Resource Efficiency, Environmental Policy and Eco-Innovation. 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. The paper presents new and wide EU evidence on the role of environmental policy and green demand drivers to sustain the adoption of resource efficiency oriented eco innovations. It originally implements new estimators to tackle the endogeneity of binary framed policy and demand covariates, which typically characterise firm's survey data. Results interestingly report that when endogeneity is appropriately tackled, existing environmental policy is the only significant factor behind the adoption of innovations that reduce the use of waste and material. The result is an important piece of knowledge for the setting of a sound and economics-based strategy towards the circular economy.

1. Introduction

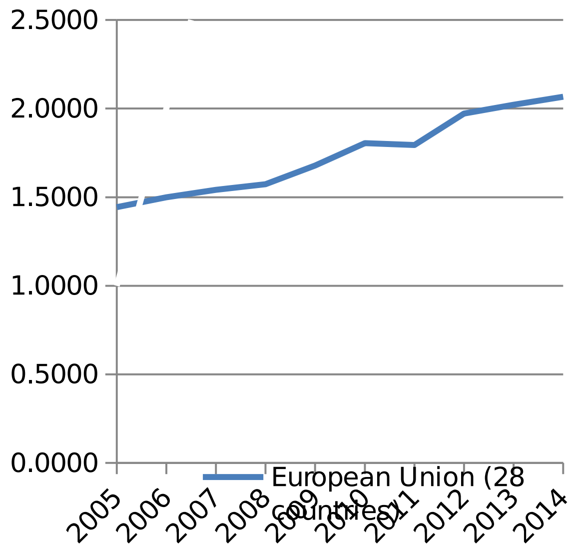
In December 2015, the European Commission launched its action plan for the Circular Economy (CE) with the objective of unlocking the growth and jobs potential of the CE and boosting EU competitiveness through new business opportunities and innovative means of production and consumption that overcome resource scarcity and the volatility in material prices (EC, 2015). The transition to a CE is highly influenced by the composition and innovation intensity of the economy, as well as by the environmental and industrial policy settings. The use of materials and resources and the production of waste should be reduced and the value of products, materials and resources maintained as much as possible along the value chains and product cycles. 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). The new EU circular economy strategy (EC, 2015) thus poses the objective to close the production and consumption loops in order to enhance the overall sustainability by contributing to increase economic and environmental efficiency. The CE realm goes far beyond the mere waste prevention, management and disposal environment, it is linked to energy related issues (e.g. waste to energy) and to bio-economy areas (e.g. bio-engineering). It is a strategy aimed at redesigning production and consumption, through pervasive technological and behavioural changes that revolve around new (uses) of materials and products (EMF, 2015). Innovation is commonly regarded as the most effective response to sustaining current standards of living while overcoming serious environmental concerns (EEA, 2014)[1]. Despite that, a broad and dynamic picture of the innovative potential in the field of resource efficiency (RE) and more broadly CE related technologies, is still lacking, despite the emphasis of official policy documents on innovation diffusion (EC, 2011). Innovation adoption and diffusion also add knowledge to relatively more abundant studies on inventions (Hall and Helmers, 2011), which have observed how patents in the waste realm have decreased over time, probably due to a diminishing effect of policies (OECD, 2011)[2]. EC (2011) recognises that: "Although many firms have already taken action to improve their resource efficiency, much scope for improvement remains". This leads to one of the milestones towards 2020 resource efficiency targets, namely 2020, market and policy incentives that reward business investments in efficiency are in place. These incentives have stimulated new innovations in resource efficient production methods that are widely used. All companies, and their investors, can measure and benchmark their lifecycle

1 Innovation is spread across various themes of the EC (2015) document, and especially in section 6 'Innovation, investments and other horizontal measures'.

2 In addition, EEA (2014, p. 55) notes that 'Adoption and diffusion of green innovations can be a powerful lever for a green economy transition strategy, possibly more significant in terms of outcomes than green invention, which nevertheless continuously feeds the reservoir of innovative options and solutions'.

resource efficiency”. Resource, material and waste related policies are necessary to correct markets in the first phase (raw materials use from extraction), in the production and consumption phases (excessive use of resources), and to tackle undesirable disposal (goods becoming ‘waste’). Current resource prices neither reflect geological scarcity nor external costs and, as a result, resources are not used efficiently. The achievement of a joint macroeconomic productivity dynamics, where resource and labour productivity increase, is a key objective. It is relevant to understand the forces behind the potential joint dynamic. Given the technological and environmental performances heterogeneity across sectors and regions, the understanding of the forces require in depth meso and micro levels analyses, which unveil the macroeconomic determinants. In The EU, the indicator of resource productivity (GDP (euro) generated by unit (kg) of resources) has been increasing between 2005 and 2014. However, it has to be noticed that the aggregate EU data is affected by the performance of countries (such as Hungary, Czech Republic and Latvia) which are “laggards” in terms of resource efficiency and shows values of the indicator below 1.00 in 2014 (see Figure 1).

Figure 1 – Resource Productivity in the EU



Source: own elaboration on EUROSTAT data

These considerations lead to the urgent need to investigate the innovation side of resource efficiency strategies and to assess the role of the main related drivers, especially the two key ones: environmental policy and market demand. The paper aims therefore at presenting new and wide 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 a survey on eco innovations in general terms). It exploits 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 innovations adoptions and adoption motivations (Mairesse and Mohnen, 2010). We aim at providing new insights within the literature that focuses on innovation adoptions, that intrinsically rely upon survey data (Cassiman and Veugelers, 2004; Mairesse and Mohnen, 2010). We take stock of recent works on environmental innovations, with the aim of extending the scope and finding more robust ways to tackle eco innovations drivers endogeneity. Among others, Veugelers (2012), Borghesi et al. (2015), while not specifically focusing on resource efficiency oriented innovations, present single countries evidence and do not treat endogeneity. Cainelli et al. (2015) and Managi et al. (2014) attempt to treat endogeneity and focus on resource efficiency, but again offer only single country based evidence. Other contributions focus on the EU (Ghisetti et al., 2015), but again with a general aim of analysing all environmental innovations, without addressing the endogeneity issue[3]. The present paper instead exploits EU data, focuses on the relationships between policy and demand factors as levers of resource efficiency innovations and originally implements new estimators to tackle 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, especially in the environmental realm. The authors note that due to the subjective measures of innovation output in surveys, compared to R&D statistics, the nature of endogeneity in production function is bending towards unobserved heterogeneity rather than simultaneity. In this paper we deal with the simultaneous elicitation of innovation adoption and motivations of innovation. Proper instrumentation is introduced by using non surveys data, a way to deal with endogeneity.

As a result, our paper provides more robust knowledge on a key strategic field – resource efficiency realm – in terms of eco innovation main drivers. Results interestingly report that when endogeneity is appropriately tackled, existing environmental policy is the only significant factor behind the adoption of innovations that reduce the use of waste and material policy and demand appear as significant in uncorrected (and therefore biased) estimates.

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

3 For a comprehensive review of the literature on the empirics of eco-innovation see, among others, the recent contribution by del Rio et al. (2016)

2. Theoretical background

Under a theoretical point of view, 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, we are connected to contributions from the literature on the incentives by firms to invest in EI to reduce compliance costs and/or emissions, starting with Milliman and Prince (1989) and Downing and White (1986)[4]; contributions on this line suggest that the chosen environmental policy instruments and their design can be crucial in determining adoption and, more generally, innovation incentives. There is, however, substantial agreement on the conclusion that a stricter environmental regulation is expected to increase adoption incentives, albeit recent works seem to cast some doubts with respect to specific technologies or environmental policy tools (e.g. Perino and Requate, 2012).

The second field of analysis we connect to is related to the so-called "Porter Hypothesis", which stresses the potential virtuous link between environmental regulation and competitiveness. 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 loss of competitiveness. On the contrary, an improvement in productivity or profits may result for regulated agents. The underlying mechanics rest on the positive potential impact environmental regulation may have in boosting productivity, efficiency and improvements in organizational or product/process innovation. 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 behaviors more costly, creating a potential *win win* situation. Jaffe and Palmer (1997) and Kozluk and Zipperer (2015), among others, propose a taxonomy that allows to recognize the different potential lines of research along the Porter Hypothesis. A "Weak" version states that, by placing constraints to regulated firms, environmental regulation may stimulate innovation. A "Strong" version holds that regulation is not only able to spur innovation, but also that this gain in efficiency is able to completely offset any loss in competitiveness due to compliance costs. Finally, a "Narrow" version suggests that certain types of environmental regulations (e.g. outcome rather than process based policies) are able to stimulate innovation.

Although the theoretical bases of these two strands of literature differ, there seems to be agreement on the potentially positive impact of environmental regulation strictness on the

4 For a very good survey, see, among others, Requate (2005).

incentives of regulated firms to adopt cleaner technologies. We expect this to apply also in a Circular Economy setting. As a result:

Testable Hypothesis H1. *Stricter environmental regulation boosts adoption of cleaner technologies.*

Our second research question deals with 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), so that indeed market demand for green goods can in principle drive eco-innovation (e.g. van den Bergh, 2008). Albeit some doubts are cast on the robustness of this conclusion (see, again, Horbach et al., 2012), it seems to be confirmed by more recent contributions (see, among others, Dangelico, 2015). This leads us to our second testable implication which, however, seems to be debated in the literature.

Testable Hypothesis H2. *Market demand for "green" products is expected to encourage eco-innovation adoption.*

3. The empirical framework

In our baseline econometric specification, we estimate the following probit model (Horbach, 2008; Cainelli *et al.*, 2015; Veugelers, 2012):

$$\Pr\left(Y_i = 1 / X\right) = \Phi\left(X, \beta\right)$$

where Φ is the cumulative distribution function of the standard normal distribution and Y_i is a dummy variable that takes the value 1 if a firm *i* introduces an EI and 0 otherwise. X is a set of the covariates described in Table 1. Our dependant variables that capture EI are ECOMAT (Environmental benefits from the production of goods or services within your enterprise - reduced material use per unit of output[5]), ECOREC (Environmental benefits from the production of goods or services within your enterprise - Recycled waste, water, or materials) and ECOREA (Environmental benefits from the after sales use of a good or service by the end user - Improved recycling of product after use). These are three measures of adopted technological EI aimed at improving the performance of products and processes in a way which is compatible with a Circular Economy based view.

5 28% of EU firms state to adopt this type of innovation, while ECOREC is adopted by 37% of firms and ECOREA by 24%. More detailed figures are available on request.

More specifically, the bulk of our data come from the EU Community Innovation Survey (CIS5, covering the period 2006-2008). The main explanatory variables are linked to “Existing environmental regulations or taxes on pollution” (ENREG), to test hypothesis H1, and “Current or expected market demand from your customers for environmental innovations” (ENDEM), to test H2. We also use data concerning environmental taxation on GDP, and blood donation, that are introduced to build instruments to control for endogeneity. The summary statistics are reported in Table 1.

Table 1 - Descriptive statistics (indep. Variables)

		mean	s.d.	max	min
ENREG	Existing environmental regulations or taxes on pollution	.2832564	.4505913	0	1
ENDEM	Current or expected market demand from your customers for environmental innovations	.1706968	.3762534	0	1
MARNAT	geographic markets did your enterprise sell goods and/or services: national	.8113651	.3912273	0	1
MAREUR	geographic markets did your enterprise sell goods and/or services: EU	.6628722	.4727398	0	1
MAROTH	geographic markets did your enterprise sell goods and/or services: all other countries	.3812794	.4857121	0	1
LSALE06	Log of sales in 2006	13.12615	3.54536	4.644391	24.38939
SALEGROWTH	Growth of sales	.4803011	1.595638	-6.658619	12.23932
BUSINESS	The firms is Part of a business group	.331917	.4709121	0	1
RRDIN	Internal R&D	.3988044	.4896663	0	1

We estimate our main econometric specifications using four different methodologies: (1) a probit model; (ii) an ivprobit model; (iii) a linear probability model (LPM) with instrumental variables and finally (iv) a special regressor method (SRM). First, we estimate our equation with a simple probit. This estimator is not appropriate since we suspect for the presence of endogeneity problems in our two main regressors: the regulation and the market demand variables. For this reason, we decided to estimate our baseline specification using different alternative methodologies. The first is the linear probability model (LPM) with instrumental variables. This method is often employed in the empirical literature ignoring the binary outcome. In fact, if some regressors are endogenous they will be correlated with the error term. In this case, it is necessary to use an instrumental variable approach, estimating the equation with 2SLS given an appropriate set of instruments for the endogenous variables. This approach has two main problems: first, the error term cannot be independent of any regressors (even exogenous regressors) unless X consists of a single binary regressor. The second problem is that in the LPM the fitted values are not constrained to lie in the unit interval. Then we estimate our specification with the ivprobit method. The main limitation of this method is that it requires the endogenous regressors to be continuous rather than binary, discrete and censored. This is the reason why the ivprobit method should not be applied to binary endogenous regressors. Finally, we estimate our main specification with 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 even if this hypothesis is not strictly necessary. Compared with the other methods, the special regressor methods (SRM) has none of the drawbacks of the others, and presents many advantages in dealing with specifications where the outcome variable is a dummy and the endogenous regressors are not continuous. This is our case.

Tables 2-4 present the econometric evidence around the three dependent variables of our model. Table 2 shows that regarding ECOMAT, the role of existing environmental regulations and/or fiscal duties on pollution (ENREG) is significant and positively explains the adoption of innovation by firms. High statistical and economic significance shows the relevance of existing policies behind EIs: H1 is not rejected. The fourth column is the key one. The SRM specification, where ENREG and ENDEM are instrumented by the share of blood donators on the population and share of environmental tax revenue on GDP, present only ENREG with a positive and significant coefficient, while ENDEM is either statistically insignificant (columns 2 and 3) or features a negative sign (H2 is rejected). Market demand does not seem to play a role. Baseline probit results would produce misleading results in terms of both statistical and economic significances[6]. In addition to ENREG, the other key factor behind innovation is in house R&D (RRDIN). Interestingly, also other market related factors do not seem to play a crucial role in driving eco-innovation: for example, sales growth turns out as not significant when endogeneity issues are addressed.

Table 3 shows similar results for ECOREC. While ENREG maintains its positive sign across specifications though changing the coefficient size (which enlarges from the baseline probit to IV (SRM) results), the evidence regarding ENDEM is not stable, and loses significance in the IV

6 We do note that also expected regulations are significant (results are available on request).

estimations. Table 4 presents the results for ECOREA. It is worth noting that while H1 is again not rejected by using this EI proxy as well, the size of the coefficient shrinks. Across resource efficiency oriented EIs, ECOMAT and ECOREC rank higher in terms of the marginal effects of existing regulations on the adoption of EIs. It seems that while the effect of environmental regulations is robust across typologies of RE innovations, it is relatively more relevant for process oriented innovations (ECOMAT, that captures material/resource efficiency and ECOREC, which describes recycling behaviour towards closing production loops) rather than product innovations (ECOREA, namely improved product recycling after use, a key circular economy innovation).

Further analyses will be carried out by disentangling the ENREG and ENDEM effects by size of the firms (SME vs big firms) and macro sectors (manufacturing vs services), due to the different policy effects on innovation that can occur across firms typologies. The evidence will also give more detailed policy implications.

Table 2 : determinants of EI – marginal effects at the means

Dependent var:	ECOMAT			
Estimation method:	probit	Ivprobit(b)	IV-LPM(b)	SRM(b)
ENREG(a)	0.170***	1.786**	0.613**	0.422***
	[0.011]	[0.746]	[0.267]	[7.09]
ENDEM(a)	0.201***	5.633	1.966	-0.854***
	[0.012]	[3.528]	[1.313]	[12.40]
MARNAT	0.004	0.060	0.019	-0.003
	[0.016]	[0.090]	[0.030]	[0.547]
MAREUR	-0.021	-0.095	-0.033	-0.039***
	[0.014]	[0.079]	[0.025]	[0.562]
MAROTH	-0.004	-0.228	-0.078	0.012
	[0.011]	[0.139]	[0.051]	[0.707]
LSALE06	0.032***	-0.014	-0.006	*special*
	[0.002]	[0.049]	[0.017]	*regressor*
SALE_GROWTH	0.014***	-0.029	-0.009	0.006
	[0.003]	[0.043]	[0.016]	[0.284]
BUSINESS GROUP	-0.033***	-0.397**	-0.131**	0.002
	[0.011]	[0.159]	[0.057]	[0.745]
RRDIN	0.145***	-0.366	-0.126	0.079***
	[0.011]	[0.424]	[0.156]	[1.804]
C_HO	-0.002	0.194*	0.067**	-0.006
	[0.004]	[0.096]	[0.034]	[0.436]
INDUSTRY DUMMY	Yes	Yes	Yes	Yes
N. Obs.	9,930	9,930	9,930	9,930
Pseudo-R2	0.121	…	…	…

*** significant at 1%; ** significant at 5%; * significant at 10%; robust standard errors are in parentheses

(a) instrumented; (b) instruments: LTAX05, LBLOOD

Table 3 : determinants of EI – marginal effects at the means

Dependent var:	ECOREC			
Estimation method:	probit	Ivprobit(b)	IV-LPM(b)	SRM(b)
ENREG(a)	0.296***	3.123***	9.516***	0.442**
	[0.011]	[0.582]	[1.176]	[13.13]
ENDEM(a)	0.192***	-4.793*	-14.163*	-0.939***
	[0.013]	[2.793]	[8.450]	[17.75]
MARNAT	-0.007	-0.020	-0.052	0.0008
	[0.016]	[0.066]	[0.208]	[0.895]
MAREUR	-0.078***	-0.127	-0.399**	-0.030**
	[0.014]	[0.059]	[0.184]	[1.00]
MAROTH	0.034***	0.123	0.360	0.022
	[0.012]	[0.110]	[0.330]	[1.12]
LSALE06	0.021***	0.026	0.074	*special*
	[0.002]	[0.036]	[0.115]	*regressor*
SALE_GROWTH	0.014***	0.050	0.149	0.007
	[0.003]	[0.034]	[0.103]	[0.452]
BUSINESS GROUP	-0.029**	-0.042	-0.149	0.001
	[0.011]	[0.119]	[0.378]	[1.196]
RRDIN	0.098***	0.406	1.177	0.080**
	[0.011]	[0.324]	[1.00]	[2.85]
C_HO	-0.008*	0.018	0.077	-0.005
	[0.011]	[0.068]	[0.223]	[0.774]
INDUSTRY DUMMY	Yes	Yes	Yes	Yes
N. Obs.	9,945	9,945	9,945	9,948
Pseudo-R2	0.135	…	…	…

*** significant at 1%; ** significant at 5%; * significant at 10%; robust standard errors are in parentheses

(a) instrumented; (b) instruments: LTAX05, LBLOOD

Table 4 : determinants of EI – marginal effects at the means

Dependent var:	ECOREA			
Estimation method:	probit	Ivprobit(b)	IV-LPM(b)	SRM(b)
ENREG(a)	0.176***	8.483***	2.515***	0.201**
	[0.010]	[1.389]	[0.457]	[13.71]
ENDEM(a)	0.210***	-9.774	-3.542*	-0.477***
	[0.011]	[6.504]	[2.114]	[19.80]
MARNAT	0.028*	0.079	0.017	0.0003
	[0.014]	[0.164]	[0.051]	[0.996]
MAREUR	-0.060***	-0.364**	-0.105**	-0.013**
	[0.012]	[0.144]	[0.046]	[1.051]
MAROTH	-0.015	0.082	0.046	0.007
	[0.010]	[0.251]	[0.082]	[1.162]
LSALE06	-0.001	-0.028	0.001	*special*
	[0.002]	[0.089]	[0.027]	*regressor*
SALE_GROWTH	0.011***	0.103	0.039	0.003
	[0.002]	[0.079]	[0.026]	[0.489]
BUSINESS GROUP	-0.026**	-0.254	-0.046	0.005
	[0.010]	[0.295]	[0.091]	[1.233]
RRDIN	0.087***	0.768	0.307	0.039**
	[0.010]	[0.775]	[0.245]	[2.954]
C_HO	-0.011	0.129	0.017	-0.003
	[0.004]	[0.175]	[0.052]	[0.785]
INDUSTRY DUMMY	Yes	Yes	Yes	Yes
N. Obs.	9,910	9,910	9,910	9,910
Pseudo-R2	0.105	…	…	…

*** significant at 1%; ** significant at 5%; * significant at 10%; robust standard errors are in parentheses

(a) instrumented; (b) instruments: LTAX05, LBLOOD

4. Concluding remarks

The main aim 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, coherently with the objectives of the European Commission. We have done this using CIS data for the 2006-2008 period, that feature a specific environment-related section, and by adopting econometric techniques that allowed us to correct for problems of endogeneity that likely plague survey cross section data, leading usually 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 indicators we adopted, being they referred to process or product innovation, albeit strongest results are obtained with respect to the former. A somewhat surprising result, that seem to depart from most of the existing contributions, relates to the not significant role played by “green” market demand and, more generally, by market related factors. Indeed, we show that green demand is only significant when we do not correct for endogeneity, while when endogeneity itself is accounted for the positive significance of the demand side vanishes. The above evidence can be considered as potential food for thought in driving future policies in improving resource efficiency on the way towards a true Circular Economy.

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