SPRU Science Policy Research Unit

# Working Paper Series

SWPS 2017-24 (November)

# Resource Efficiency, Environmental Policy and Eco-Innovations for a Circular Economy: Evidence from EU Firms

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UNIVERSITY OF SUSSEX

## SPRU Working Paper Series (ISSN 2057-6668)

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# Resource Efficiency, Environmental Policy and Eco-Innovations for a Circular Economy: Evidence from EU Firms

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**Abstract**. Innovation adoption and diffusion by firms are key pillars for the EU strategy on resource-efficiency and the development of a circular economy. This paper presents new EU evidence regarding the role of environmental policy and green demand drivers to sustain the adoption of resource efficiency-oriented eco-innovations. This paper originally implements new estimators to address the endogeneity of binary framed policy and demand covariates, which typically characterise firm level survey data. Our results suggest that when endogeneity is accounted for, environmental policy is the only factor always significant in driving the adoption of innovations that reduce the use of waste and material, while demand-side and market-factors do not always play a central role. The result is an important piece of new quantitative-based knowledge, which complements the currently large case study-based evidence on the setting of sound management and policy strategies for the circular economy.

**Keywords:** Eco innovation; circular economy; innovation drivers; EU; environmental regulation; market demand

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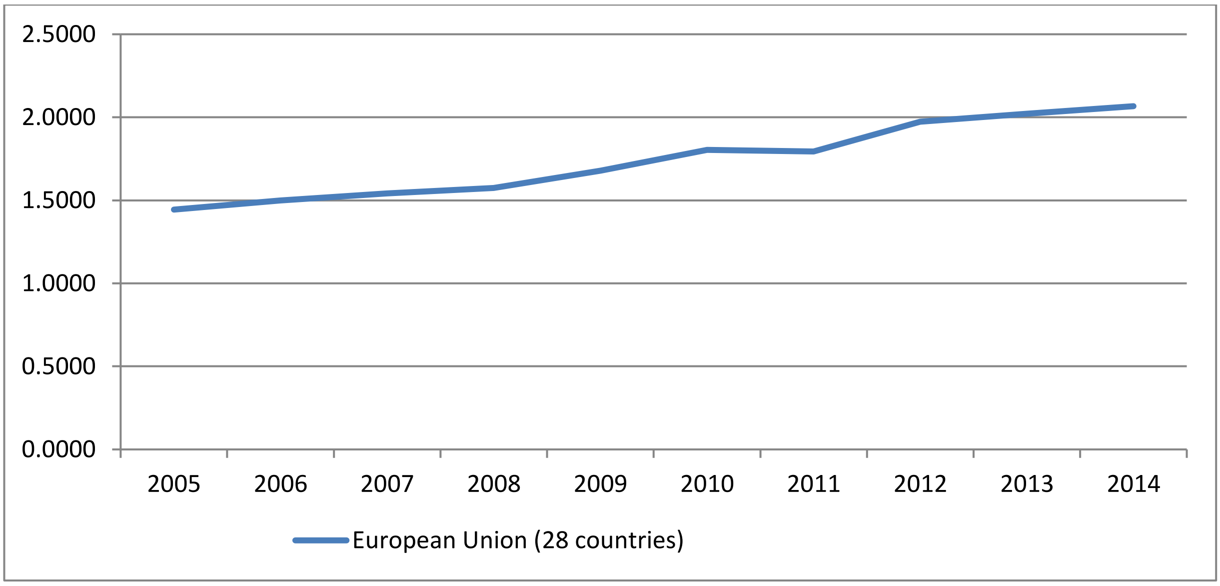
[1] SEEDS – www.sustainability-seeds.org. We kindly acknowledge precious comments we received by an anonymous reviewer on a previous version.

# 1. Introduction

In December 2015, the European Commission launched its action plan for the circular economy (CE) with the aim of unlocking the growth and jobs potential of the CE and boosting EU competitiveness through new business opportunities and innovative means of production and consumption that overcome resource scarcity and the volatility in material prices (EC, 2015). The decoupling of the economy, an increase in economic value, while decreasing resource use, depends on innovation and structural change factors (OECD, 2010; UNIDO, 2011). It follows that the transition to a CE is highly influenced by the composition and innovation intensity of the economy, the evolution of new green markets, and by the environmental and industrial policy settings.

In the EU, the indicator of resource productivity has been increasing between 2005 and 2014 (see Figure 1). However, the aggregate EU data are affected by the performance of countries (such as Hungary, Czech Republic and Latvia) that are laggards in terms of resource efficiency and show values of the indicator below 1.00 in 2014 (by country results available on request). Heterogeneity is high as in many other environmental realms that are linked to resource efficiency and environmental management (EEA, 2014).

Figure 1 – Resource Productivity in the EU (GDP per unit of material resources used in production - €/kg)




Source: own elaboration on EUROSTAT data

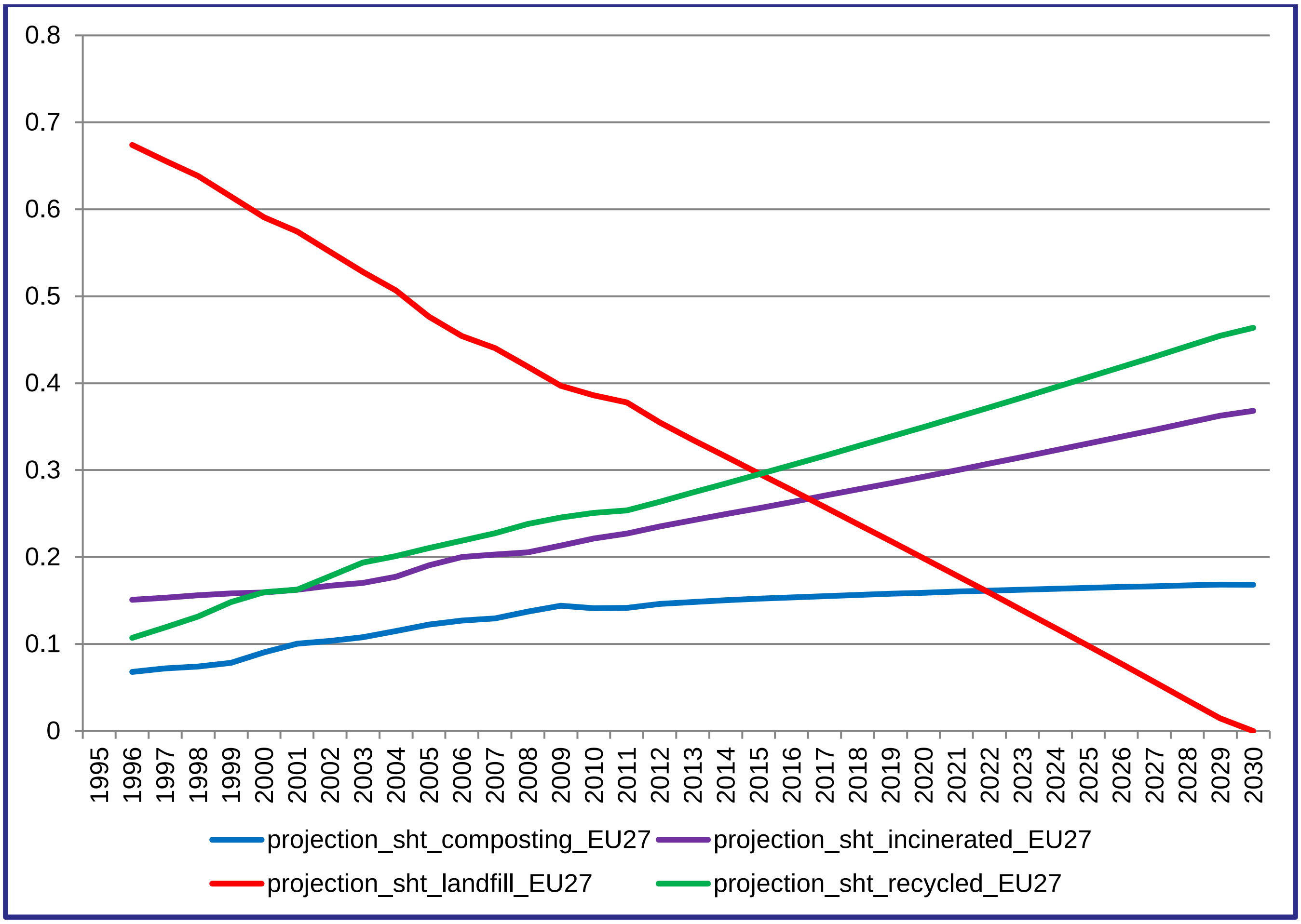
Innovation is among the relevant factors behind resource productivity (Mazzanti and Zoboli, 2009). Conceptually, the IPAT (Impact≡Population-Affluence-Technology) identity shows how Green technological development (resource/emission efficiency of production) can compensate scale economy-driven effects (Marin and Mazzanti, 2013). Given the heterogeneity of technological and environmental performances across sectors, the understanding of the underlying forces requires in-depth meso and micro-level analyses, which unveils the macroeconomic determinants (UNIDO, 2015).

Although innovation is commonly regarded as the most effective response to sustaining current standards of living while overcoming serious environmental concerns (EEA, 2014), a broad picture of the innovative potential in the field of resource efficiency (RE) and CE-related technologies remains lacking. Innovation adoption and diffusion research also adds knowledge to relatively more widely investigated issues, such as inventions. Hall and Helmers (2011), among others, have observed how patents in the waste realm have decreased over time, probably due to a weakening effect of policies (OECD, 2011). In a firm and sector level study, Albrizio *et al.* (2016) focus on green inventions and performances, noting that, "there are various problems of using patents as a proxy for innovation (...) Most "innovations" are not patented (…) most firms in the population do not patent at all (in our sample, just over 1% of firms patent in each year)" (p. 216). The authors also suggest that environmental policy effects through patented (and/or break-through) innovation occur only after long-time periods. The question of what drives technology adoption related to resource-efficiency therefore remains open and can provide new considerations for policy makers.

Maintaining pace with the ongoing improvements in recycling dynamics is indeed crucial, but the reduction of waste production is increasingly recognised as central[2]; process, marketing and product innovations are crucial to the fulfilment of the CE strategy (EEA, 2016). The CE path is intrinsically driven by the consolidated waste pattern, which moves away from disposal and towards better waste management and prevention of waste production. Figure 2 exemplifies the long-run expected policy driven evolution of waste trends, which relate to the opening of new markets and new technologies. The consumer side is also relevant for this development. For example, existing studies suggest that consumers are willing to pay 5-10% more for products with recycled packaging (EMF, 2015).

[2] Recent *Estimates are that 500 million tons/year of materials in waste waiting to be circulated back to the economic system* are potentially exploitable (http://www.emininn.eu/). This finding is a somewhat radical change that leads to winners and losers. The net benefit that arises from the reorganisation of the international value chain is now unclear and is scoped for further research. The analysis of innovation adoptions is a piece of the set of analyses around the role of innovation and structural change in the circular economy transition. 'Waste based value chains'' evolution play a pivotal role, as well as the involved sectors, among others that use waste as inputs, such as the following: paper and paperboard, wood-based panels, renewable energy sources, and metals. Global plastic packaging value chains are another example; without product redesign and innovations, 30-50% of plastics will never be used (EMF, 2015).

Figure 2 – Waste trends in the EU (expected patterns, % of total waste generation)




Elaborations conducted within the activities of the WMGE EEA Topic centre activities (http://www.eionet.europa.eu/etc-wmge)

Enhanced waste-based value chains are frameworks where innovation may arise. A compelling example is Biofuels Ltd, a Finnish firm that focuses on the decentralised production of fuel bioethanol in Finland using side streams from the food industry and from domestic waste[3].

Although waste is an important part of it, the CE realm extends far beyond the waste realm; it is linked to energy-related issues (e.g., waste to energy) and to bio-economy areas (e.g., bio-engineering). CE may be viewed as a business and policy strategy that targets the redesign of

[3] Specifically, through new processes (called Etanolix for food waste and Bionolix for domestic waste), the waste is converted into an ethanol (85%)-water (15%) mixture at food industry sites, then the ethanol is concentrated/dried to a purity of 99.8% in a dehydration facility.

production and consumption through pervasive technological and behavioural changes that revolve around new (uses of) materials and products (EMF, 2015).

Case studies and examples originate from many different sectors. There may be examples from 'old economy' industries that innovate, such as sustainable fashion industries that reutilise materials and old clothes and key materials such as glass that may be reused to build cement[4]. Key old economy sectors such as automotive may play a role by integrating organisational and technological innovations. A famous case-study is the French Choisy le roi automotive plant (Renault) working on remanufactured parts. The new reorganised and fully reshaped plant consumes 80% less energy, 88% less water and 92% less chemical products and produces 70% less waste. Waste is barely landfilled; 43% of the carcasses are re-usable, and 48% are recycled in the company's foundries to produce new parts. The remaining 9% is valorised in treatment centres.

Radical innovations can derive from emerging start-ups. REEP Tech Ltd, an Israeli start up, invented a scanner system that processes printed paper; the scan tool deletes existing text or figures from printed paper, which can thus be reused in printers again, and saves the written information as a file in a cloud archive. Dry Phase Patterning is another potentially path breaking technology for electronic circuits; the new process is based on mechanical machining of the material, rather than on the traditional use of chemical etching[5]. Finally, Acre Display is a thin, creatable, biodegradable electrochromic display that is produced with conventional printing processes; packaging and display printing can be performed simultaneously[6].

These examples suggest that a wide technology adoption process related to the CE is occurring, particularly in the EU. Our capability of governing this process is based on a proper understanding of the related determinants; this is what we do in this paper. We present new EU evidence on the role of environmental policy and green demand drivers to sustain the adoption of resource efficiency oriented eco-innovations (Mazzanti and Zoboli, 2006; Kemp and Pontoglio, 2011 for surveys on eco-innovations). We exploit a large European dataset on manufacturing and services firms, namely EU data from the Community Innovation Survey CIS5, the first wave that hosted a proper section on environmental innovation adoptions and adoption motivations (Mairesse and Mohnen, 2010)[7]. Specifically, we focus on three types of environmental innovations closely related

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[4] Several real-life examples are available at https://www.ellenmacarthurfoundation.org/circular-economy.

[5] See http://www.dppatterning.com for details.

[6] Applications of this technology potentially include screen printed labels, low-end displays with short usage time, medical diagnostics, labels for perishable foods, labels for logistics tracking and smart cards. See https://www.acreo.se/expertise/acreo-display.

[7] Data are gathered from the Cd-rom Eurostat source (scientific use files) through a formal agreement between Eurostat and the University of Ferrara for research purposes. It is worth noting, quoting Eurostat "How to apply for microdata?" document by the EC and Eurostat (January 2017) that 'Most microdata sets released by Eurostat are partially anonymised. In addition to removing direct identifiers from the records, some variables

to a CE-oriented approach and to resource efficiency: (i) reduced material use per unit of output; (ii) recycled waste, water, or materials and (iii) improved recycling of product after use.

Focusing on these three EI variables, our aim is to provide new insights within the literature on innovation adoptions with a focus on the CE. This literature intrinsically relies upon survey data (Cassiman and Veugelers, 2004; Mairesse and Mohnen, 2010). We also take stock of recent works on environmental innovations, with the aim of extending the scope and finding more robust estimates addressing for endogeneity.

Among others, Veugelers (2012) and Borghesi *et al.* (2015), while not specifically focusing on resource efficiency-oriented innovations, present evidence from single countries and do not cope with endogeneity. Cainelli *et al.* (2015) and Managi *et al.* (2014) attempt to deal with endogeneity and focus on resource-efficiency but again offer only single country-based evidence. Other contributions focus on the EU (Ghisetti *et al.*, 2015), again with a general objective of analysing all environmental innovations, without addressing the endogeneity issue. This paper instead exploits EU data, focusing on the relationships between policy and demand factors as levers of resource-efficiency innovations. In so doing, it implements new estimators to address the endogeneity of binary-framed policy and demand covariates, which typically characterise firm's survey data. Mairesse and Mohnen (2010) discuss in detail the intrinsic endogeneity issue in survey data. While the construction of dynamic model and panel data through repeated surveys is a way to mitigate endogeneity, the occurrence of repeated surveys is rare, particularly in the environmental realm. This paper addresses this problem using instruments taken from external statistical sources.

The results interestingly report the central role of policies in driving the transition towards a full CE implementation. Conversely, we show that moving down the life cycle of goods, namely to the after sales use, an appropriate addressing of endogeneity issues implies that demand disappears from the set of drivers of the circular economy that are related EI.

The paper is structured as follows. Section 2 presents the theoretical background and the relevant literature. Section 3 comments on the data and the empirical model and elaborates the main econometric results. Section 4 concludes.

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are further anonymised, i.e. grouped together, aggregated etc. This sometimes limits the usage of microdata' (http://ec.europa.eu/eurostat/web/microdata/overview). In our case, limitations exist when using continuous variables such as turnover or employment. The paper nevertheless analyses innovation functions through exploiting binary variables (besides external IVs). Works on production functions should rather rely on estimations based on the alternative safe data centre in Luxembourg (non anonymised data).

## 2. Theoretical background

Under a theoretical perspective, our research questions link to different strands of the literature. The link between regulation and incentives to innovation (and, specifically, adoption) is the subject of two main strands of research.

Firstly, the work is connected to contributions from the literature on the incentives by firms to invest in environmental innovation (EI) adoption to reduce compliance costs and/or emissions (Milliman and Prince 1989, Downing and White, 1986)[8]. The associated contributions suggest that the chosen environmental policy instruments and their design can be crucial in determining adoption and innovation incentives in general. However, there is substantial agreement on the conclusion that stricter environmental regulation is expected to increase adoption incentives, although recent work appears to cast doubts with respect to specific technologies or environmental policy tools (Perino and Requate, 2012).

The second field of analysis is related with to the so-called "Porter Hypothesis", which stresses the potential virtuous link between environmental regulation and competitiveness (Ambec *et al.* 2012; Costantini and Mazzanti, 2012). In the original formulation (Porter, 1991 and Porter and van der Linde, 1995), such theoretical conjecture suggests that more stringent environmental policies do not (necessarily) cause a loss of competitiveness. On the contrary, an improvement in productivity or profits may result for regulated agents. The underlying mechanics are based on the positive potential impact environmental regulation may have in boosting productivity, efficiency and improvements in organisational or product/process innovations. An underlying hypothesis is that there are reasons preventing firms from fully exploiting their efficiency or technological potential; under this assumption, regulation triggers improvements by making inefficient behaviours costlier, creating a potential *win* situation[9].

Although the theoretical bases of these two strands of literature differ, there appears to be agreement on the potentially positive impact of environmental regulatory stringency on the incentives of regulated firms to adopt cleaner technologies. We expect this finding to also apply in a CE setting. Although the CE strategy does not set specific binding targets, as done for climate change, the overall objective is to reduce the use of materials and resources in the production and consumption phases.

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[8] For an excellent survey, see Requate (2005).

[9] Jaffe and Palmer (1997) and Kozluk and Zipperer (2015), among others, suggest different possible definitions for the Porter Hypothesis (PH). According to the "Weak" PH, environmental regulation stimulates innovation by placing constraints on regulated firms. A "Strong" PH suggests that regulation is not only able to spur innovation, but also that this gain in efficiency completely offsets any loss in competitiveness. Finally, a "Narrow" PH highlights the relevance of policy design in stimulating innovation.

Consequently, if regulated firms perceive a more stringent commitment towards environmental objectives, our conceptual framework suggests that more EI adoption will occur:

**Testable Hypothesis $H_1$.** *Stricter environmental regulation boosts the adoption of cleaner technologies.*

Our second research question addresses the role played by market conditions, the most prominent being market demand, on the incentives to adopt cleaner technologies. Horbach et al. (2012) identify "market pull factors" as potential drivers of eco-innovation incentives. Among these factors, an important role is played by customer benefits (Kammerer, 2009), such that, indeed, market demand for green goods can, in principle, drive eco-innovation (e.g., van den Bergh, 2008). Although certain doubts are cast on the robustness of this conclusion (see, again, Horbach *et al.*, 2012), it appears to be confirmed by more recent contributions (see, among others, Dangelico, 2015). This finding leads us to our second testable implication.

**Testable Hypothesis $H_2$.** *Market demand for "green" products is expected to encourage eco-innovation adoption.*

# 3. Dataset and econometric modelling

## *3.1. Dataset*

Our empirical analysis uses statistical information at the firm level taken from the European Community Innovation Survey (CIS). We consider a sample of approximately 48,059 service and manufacturing firms for the 2006-2008 period. These firms are located in nine different European countries: Portugal, Estonia, Hungary, Sweden, Lithuania, Germany, Italy, the Czech Republic, and Romania[10]. The coverage reflects the focus of the analysis on CIS data by Ghisetti *et al.* (2015). It is useful to remember that the data collected in this survey are self-reported information by respondents and thus has not an objective nature as in the cases of information drawn from other variables such as patents.

[10] These countries are selected according to data availability. Conversely, these countries can be considered representative of the whole environmental innovative activities of the kind under scrutiny in this paper. Indeed, the involved countries represent between 73.15% (ECOREC) and 77.29% (ECOREA) of all eco-innovation in the manufacturing sector, according to Eurostat data (extracted 2/5/2017).

## *3.2. Econometric modelling*

In our econometric specifications, we estimate the following equation (Horbach, 2008; Cainelli *et al.*, 2015; Veugelers, 2012):

$$Y_i = f(\mathrm{ENREG_i}, \mathrm{ENDEM_i}, \mathbf{X}_i)$$

where $Y_i$ is a dummy variable that takes the value 1 if a firm *i* introduces an EI and 0 otherwise. $\mathbf{X}_i$ is a set of control variables including: (i) RRDIX which is a dummy taking value 1 if the firm undertake in-house R&D ; (ii) BGROUP is dummy taking value 1 if the firm belongs to a business group; (iii) C_HO is dummy taking value 1 if the head office of the business group is located in the same country of the firm (iv) MARLOC, MARNAT, MAREUR and MAROTH are dummy variables taking value 1 if the geographical market of the firm is respectively local, national, European or global (MARLOC is the reference dummy); (v) EURO is a dummy variable that takes value 1 if the country where the firm is located is within the Euro area. Finally, we also control for firm size and industry characteristics.

Our dependent variables, which capture EI, are ECOMAT (environmental benefits from the production of goods or services within an enterprise, which is measured as reduced material use per unit of output), ECOREC (environmental benefits from the production of goods or services within the enterprise, utilising recycled waste, water, or materials) and ECOREA (environmental benefits from the after sales use of a good or service by the end user, measuring improved recycling of product after use)[11]. These three variables are adopted as technological EI targets to improve the performance of products and processes in a manner that is compatible with a CE based-view. See Figure 3 for a sketch of the dependent variables at the EU level.

[11] The analysis is repeated for three types of environmental innovation, relating to material intensity of production (ECOMAT), goods or services produced using recycled resources or materials (ECOREC) and improved recycling of product after use (ECOREA). The elicitation is carried out by Question 10.1 in the 2008 CIS Survey questionnaire (http://ec.europa.eu/eurostat/web/microdata/community-innovation-survey): "During the three years 2006 to 2008, did your enterprise introduce a product (good or service), process, organisational or marketing innovation with any of the following environmental benefits?" The difference is that the first two dependent variables refer to environmental benefits in the production of goods and services, while ECOREA to the after sales use of goods and services.

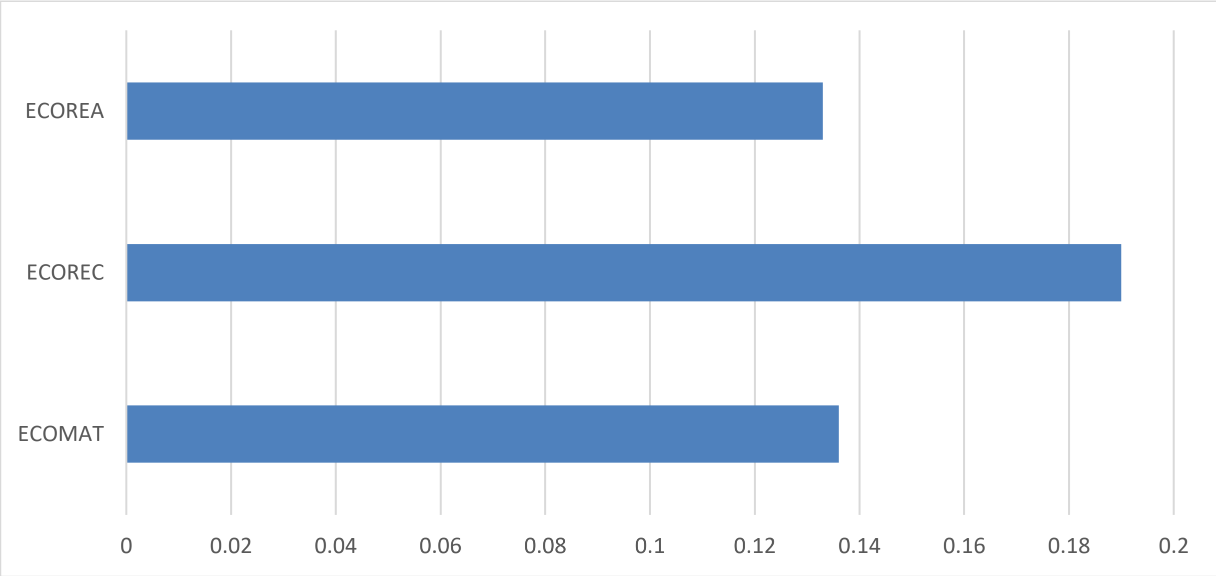


Figure 3 – Resource efficiency innovation adoption in the EU (CIS5 data) – share of firms[12]

Our two main explanatory variables are linked to "existing environmental regulations or taxes on pollution" (ENREG), to test hypothesis $H_1$, and "current or expected market demand from your customers for environmental innovations" (ENDEM)[13], to test $H_2$. The summary statistics are reported in Table 1.

**Table 1: Descriptive statistics**

| | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| ECOMAT | 0.136 | 0.342 | 0 | 1 |
| ECOREC | 0.190 | 0.392 | 0 | 1 |
| ECOREA | 0.133 | 0.339 | 0 | 1 |
| ENREG | 0.168 | 0.374 | 0 | 1 |
| ENDEM | 0.096 | 0.295 | 0 | 1 |
| RRDIN | 0.160 | 0.367 | 0 | 1 |
| BGROUP | 0.246 | 0.431 | 0 | 1 |
| MARNAT | 0.655 | 0.475 | 0 | 1 |
| MAREUR | 0.381 | 0.485 | 0 | 1 |
| MAROTH | 0.197 | 0.397 | 0 | 1 |
| C_HO | 1.078 | 1.230 | 0 | 1 |

[12] The three variables appear to describe somewhat different innovations, although they are correlated. Correlations among the three are between 0.25-0.34. All correlations for the set of independent variables are available on request. The correlations do not present very high values. The appendix presents maps of firms adopting those kind of EI in the EU.

[13] ENREG and ENDEM are two of the questions within the general 10.2 question in the 2008 CIS survey questionnaire "During 2006 to 2008, did your enterprise introduce an environmental innovation in response to:". Dependant and independent variables are selected out of the CIS2008 to provide original specific insights on policy and market drivers of resource efficiency/waste oriented innovation adoptions.

We estimate our main specification using two different econometric methodologies: (1) a probit model and (2) a linear probability model (LPM) with instruments. First, we estimate our equation with a simple probit as usual in this literature. This estimator is not appropriate if (potential) endogeneity problems arise with reference to our two main regressors: the regulation and the market-demand variables. Therefore, we decide to estimate our baseline specification using a linear probability model (LPM) with instrumental variables. We instrument our two main explanatory variables (ENREG and ENDEM) with two different instruments: (i) the election participation (*lelection*) at the country level during the 1995-2000 period and (ii) the blood donations at the country level for the year 2009 (*lblood*). With regard to the second instrument, we use information at country level taken from the Eurobarometer survey commissioned by the European Commission on the following question: “Have you given blood before?”. Some papers showed that blood donation is a good proxy for social capital. The idea behind the choice of these two instruments is that in countries where political participation and social capital are higher the sensibility towards environmental policies and the demand for environmental innovations should be greater. We are conscious that these two instruments could be criticised but in our opinion they constitute a possibility which must be seriously taken in account. The main reason is that these two explicative variables are endogenous. In fact, the endogeneity of these two variables – ENREG and ENDEM – is tested using the Wu-Hausman and the Durbin-Wu-Hausman tests. Both these statistical tests confirm that ENREG and ENDEM are endogenous.[14] This means that we need to instrument these endogenous explanatory variables. In addition, for all our three estimates the first-stage F statistic on excluded instruments is larger than 10. As is known this test allows us to reject the null hypotheses  of weak instrumentation.

## 4. Empirical results

Tables 2-4 report the econometric evidence for the three dependent variables of our model. We begin with Table 2, where we show the empirical results in relation to ECOMAT (environmental benefits from the production of goods or services within the enterprise, reduced material use per unit of output). As it clearly emerges, the existing environmental regulations and/or fiscal duties on pollution (ENREG) significant and positively explains the adoption of innovation by firms; $H_1$ is not

[14] The recent econometric literature has suggested another estimator that can be used when the outcome variable is a dummy and the endogenous regressors are not continuous; this is the special regression method (SRM), first proposed by Lewbel (2000) and then implemented by Dong and Lewbel (2015). As is known, this approach assumes that the model includes a particular regressor, the special regressor V, with three properties: (a) it is exogenous and appears as an additive term in the model; (b) it is continuously distributed; and (c) it has a thick-tailed distribution, although this hypothesis is not strictly necessary. Unfortunately, in our dataset, we have no variable with these characteristics.

rejected. In addition, ENDEM is significant in explaining increases in EI related to reduced material use per unit of output; consequently, our testable hypothesis $H_2$ is not rejected. In addition, the other key factors behind innovation are in-house R&D (RRDIN) and countries belonging to the Euro area (EURO). Interestingly, other market-related factors do not appear to play a crucial role in driving eco-innovations; for example, belonging to a business group appears to not be relevant. Instead, the factors imply a (small but significant) decrease in EI adoption. The results reported in Table 2 are, for our purposes, robust to the adoption of a LPM with instruments. The sign and statistical significance of coefficients associated with ENREG and ENDEM are confirmed. Therefore, our testable hypothesis cannot be rejected when focusing on material saving EIs. On the contrary, the control variables that refer to reference markets (as described by dummies MARNAT, MAREUR and MAROTH) are no longer significant when adopting an IV approach.

Table 3 (first column) shows similar results for ECOREC (environmental benefits from the production of goods or services within the enterprise, recycled waste, water, or materials). This innovation refers to recycling strategies, the core of the first wave of waste policies in the EU. ENREG and ENDEM maintain their significance and sign. The same holds with respect to R&D and belonging to a group. In contrast to the ECOMAT case, when addressing EIs related to recycling, the reference market can indeed make a difference; in our DProbit estimate (column 1 in Table 3), firms exporting in the European market are also characterised by a lower EI likelihood. Things change when we adopt an IV LPM approach (second column in Table 3); ECOREC appears less relevantly related to the necessity of absorbing innovation by means of internal research and knowledge pools, and such internal R&D effort becomes negative in explaining the presence of EI adoption. All dummies related to reference markets (National, European, other global-like markets) imply a decrease in EI oriented to recycling, which signals the relevance of localised economic markets. This implication highlights that at least in the first phase of the waste/material-related innovation adoption wave, local markets are dominant with respect to firm's strategies (Cainelli *et al.*, 2015). This statement is coherent with the relatively local public good flavour of waste externalities and the decentralised management of such environmental issue.

However, ENREG and ENDEM, our variables of interest, retain their sign and significantly explain adoption. In sum, external (policies and demand) phenomena are at play, while other internal (R&D) and market-related factors do not have a straightforward impact.

It is worth noting that while the negative sign related to in-house R&D is explainable by general R&D investments targeted to general innovations (firms with R&D, which are, on average, larger in size, tend to focus on general non-eco innovations), the literature on EI has seldom shown very robust and constant (across datasets and sectors) significant roles for R&D among the drivers or shows correlated factors[15]. Among others, the seminal paper on eco-innovation drivers by Horbach (2008) places R&D on the supply side factors that enhance technological capabilities. For Germany, he finds significant R&D effects behind environmental product innovation adoption (German establishment survey), while in other estimations (Mannheim Innovation panel), R&D does not significantly explain the adoption of 'general' environmental innovations with medium/high effects on the health and environment. For Germany, Frondel *et al.* (2008) find that (environmentally oriented) R&D is not one of the 'facility characteristics' that explains the adoption of abatement technology. The presence of dedicated staff who manage environmental issues and the necessity to reduce environmental impacts are more relevant and significant factors. Cainelli *et al.* (2012) focus on a regional system; they also find certain negative and insignificant effects regarding the presence of R&D. The researchers note that 'R&D is too far a generic and weak innovation commitment to enhance the adoption of EIs. While it may be found significant in increasing the firm knowledge base and its absorptive capacity, other techno-organisational internal features are possibly required to complement better the adoption of EI' (p. 718). Finally, a more recent paper by Borghesi *et al.* (2015), in a study that analyses the effects of the EU emissions trading on energy and climate change innovations, finds very mixed evidence about the R&D significance. In certain cases, negative, although not significant, coefficients also arise. Overall, the researchers note that general R&D is relevant for enhancing the capacity to absorb and adopt innovation from the market. More radical innovations may need specific forms of R&D and/or specific cooperation with other firms or research institutions (Cassiman and Veugelers, 2003).

Given that resource use, material use and waste are largely environmental public goods with local effects and decentralised territorial management and policy governance, the unexpected relevance of international effects does not surprise (the questions refer to 'within your enterprise' innovation benefits). With respect to resource and waste management, firms generally fail to internalise impacts that are far from their boundaries. ECOREC and ECOMAT present expected similar results; both recycling and material use refer to consolidated resource efficiency firms' strategies that were previously pushed ahead in the mid 90s.

Table 4 reports the findings for ECOREA (environmental benefits from the after sales use of a good or service by the end user, *Improved recycling of product after use*). It is worth noting that $H_1$ is again not rejected by using this EI proxy as well. This finding holds true both in the standard probit (column 1) and in the linear probability model IV (column 2) estimate. Consequently, the role of

[15] The overall evidence could also be driven by the specific set of countries defined based on CIS data availability for EI. Further investigations can be performed on a sub-sample of countries (e.g., main countries in terms of GDP per capita and R&D, laggard countries) to verify the eventual heterogeneity in the R&D-EI adoption link.

regulation is robust to endogeneity issues. The puzzling evidence stemming from empirical analysis in the ECOREC case is confirmed here. It is instead interesting to note that the demand-related factors are no longer significant when correcting for endogeneity. This result is crucial; certain types of eco-innovation strategies related to the circular economy do not appear to fit the standard conclusion that demand factors are important. This result is particularly striking, given that ECOREA is the type of EI we scrutinise that is closer to consumers' level. A possible explanation may be related to the observation that the relevant factor is not a demand for EI; instead, it is related to the social capital embedded in the consumers' attitudes that drive that demand and, indirectly, EI.

**Table 2: Determinants of EI – marginal effects**

| Dependent variable | ECOMAT | |
|---|---|---|
| Estimation method | DProbit | IV-LPM |
| | [1.] | [2.] |
| *ENREG* | *0.228**** | *0.362**** |
| | *[0.005]* | *[0.051]* |
| *ENDEM* | *0.196**** | *0.735**** |
| | *[0.007]* | *[0.084]* |
| RRDIX | 0.144*** | 0.054*** |
| | [0.005] | [0.015] |
| BGROUP | -0.029*** | -0.039*** |
| | [0.003] | [0.004] |
| MARNAT | 0.022*** | 0.003 |
| | [0.003] | [0.004] |
| MAREUR | 0.009** | 0.002 |
| | [0.004] | [0.004] |
| MAROTH | 0.019*** | -0.003 |
| | [0.004] | [0.006] |
| C_HO | 0.016*** | 0.017*** |
| | [0.001] | [0.001] |
| EURO | 0.048*** | 0.047*** |
| | [0.003] | [0.005] |
| Size dummy | Yes | Yes |
| Industry dummy | Yes | Yes |
| N. Obs. | 48,059 | 48,059 |
| Pseudo R2 | 0.223 | … |
| First-stage F statistics on excluded instruments | … | 187.3 |
| Wu-Hausman F test (p-value) | … | 0.000 |
| Durbin-Wu-Hausman test (p-value) | … | 0.000 |

*** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are clustered at the firm level. Instruments= lblood, lelection

**Table 3: Determinants of EI – marginal effects**

| Dependent variable | ECOREC | |
|---|---|---|
| Estimation method | DProbit | IV-LPM |
| | [1.] | [2.] |
| *ENREG* | *0.391**** | *2.102**** |
| | *[0.006]* | *[0.112]* |
| *ENDEM* | *0.210**** | *0.690**** |
| | *[0.008]* | *[0.187]* |
| RRDIX | 0.102*** | -0.270*** |
| | [0.005] | [0.034] |
| BGROUP | -0.021*** | -0.063*** |
| | [0.004] | [0.009] |
| MARNAT | 0.021*** | -0.038*** |
| | [0.004] | [0.009] |
| MAREUR | -0.010** | -0.044*** |
| | [0.004] | [0.009] |
| MAROTH | 0.034*** | -0.081*** |
| | [0.005] | [0.015] |
| C_HO | 0.0006 | 0.016*** |
| | [0.001] | [0.003] |
| EURO | 0.132*** | 0.227*** |
| | [0.004] | [0.012] |
| Size dummy | Yes | Yes |
| Industry dummy | Yes | Yes |
| N. Obs. | 48,059 | 48,059 |
| Pseudo R2 | 0.217 | … |
| First-stage F statistics on excluded instruments | … | 104.9 |
| Wu-Hausman F test (p-value) | … | 0.000 |
| Durbin-Wu-Hausman test (p-value) | … | 0.000 |

*** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are clustered at the firm level. Instruments= lblood, lelection

**Table 4: Determinants of EI – marginal effects**

| Dependent variable | ECOREA | |
|---|---|---|
| Estimation method | DProbit | IV-LPM |
| | [1.] | [2.] |
| *ENREG* | *0.244**** | *1.711**** |
| | *[0.005]* | *[0.087]* |
| *ENDEM* | *0.205**** | *0.214* |
| | *[0.007]* | *[0.149]* |
| RRDIX | 0.059*** | -0.182*** |
| | [0.004] | [0.027] |
| BGROUP | -0.005* | -0.038*** |
| | [0.003] | [0.007] |
| MARNAT | 0.014*** | -0.025*** |
| | [0.003] | [0.007] |
| MAREUR | -0.012*** | -0.038*** |
| | [0.003] | [0.007] |
| MAROTH | 0.002 | -0.076*** |
| | [0.004] | [0.012] |
| C_HO | -0.002 | 0.010*** |
| | [0.001] | [0.002] |
| EURO | 0.090*** | 0.184*** |
| | [0.003] | [0.009] |
| Size dummy | Yes | Yes |
| Industry dummy | Yes | Yes |
| N. Obs. | 48,059 | 48,059 |
| Pseudo R2 | 0.217 | … |
| First-stage F statistics on excluded instruments | … | 104.8 |
| Wu-Hausman F test (p-value) | … | 0.000 |
| Durbin-Wu-Hausman test (p-value) | … | 0.000 |

*** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are clustered at the firm level. Instruments= lblood, lelection

# 5. Concluding remarks and further research

The dynamics of CE-related innovation are a slow techno-economic transformative process; it is possibly more a ‘reform’ than a ‘revolution’, passing through the adoption of both incremental and radical innovations. CE is a realm where innovation is relatively more important than invention, if compared to energy and climate change. The main objective of this paper has been the evaluation of the role played by two key drivers of clean technologies adoption in relation to the circular economy, policies/regulations and market demand. We have conducted this evaluation using CIS data for the 2006-2008 period in the EU, which features a specific environment-related section and, by adopting econometric techniques that allowed us to correct for the problems of endogeneity that likely plague survey cross section data, usually lead to biased estimates. Our main results confirm the relevance of environmental policies in driving eco-innovation in the form of adoption. This result is robust across the different EI indicators we adopted, although they show different “strengths”;

product-related innovation related to recycling and organisational innovations related to the after-use are suggested to be more strongly affected by policy. A somewhat surprising result, which appears to depart from most of the existing contributions, relates to the not significant role played by "green" market demand in boosting consumption-related EI and, in general, the unexpected negative role played by R&D and market-related factors in reference to recycling-related product innovation and organisational innovation. Indeed, we show that green demand is always significant when we do not correct for endogeneity; however, when endogeneity is explained, the positive significance of the demand side vanishes if end use-related innovations are involved.

The circular economy business windows that pass through the adoption of various environmental innovations are dependent on the policy platform. This policy platform's construction has evolved through the history of waste policies, from the first EU Packaging Directive in 1994 to the End of Life Vehicles Directive in the late nineties and the WEEE Directive. Important stimulus was also provided by the Landfill Directive in 1999. Finally, the 2008 Waste Framework Directive constituted the last item before the definition of the CE strategy; this extends the scope of the reasoning, adding a strong orientation towards innovations and business opportunities, departing from the core waste prevention objective, which implicitly stimulate better designs, resource efficiency, recycling, re-use, new forms of organising production and consumption.

The relevance of policies and the less significant role of market demand shows that, on the one hand, the environmental benefits (mixed public goods such as resource efficiency in primis and energy savings) are clear and possibly broad; on the other hand, the (net) economic benefits for firms and sectors depend on how the CE transition occurs. In other words, public policies remain crucial in driving the EU towards a full CE implementation.

Future research can extend the analyses around firm's behaviour towards the achievement of a circular economy. The issue is not only updating datasets. Most recent CIS surveys, even when they address EI, do not offer more details than the 2008 survey. New data and research are necessary to understand (i) the different effects of process and product EI, (ii) the effects of more or less radical EI, (iii) innovations → performances relationship (Mazzanti et al. 2016). It is worth noting, for example, that Innovations develop rather specifically at the sector and regional level, where most environmental and innovation policies are implemented: EU regions play a significant role in the achievement of a greener, resource-efficient economy. Their role in this transition has been somewhat overlooked. New data and research are necessary to further investigate at the EU regional level, the socio- economic effects of EI: labour productivity and employment effects, skill and wage effects.

Empirically speaking, the new surveys should recover localisation information by which rich and diversified spatial disaggregated analyses on local spillovers, local diffusion of knowledge and policies are performed. The firm is embedded within economic and institutional environments: relationships with other firms, stakeholders and research centres, the presence of forms of capital (social, institutional, etc.) in a given territory, etc. Meso information at NUTS2-3 can enrich the microeconomic survey-based information layer with sector and geographical elements. Lastly, balance account sheets can be fruitfully merged with survey data to study the dynamics concerning eco-innovation and economic performance.

Summing up, future research that empirically investigates firms behaviour should attempt improving the current quality of data collection around EI: more specific information on types of EI, more disaggregated geographical datasets and mergers with balance sheets and other meso indicators are original pathways to understand the drivers and effects of EI in the resource efficiency / waste realm. The efforts will give more robust empirical backgrounds to the analysis of the Circular economy transition.

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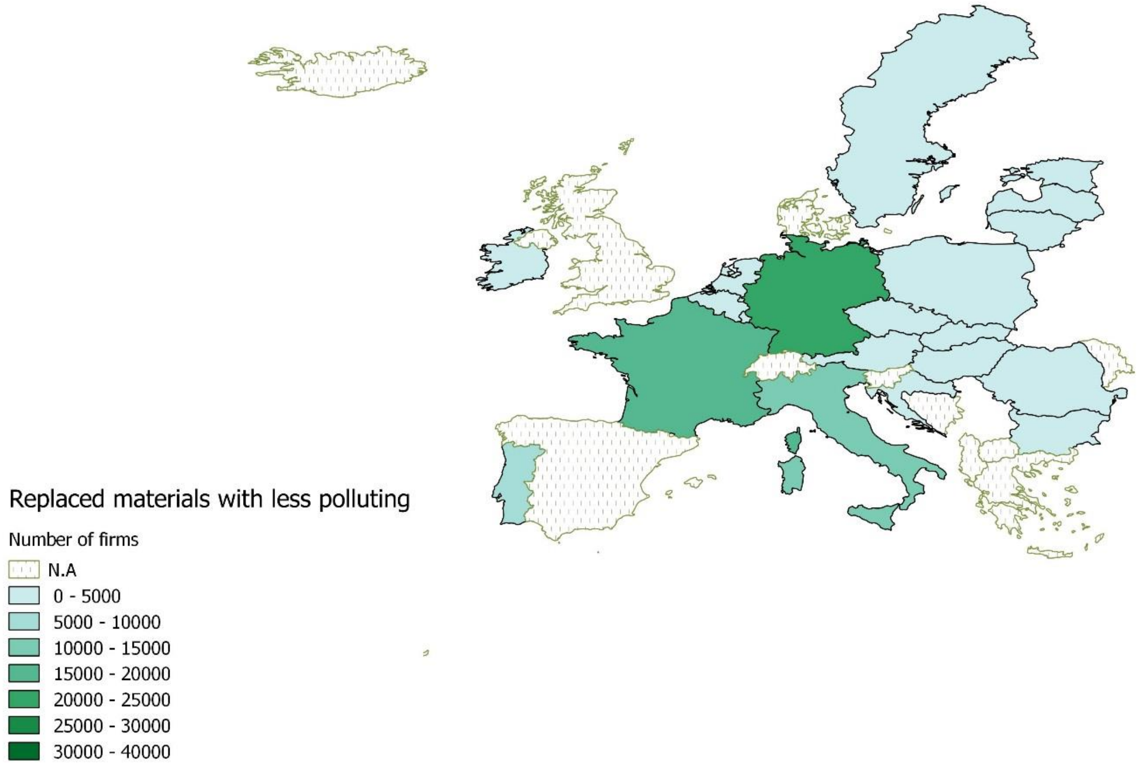
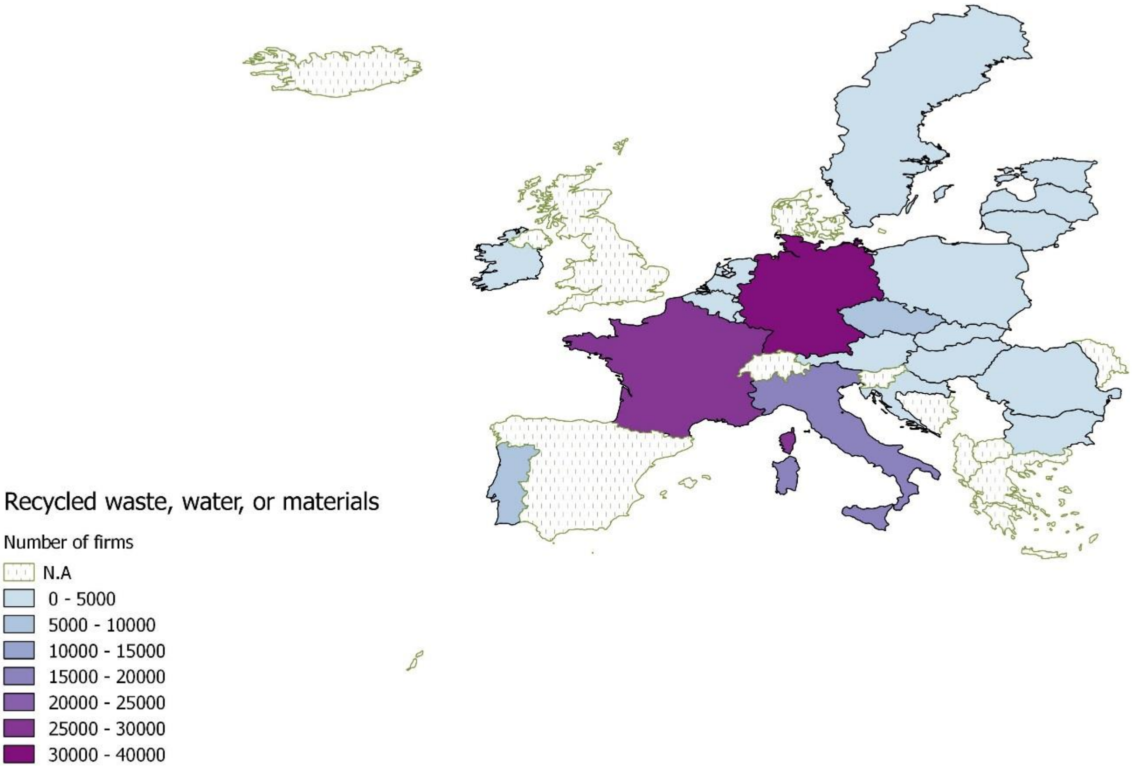
## Appendix

Figure A1 – Number of firms adopting CE oriented eco innovations in the EU




Reduced material use per unit of output
Number of firms
N.A
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
20000 - 25000
25000 - 30000
30000 - 40000


Recycled waste, water, or materials
Number of firms
N.A
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
20000 - 25000
25000 - 30000
30000 - 40000

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**Suggested citation:**
Giulio Cainelli, Alessio D'Amato and Massimiliano Mazzanti (2017). *Resource Efficiency, Environmental Policy and Eco-Innovations for a Circular Economy: Evidence from EU Firms*. SPRU Working Paper Series (SWPS), 2017-24: 1-23. ISSN 2057-6668. Available at: www.sussex.ac.uk/spru/swps2017-24

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