ Since we are testing one linear restriction at a time, the Chi2 distribution has 1 degree of freedom. Linear restrictions: H0: b1+b4-b2-b3=0; Critical values of Chi2 distribution with one degree of freedom: 6.63, 3.84 and 2.71 (***1%, ** 5% and * 10% level of significance respectively); Dependent variable: EI (Eco-innovation adoption). N=2087.

^Adjusted p-value for inequality tests when the Wald Chi2 statistics has 1 degree of freedom

(b1+b4)+(-b2-b3)≥0 is index of supermodularity

(b1+b4)+(-b2-b3)<0 is index of submodularity

Our research hypothesis of complementarity is not rejected in four cases. That is to say, 'policies oriented toward relaxing Financial constraints' result to be complementary with the following 'innovation policies':

- ✓ COOP: (relax) lack of collaboration with research institutes and universities;
- ✓ LOCK-IN: (relax) technical and technological lock-ins in economy;
- ✓ MARKET: (relax) market dominated by established enterprises;
- ✓ REGULATION: (relax) existing regulations and structures not providing incentives to eco-innovate;
- ✓ SUBSIDIES: (relax) lack of access to subsidies and fiscal incentives.

It is worth noting that these pertain to specific realms. General policies aimed at relaxing financial constraints (expansionary monetary policy, better financial market conditions, treasury bonds supporting banks in critical conditions, support to SMEs by cooperative banks, etc..), or specifically to EI, effectively integrate with actions that support firms to cooperate (e.g. tax incentives for enlarging the scale of activity, R&D funding to networks which include universities, incentives for spin offs, incentives for labelling at district area level, etc..), actions that enhance market competition. Financially oriented policies are thus complementary with environmental regulations and subsidies as expected. The recent history of renewable market expansion and contraction is largely driven by a strong public intervention which has created or generally creates the pre-conditions for banks and financial institutions to pour money into those embryonic, risky and long-term investments. The correlation is strong. What we stress here is not only that (credible) environmental regulations activate and support private markets in their support to green technologies[15], but that both environmental/fiscal/innovation policies and financially-oriented policy are necessary to support EI adoption in manufacturing SMEs.

[15] A kind of Mazzucato's hint developed around the notion of the Entrepreneurial state.

In other words, the implementation of one of these four policies might result ineffective in spurring firms' investment in EI, if a complementary policy oriented toward relaxing financial constraints to EI is not implemented as well.

3.3 Stakeholder's interviews. Main outcomes

To complement our empirical findings we carried out qualitative interviews with both firms - of different sectors- and associations in Italy. The main goal of the interviews was to understand the mechanisms through which financial constraints act in limiting EI's adoption and to evaluate the diffusion of specific funds targeted towards green economy that may (or may not) facilitate access to credits for EI's uptake.

Interviews were conducted between May 2014 and December 2014. Respondents have been contacted by email and then a meeting have been scheduled to discuss on the topic of financial constraints and EI.

The interviews we had with both firms and associations were conducted as free talks centered on a frame of pre-established questions, as reported into Box 1. Assolombarda Lombardy furthermore conducted on its associated firms 6 interviews on the same questions and provided us with their responses.

First, we conducted interviews with industry associations, to better understand the phenomena under scrutiny and to proper frame the questions for the firm-based interviews.

The first interesting pattern that emerged from interviews we had with firms industry associations is that access to credit to finance EI has no specific "green" channel: the likelihood to receive funding for an EI project is the same than for any other investment project.

In other terms, the talks suggested that the only criterion behind financial institutions choices to give or not to give credit is thus firm's credit merit, which is clearly not depending at all on the environmental aspects of any environmental project.

The first evidence is that of a lack of sensibility of the financial sector towards environmental investments plans.

Furthermore, industry associations reported that even though firms tried to access external financial sources, it usually happens that – in the absence of external financing or even when the time required for obtaining it is too high – they choose to finance their green project internally. In other words, industry associations mainly reported that – when firms strongly believe in their green investment – they usually do their best to finance it also in the absence of external sources of credit.

We then focused on the potential role of green financial instruments such as "Green or Climate Change Bonds" to supply credit to environmental projects, in particular in the absence or lack of traditional funding.

Evidence of the interviews we had with industry associations is that those instruments are known by the respondents, but their diffusion is still absent and, most importantly, those instruments are neither known nor exploited by associated firms. Firms associations have also reported their attempts to favor the uptake of such green financial instruments by sensitizing the national banking system, as so far they signal that these instruments are only feasible for big firms.

For instance, one respondent highlighted their concrete attempts to redirect the national banking system towards "smarter" financial instruments, such as Private Equity funds specialized in clean technologies and energy efficiency and outlined some events they have organized to share information on such instruments. So far, however, these attempts have not been followed by any change in the financial sector.

Lastly, an interesting element that have been outlined during our interviews with industry associations is the peculiarity of the Italian economy in terms of high dependence of Italian firms from the national banking system, which might make those firms less able to take advantage of "other" financial instruments such as those under scrutiny, i.e. Green or Climate Change Bonds, to favor more "standard" financing instruments.

These evidences have been mainly confirmed by the interviews we conducted with firms.

Most of the respondents have never heard about "green bonds" "climate change bonds", "green funds" or private equity funds specialized in clean technologies or energy efficiency. In the few cases those instruments were known, firms reported that they have however never used any of them to finance their environmental investments or innovations.

Furthermore, a confirmation that no distinction between a green investment project and a non-green investment is made in the financing mechanism has been found. This is consistent with the similarity of results in quantitative analyses between innovation and EI.

Also firms reported that the environmental content of an investment project was not evaluated to determine whether to supply funding or not. In other words, the financial system seems to be totally detached from the environmental content of any innovation project. Consequently the transition towards a green economy does not seem to be supported at all by the financial sector.

Clearly another last step has to made to understand the role of finance as a driver or barrier to environmental innovation. This is to investigate how firms are used to finance their environmental investments and whether they were/would have been able to finance it internally in the case of lack of liquidity.

In other terms, we then tried to understand whether the afore described system is a concrete limit for EI uptake – finance is a barrier to EI - or, on the contrary, whether the tendency is to innovate also in the absence of credit – finance is not a real barrier to EI.

Intuitively, the expectation is that the lack of access to external finance is a higher limit to EI the greater is the overall lack of liquidity. When the firm cannot afford to finance its EI

project in other ways, for instance by recurring to internal funding, then the financial barrier will be greater than in firms with internal availability of funds to invest in EI projects.

This expectation has been mainly confirmed by our interviews, but some distinctions have to be made.

In the case of small and medium firms access to external credit actually is a limit to EI adoption.

When we move to interviews with bigger firms, the main evidence seem to be that EI investments would have been financed anyway, i.e. also in the absence of external funding.

In such cases, investment projects were mainly devoted at increasing energy efficiency, which is an environmental improvement but it also engenders a positive economic return. Consequently, firms choices to commit resources into such projects were motivated by the economic impacts as well, in a way that a) their investment decisions were independent on the availability of external funding and b) the expect returns of the investments were high enough for banks to give them findings but also c) in the absence of external funding firms were able to allocate internal resources to these investments, as they were seen as strategic for the firm[16].

A further distinction has to be made with respect to multinational firms, for whom decisions and financing of innovation projects is made by the mother company, so that subsidiaries do not face financial constraints for EI and do not perceive financial barriers to EI as relevant at all.

Interestingly, we also faced a case in which respondent answered that "access to credit is not a problem at all: we have never faced problems in getting our investment projects financed by banks (…) we are in good relationships with banks". This firm has furthermore received a consistent access to credit, in the absence of which some of the (many) environmental investments would not have been feasible for the magnitude of the investment required.

Lastly, we had a talk with financial experts to assess the diffusion, in Italy, of these instruments, which confirmed previously outlined evidences: green bonds might help the transition to the green economy but they a) still respond to financial (rather than environmental) requirements and b) in Italy their diffusion is still scarce. To be signaled is the case of the Italian operator "Hera Group", which has launched in June 2014 a 500 mln euro green bond.

Overall the interviews helped us to better frame the empirical evidences and complements quantitative analyses.

[16] Complementary evidence can be found in Ghisetti and Rennings (2014), in which it is highlighted that different typologies of EI create differential profitability gains and that, in particular, innovations that lead to energy efficiency or material savings do have positive economic returns for firms adopting them.

The first results of the interviews is that a big heterogeneity is at stake in the way financial constraints act on EI adoption. Furthermore, this heterogeneity is not fully explained by sectorial differences, as, in some cases, it was mainly dependent on firm structural and managerial characteristics.

These are actually difficult to be captured into empirical analysis, and they do support the need to complement empirical analysis with qualitative interviews.

Whereas we concluded –from the empirical analysis- that financial constraint do matter in limiting EI's adoption in SMEs, this is only partially confirmed by the interviews we conducted.

Firms' perception of the role of financial constraints and firms' possibility to get funds for environmental investments depend on the nature of the firm as well on firms' economic performances. Better performing firms are more likely to have a good credit merit and thus to receive more funding. But, at the same time, these firms are also more likely to be able to finance their EI projects anyway, i.e. also in the absence of external funding. On the contrary, smaller or worse performing firms are less able to get access to credit, while at the same time they are not able to finance an EI project in the absence of credit.

More interestingly, our interviews suggested that no distinction exists in terms of the relevance of the financial barriers when a firm chooses to innovate vs eco-innovate, as no specific green channel of finance seems to be at stake. This last evidence is strongly supported by all the interviews we conducted and – in our opinion – this is a key starting point to derive proper policy implications. Building a proper channel for giving value to the environmental content of a project, so to increase the probability that a project with a high environmental potential gets credit, would undoubtedly favor the uptake of EI. The role of "green bonds" or similar instruments is however unclear so far, as we were not able to find any firm who have ever used them.

Box 1 Frame of questions for interview

1. ***Financial constraints.***

Does the limited access to external financing constitute a concrete limit for the development or adoption of EI in your firm/for your associated firms [we defined EI according to the MEI project definition (Kemp & Pearson, 2007) or, alternatively, do you finance your EI activities internally, independently on the presence of external financing?

To deeply understand the question we asked firms to describe their R&D expenses, to state if they have a dedicated environmental R&D and, for energy intensive firms, what is the share of energy expenditures with respect to their cost structure.

2. ***Financial instruments***.

Have you ever heard about external financing instruments such as "Green Bonds"; "Climate Change Bonds? Have you ever used them to finance your EI/ have your associated firms ever used them to finance their EI?

Box 2 Interviews conducted

Firms	**Sectors**
BASF	Chemicals
Sicem Saga	Pulp and paper
Florim	Ceramics
Italgraniti	Ceramics
Gaiamobili	Ceramics
Association	
Confindustria Emilia Romagna	Manufacturing association
Federchimica	Chemicals
Assolombarda Lombardy* 6 interviews on anonymous firms carried out by this association	Manufacturing & services
Banking and Finance	
Financial economists and experts	Finance

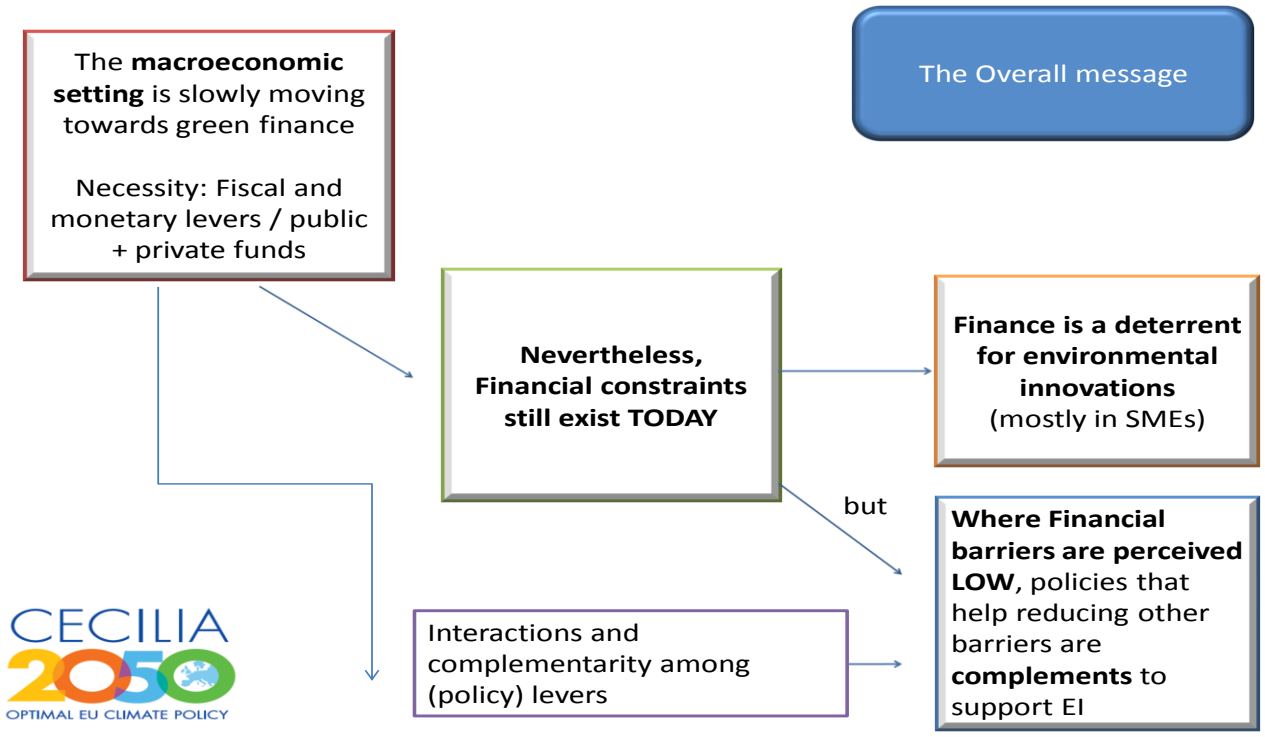

Figure 3 – The Overall message

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Appendix

Table A1- Results by (other) sectors Step 1

	(1) Filtered Agriculture & Fishing	(2) Filtered Water & Waste	(3) Filtered Food Service
TEC_LOCK	0.5177*	0.2361	0.1626
	(0.2899)	(0.4536)	(0.3956)
UNCERTRETURN	0.2232	0.2765	0.5921
	(0.3196)	(0.5225)	(0.3998)
UNCERTDEMAND	0.0413	0.3263	0.4008
	(0.3219)	(0.4695)	(0.3869)
MARKET	0.4192	-0.2423	0.4331
	(0.2970)	(0.5060)	(0.3669)
SIZE_MEDIUM	-0.0638	-0.6639	-0.4877
	(0.3213)	(0.4660)	(0.5480)
REG	0.3817	0.5990	0.9350**
	(0.3013)	(0.4729)	(0.3803)
INC	0.8438***	1.1395**	0.8355**
	(0.3051)	(0.4676)	(0.4009)
FUT_ENPRICE	-0.2308	0.1330	-0.6427
	(0.4582)	(0.7374)	(0.8669)
FUT_REG	-0.9881**	0.0042	-0.1774
	(0.4292)	(0.5424)	(0.4548)
Constant	0.7327	-0.9027	-0.0178
	(0.5470)	(0.7677)	(0.9348)
N	327	122	221
pseudo R^2	0.085	0.106	0.161
AIC	342.2930	162.5517	220.2967
BIC	380.1926	190.5919	254.2783

Results by (other) sectors Step 2

	(1) Filtered Agriculture & Fishing	(2) Filtered Water & Waste	(3) Filtered Food Service
eFIN	0.2445	4.6300	-1.4278
	(1.5315)	(4.3409)	(2.1217)
SIZE_MDIUM	-0.1614	0.7603	0.0562
	(0.3007)	(0.8091)	(0.5235)
TURNLOW	-0.6508**	-0.6792	-0.4653
	(0.2631)	(0.4506)	(0.3573)
MARKET	-0.2467	-0.4632	-0.5108
	(0.2795)	(0.4749)	(0.3520)
INT_KNOW	0.2209	-0.4212	0.1169
	(0.2418)	(0.4693)	(0.3157)
EXT_KNOW	-0.3367	0.6104	0.0139
	(0.2627)	(0.5218)	(0.3604)
DEMAND	0.5045*	1.0731**	0.6653*
	(0.2908)	(0.4969)	(0.3688)
REG	-0.0831	-0.6728	0.2457
	(0.2874)	(0.8344)	(0.5140)
INC	-0.1898	-2.3913**	-0.1699
	(0.3605)	(1.1750)	(0.5751)
Constant	0.6080	-0.6833	1.3132
	(0.9615)	(1.7905)	(1.1306)
N	327	122	221
pseudo R^2	0.031	0.109	0.044
AIC	450.4072	161.0757	310.4892
BIC	488.3068	189.1159	344.4708

Tab A3 (statistics on all sectors, extension of table 1)

Variable	N	mean	Sd	Min	Max
EI	4737	0.442474	0.496732	0	1
External_Fin	4737	0.556681	0.496829	0	1
TEC_LOCK	4737	0.526705	0.499339	0	1
UNCERTRETURN	4737	0.661389	0.473287	0	1
UNCERTDEMAND	4737	0.6692	0.470551	0	1
SIZE_SMALL	4737	0.79354	0.404807	0	1
SIZE_MEDIUM	4737	0.20646	0.404807	0	1
TURNLOW	4737	0.527338	0.499305	0	1
MARKET	4737	0.510239	0.499948	0	1
EXT_KNOW	4737	0.538738	0.49855	0	1
INT_KNOW	4737	0.515094	0.499825	0	1
INC	4737	0.605235	0.488852	0	1
REG	4737	0.593836	0.491168	0	1
FUT_REG	4737	0.73612	0.440782	0	1
FUT_ENPICE	4737	0.840194	0.366465	0	1
DEMAND	4737	0 .689888	0 .462588	0	1