Adoption of waste-reducing technology in manufacturing: Regional factors and policy issues

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Abstract: We present a joint theoretical-empirical investigation to assess the adoption by manufacturing firms of innovations aimed at increasing recycling and, consequently, reducing the use of material and waste in production processes. According to the recent emphasis on the 'external' factors stimulating innovation which often may be more important than the classic drivers, such as R&D, we address the role of local influences, such as policy environments and regional structural features. First, we analyse firms' innovation adoption choices in a simplified technology adoption model augmented by discussions in the environmental innovation (EI) literature that rationalize the research hypotheses underlying empirical models. We frame our empirical analysis on an original integration of data from a firm survey (EU CIS2008 survey of manufacturing firms) and regional level waste related information obtained from Italian environmental agency waste reports. The EU CIS2008 was the first of these surveys to ask for information on EI adoption in the waste sector. Our econometric analysis shows that firms adopt EI on the basis of some relational factors, while drivers such as R&D have no impact. The evidence of our study supports the role of regional factors related to waste management and policy. For example, firms located in regions with better separated waste collection and waste tariff diffusion systems are more likely to adopt EI. Networking and agglomeration economies do not seem to have any effect.

Keywords: waste and material reduction technology, innovation adoption, firm behaviour, waste policy, regional frameworks, agglomeration economies.

JEL Codes: D22, Q53, Q55

1. Introduction

Various streams of literature in the area of the 'economics of waste' have explored the factors correlated with waste performance, ranging from waste generation, waste recycling/waste management to waste disposal, at the macro and micro levels (Johnstone and Labonne, 2004; Mazzanti and Montini, 2009; D'Amato *et al.*, 2013; Shinkuma and Managi, 2011). It is surprising, therefore, that the role and determinants of innovation in waste and materials/resource consumption has only recently begun to attract some research attention. Among the very few papers in this area, Horbach *et al.* (2012) use 2009 German CIS data to assess the drivers of eco-innovation (including waste, material resources reductions and recycling), focusing on the role played by (current and expected) regulation, cost savings and consumers benefits. Managi *et al.* (2012) analyse the technology adopted by municipalities in Japan and suggest that inappropriate incentives for technology adoption can arise. We try to fill a gap in the literature by developing a joint theoretical-empirical investigation of the decisions made by manufacturing firms about innovation adoption, aimed at improving the recycling of waste and materials and, ultimately, reducing resources consumption.

More efficient use of resources is one of the pillars of a more sustainable economy. The diffusion of environmental innovation(EI) is crucial (Kemp and Pontoglio, 2011) to achieve sustainability and competitiveness, especially in very industrialized countries. The literature suggests that several social, economic and policy factors contribute to explaining waste performance and, possibly also driving related innovation (Mazzanti and Zoboli, 2009; Mazzanti *et al.*, 2008). Within this literature, there are several studies of waste generation and disposal and their drivers that focus on analysing regional frameworks (Hage and Soderholm, 2008; De Jaeger and Eyckmans, 2008, Dijkgraaf and Gradus, 2009, 2004; Allers and Hoeben, 2010).

Our specific focus on Italy (our case study), is motivated by the waste crisis that is affecting primarily some Southern Italian regions since 2000 (D'Alisa et al, 2010). It is also prompted by the strikingly different environmental and economic performance across different areas of Italy (Mazzanti et al., 2012), which has created problems related to the

management of local 'hot spots' (Pasotti, 2010 for an institutional analysis of Naples) and the siting of waste disposal infrastructures (Jenkins *et al.*, 2004). Italy provides a vivid example of the need to boost innovation, starting at the firm level, in order to reduce the consumption of material resources and related production of waste.

We present a joint theoretical-empirical investigation to study the innovation adoption decision by manufacturing firms, aimed at reducing the use of input materials and waste in production processes (Nicolli and Mazzanti, 2011; Nicolli et al., 2012) In line with work highlighting the external influences affecting innovation and their possibly higher importance than the classic drivers such as R&D, we investigate the role of local policy environments and regional structural features. R&D investment seems to have lost its primacy among the drivers of innovation at firm level. This 'new framework' is especially relevant for radical and socially interlinked innovations such as environmental inventions. Research is shifting the focus of analysis towards non-R&D centric directions.

We develop a series of theory-based testable implications regarding the extent to which firm behaviour is influenced by external factors, such as waste policies (landfill taxation, and indicators of local commitment and performance related to waste, waste policy stringency, waste disposal 'capacity' indicators, etc.). We also propose a simple model of the idiosyncratic geographical features of our case, which may be linked to waste policy.

We frame our empirical analysis in an original integration of firm survey data (CIS5 – 2006-2008 data)[1] and waste related information at regional level derived from the Italian environmental agency waste reports. We use CIS2008 data because this was the first survey to ask for information on EI adoption. The dataset we exploit contains more than 6,000 Italian manufacturing firms observed over 2006-2008. The merging of CIS data on

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[1] The Community Innovation Survey (CIS) is the main and official EU survey on innovation adoption by firms. CIS5 is the 5th wave of the survey since the early 90's. See http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis. See also for EI aggregate figures. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Innovation_statistics#Innovations_with_environmental_benefits. EUROSTAT provides only sector data. Micro data are available only at the national (not regional) level, which is one of our justifications for choosing Italian data. Information on regional location complements the relevance of Italy as one of the main industry actors in the EU and as a strongly 'federal' state in terms of economic and environmental policies.

waste and material innovation adoptions with regionally related data on waste performance is, to our knowledge, a novel direction in the EI literature, which allows us to analyse how innovation adoption is influenced by firm-based, sector-based and geographic policy-based factors (Hollander *et al.*, 2009).

Our paper links mainly to two literature streams. We refer to the literature on technology adoption and environmental policy that originated with Milliman and Prince (1989) and Downing and White (1986).[2] The very simple theoretical model developed in Section 2 of this paper rests on the standard assumptions from this literature and derives plausible conclusions about how a price based instrument (in our setting, a landfill tax and/or waste tariff) can increase the incentives for technology adoption. They also investigate the role of policy drawing on the well known Porter hypothesis (Popp *et al.*, 2011; Costantini and Mazzanti, 2012; Ambec and Barla, 2006).

However, the main work cited in this paper is from the literature on the drivers and determinants of EI. Specifically, we refer to EI adoption. Definitions of eco-innovation (Kemp, 2000, 2010) highlight the ecological attributes of individual new processes, products and methods from a technical and ecological perspective. For example, the MEI (Measuring Eco-Innovation) research project defines eco-innovation as the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives. The inclusion of new organizational methods, products, services and knowledge oriented innovations in this definition differentiates from the definition of environmental technologies as all technologies whose use is less environmentally harmful than relevant alternatives (Kemp, 2010). Along these lines, we aim at capturing the drivers of EI outside the firm's boundary, in the institutional and economic features of the territory. Theoretically, this implies the need to enrich the predictions of (policy oriented) theoretical analysis with the considerations in a 'regional systems of innovation' approach

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2 For a very good survey, see Requate (2005).

(Iammarino, 2005; Iammarino and McCann, 2006; Beaudry and Breschi, 2003, Boschma and Loomboy, 2002) in order to investigate the key elements of regions (Cainelli, 2008; Cainelli et al. 2007) that foster waste and resource use related innovations. Several papers investigate EI drivers. These include Horbach *et al.* (2012) which, as already referred to, focuses on the determinants of EI in several environmental realms in Germany, and Kneller and Manderson (2012), which examines the link between EI and regulation in UK. However, we consider that our contribution is unique in being, to our knowledge, one of the very studies to focus on how firm level innovation incentives related to waste and materials are affected by local idiosyncratic features of waste related technologies and infrastructures, and by the shape of policy interventions. In other words, the theoretical and empirical study in this paper allows us to analyse how innovation adoption is influenced by firm, sector and geographic policy based factors. We hope our results will provide food for thought for policy makers especially in relation to the case of Italy, where the numerous and diverse waste related problems require urgent attention.

The paper is organized as follows. Section 2 presents the theoretical background that informs the empirical analysis; Section 3 describes the data and models; Section 4 discusses the main econometric evidence; and Section 5 concludes.

2. Conceptual framework

This section sets out our research hypotheses with respect to the main determinants of innovation related to waste and material resources. We focus on the impact of waste related policies and the existing waste infrastructure (technologies) and their influence on firms' adoption of less resource-intensive technologies. We discuss the role of other, relevant factors, including available information and firm specific features, which cannot be explicitly included in our simple theoretical model.

2.1. Role of policy, infrastructure and available technology

We propose a representative economic agent (e.g. a firm or a consumer) generating an exogenous level of unregulated (i.e. business-as-usual) waste, denoted y. Regulation takes place through two instruments:

- a landfill tax, t, paid in proportion to the waste going to landfill – this depending on past choices related to recycling and recovery - resulting in an exogenous percentage of recycling, that we label $1-d$;
- a waste tariff, τ, levied on the total level of waste produced.

Regulation implies that the amount of waste produced is lower than the business as usual level; actual waste production is denoted g. Thus, the amount of waste reduction is $y-g$.

The economic agent can choose whether to use an old technology for waste reduction, the corresponding costs being given by the increasing and convex function $c(y-g)$. We focus on waste reduction understood very broadly, including improvements to materials recycling during the production process. Alternatively, by paying a fixed cost F, the agent can reduce these costs by a factor $0 < \alpha < 1$, the smaller the factor the larger the cost savings due to the new technology. Finally, the part of the waste that is not landfilled can be sold for recycling. For simplicity, we label its corresponding 'price' or value as p.

The agent's cost minimization problem when the old technology is adopted can be written as:

$$\min_g C_o = c(y-g) + (\tau + td)g - p(1-d)g \tag{1}$$

where subscript o denotes 'old technology'. The corresponding problem under the new technology is:

$$\min_g C_n = F + \alpha c(y-g) + (\tau + td)g - p(1-d)g \tag{2}$$

where subscript n denotes 'new technology'.

Assuming a quadratic shape for the *c(.)* function,[3] and solving (1) and (2), implies the following equilibrium values for waste production under the two technological regimes (old and new) respectively:[4]

$g_o = y + p(1-d) - (\tau + td)$ and

$g_n = y + \frac{1}{\alpha}\left[p(1-d) - (\tau + td)\right]$.

Clearly, a stricter waste management and disposal policy (a higher tariff and/or landfill tax respectively on the side of management and disposal) implies lower waste production (larger waste reduction).

Substituting the equilibrium values of g into the cost functions under the old and the new technology from *(1)* and *(2)* respectively, we see that the new technology is indeed adopted when:

$$F < F_h = \frac{1}{2}\left(\tau + td - p(1-d)\right)^2 \frac{1-\alpha}{\alpha}$$

Comparative statics provide the testable implications of our model.

Result 1. *The stricter the policy, in the form of a larger waste tariff or landfill tax, the larger the adoption incentive, namely the induced effect of the policy.*[5]

This is reasonable; it is easily shown that $\frac{\partial F_h}{\partial t} = d\left(\tau + td - p(1-d)\right)\frac{1-\alpha}{\alpha} > 0$ and $\frac{\partial F_h}{\partial \tau} = \left(\tau + td - p(1-d)\right)\frac{1-\alpha}{\alpha} > 0$. A higher value for landfill tax or tariff implies a lower

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3 I.e., we assume $c(y-g) = \frac{(y-g)^2}{2}$.

4 Notice that in order for *y-g* to be positive in equilibrium under any possible technological regime, we need to assume $p(1-d) < (\tau + td)$. Also, second order conditions are easily shown to hold. We assume finally that y is large enough to guarantee that equilibrium waste g is positive for any given technology.

5 See Johnstone et al. (2012) for conceptual sketches on induced innovation issues.

level of waste production, making the cost savings from the new technology more attractive for any possible level of recycling and fixed costs.

Result 2. *A better state of the 'waste management related infrastructures', namely better separated collection of waste performance, might imply larger or smaller adoption incentives.*

This result is less straightforward than result 1. Indeed $\frac{\partial F_h}{\partial d} = (p+t)(\tau + td - p(1-d))\frac{1-\alpha}{\alpha} > 0$, so that landfill diversion reduces the incentives to adopt since it implies, *ceteris paribus,* that lower landfill taxes are paid. On the other hand, a better state of the existing technology or of the related infrastructures can also imply a lower α (the new technology provides better waste reduction cost improvements) and it is easily shown that $\frac{\partial F_h}{\partial \alpha} = -\frac{1}{2}\frac{(\tau + td - p(1-d))^2}{\alpha^2} < 0$.

The sign of the net effect cannot be determined a priori, and will be one of the main subjects of our empirical investigation.

2.2. Other factors affecting eco-innovation related to waste and material resources

Horbach *et al.* (2012) provide a very detailed investigation of the potential determinants of eco-innovation in general; these include factors that cannot be addressed properly in a static model like the one developed in the preceding subsection. Indeed, together with current regulation, infrastructures, and the state of technology, already addressed, other factors are worth highlighting and are considered in our empirical analysis, namely:

- firm specific factors, including technological capability improvements led by R&D, and organizational innovations, such as Environmental Management Systems (EMS, Rennings et al. 2006), which might be intended as a system for detecting available information and also as a sign of commitment to greener production;
- quality of the available knowledge transfer mechanisms, according to the source of the knowledge and the firm's effectiveness in using the information.

Both factors are expected to have a positive impact on eco-innovation. In other words, stronger technological capabilities and the presence of organizational innovative structures should lead to eco innovation improvements, as should increased ability of the firm to gather and use information.

We exclude market pull factors from our analysis. According to Kammerer (2009), consumer benefits play an important role in eco-innovations if these innovations are a source of added value for consumers. Horbach *et al.* (2012) show that the existence of consumer demand for environmental quality boosts eco-innovation related to benefits (for firms or consumers) in the areas of recycling and use of materials. Evidence on the relevance of demand pull factors, however, is mixed (Rehfeld *et al.*, 2007). We lack comprehensive information on the demand for EI related to waste and material resources use and leave the impact on EI performance for future research.

There are two other factors, which, in our view, are important for determining EI activities in the waste and resources sectors. These are related to the commitment of local authorities, measured, for example, by a change towards incentive based environmental policy design, and attitude to cooperation and networking at firm level (Cainelli *et al.*, 2012). Stronger commitment of local authorities might increase EI by increasing the sources and size of funding, and by providing economic incentives. Firms' attitudes to networking is also expected to have a positive impact on EI, although this relationship cannot be taken for granted.

Finally, we focus on agglomeration effects and networking; previous analyses (Cainelli *et al.*, 2012) suggest that these factors play a limited role, and only in specific circumstances, and are affected, among other things, by patterns of specialization and urbanization.

2.3. Research hypotheses

The theoretical model suggests several testable hypotheses that derive from the conceptual scheme presented above and the literature on EI.

H1: idiosyncratic regional waste factors related to (past and present) waste management and waste policy are positively correlated to EI. This hypothesis is oriented to capturing 'regulatory' aspects of the waste systems that may influence EI (Johnstone *et al.*, 2010), in a regional context. The assumption of a positive correlation is based on Results 1 and 2 in Section 2.1, although the positive link between technology/infrastructures and EI cannot be taken for granted. We expect the likelihood of EI adoption to be explained more by regional idiosyncratic factors than the usual geographical factors captured by geo-dummies. We use three regional waste management and waste policy related proxies to test diverse elements of the 'decentralized environment' and enable sensitivity analysis: (i) regional performance in separated collection of municipal waste; (ii) diffusion of the new waste tariff,[6] (iii) regional landfill tax levels – introduced in 1996 in Italy subject to regional competence in the definition of tax levels. These proxies capture regional waste management and policy strategy measured by actual performance (partly regulatory driven) and policy commitment (e.g. taxes and tariffs).

H2: the quality of information diffusion, level of cooperation in local networks and firm specific features (organizational innovation, R&D) are expected to increase EI performance. This set of drivers stem from the literature on EI discussed in the Introduction and Section 2.2. Based on the works cited, it is clear that not all of the expected linkages will be supported by our empirical results. We are especially interested in whether and to what extent

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[6] The new waste management tariff was introduced by Italian Law No. 22/1997 and in theory substitutes for the former waste management tax. However, the earlier tax continues to be levied in many Italian municipalities because law 22/1997 provides for a transition phase that has proven gradual and slow. The former tax was calculated on the area of household living space; the new tariff is based on full-cost pricing for waste management services principles, and includes some market based incentives. Effective implementation of the tariff system is highly dependent on local policy decisions and practices, which are based partly on the choices made by the municipalities in the provinces that coordinate waste regulation at the local level. Thus, early implementation of the new tariff-based system might be a sign of stronger policy commitment. Implementation is heterogeneous even across areas with similar incomes and similar socio-economic variables. The shift from the old 'non environmentally oriented' tax should capture the incentives for better waste management inherent in the new tariff.

agglomeration economies and R&D are relevant factors explaining the adoption of EI in the area of waste and materials resources.

3. The Data

We address our research questions by exploiting data from two different statistical sources that enrich the 'standard' EI setting with local idiosyncratic, real environmental features.

The first source the 5th wave of the Italian CIS covering the years 2006-2008, which provides information on techno-environmental innovation for a representative sample of 6,483 manufacturing firms. This is an original firm level dataset which asks for information on the adoption of EI along various dimensions. EI adoption is a more effective proxy for firms' innovation capacity and intensity than environmental invention (patents).

The second source is the panel dataset provided by ISPRA (the Italian environmental agency), which covers regional waste management and waste disposal and provides information on regional waste policy. These data allow us to link regional information on waste to firms. Although CIS data do not provide exact information on the location of specific firms, we know the region in which the firm is located, which, given the idiosyncratic features characterizing local systems of production, is very useful (Cainelli *et al.*, 2012; Antonioli *et al.*, 2013). This particularity of production systems applies especially in Italy, where each of its regional systems has peculiar characteristics. The different 'capitalistic models' that typify different parts of Italy – some characterized by big firms (Lombardy, Piedmont), others by dense networks of small firms agglomerated around districts (Veneto, Emilia Romagna) - and the decentralized nature of the waste management/policy process, require an understanding of whether, and how significantly, EI adoption derives from these local factors. There are also some 'management/policy' variables associated with waste, such as collection of separated waste, waste tariffs, and landfill taxation, that capture diverse elements of the regional regulatory framework for waste management/disposal.

We merged CIS firm and waste data so that each firm is associated with well defined heterogeneous regional – 'meso' - characteristics (Cole *et al.*, 2009). The combination of these data, to our knowledge, is novel in the environmental innovation literature. It allows investigation of new areas of regionally related waste performance, and analysis of the way that EI adoption is influenced by firm, sector and geographic-policy based factors.

Table 1 presents descriptive information for the variables related to internal, external and 'policy' factors influencing EI adoption. Their role is specified in the econometric analysis. We depict waste related information in a series of maps (Figures 1, 2 and 3) that provide insights into the high within country heterogeneity of Italy.

(FIGURES 1 TO 3 ABOUT HERE)

(TABLE 1 ABOUT HERE)

4. Empirical results

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

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

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 variable is ECOWA,[7] that is, the share of firms that adopted technological EI aimed at reducing waste and materials flows in 2006-2008.

7 The specific question in the CIS5 survey is (section 10.1): "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 sixth option in the 'Environmental benefits from the production of goods or services within your enterprise' area is <Recycled waste, water or material>".

Table 2 and Table 3 (which shows waste related marginal effects) present the first (baseline) econometric results based on a bivariate probit, which accounts for the correlation between ECOWA and the general propensity to innovate in technological dimensions (INNOVA).[8]

The information from various sources is positively correlated to ECOWA. This confirms the 'relational' needs and content of EI. In order to innovate, firms exploit their networks. Somewhat surprisingly, R&D is not significant for determining waste specific EI. This is a peculiar feature of the waste related EI under scrutiny, while it is relevant for explaining innovation in broader terms. Among the firm specific variables, the share of workers receiving training, and lagged labour productivity positively explain the adoption of ECOWA.

Next we move to the main analysis. We find CIS information on local funding for innovation (*funloc*), and the geographic dummies are not significant, indicating the need to explore other regional factors.

(TABLES 2 AND 3 ABOUT HERE)

Table 4 presents some evidence related to the testable implications derived in Section 2. Introducing the share of separated waste collection, which is a target of EU and Italian laws, does not alter the previous results. Its statistical significance is high which means that firms that are located in regions with higher levels of separated collection (higher policy commitment), are more likely to adopt ECOWA. This is evidence that better infrastructures and/or existing technologies (producing better recycling performance) can be expected to boost waste related EI. In light of the comparative statics in Result 2, this implies that the impact of waste policy commitment and infrastructures from the application of new technology, is stronger than considerations related to short sighted cost

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[8] The hypothesis of a correlation between two innovation adoption variables errors is rejected. We test this hypothesis which is crucial for understanding whether the phenomenon of eco innovation adoption shows correlations with the general propensity to innovate. In others words, eco innovators might be a diversified example of general innovators. In this case, adoption of ECOWA would be a phenomenon that can be treated in isolation from innovation.

saving considerations. Also, once again, these regional factors are more important than the effect of geographical factors. We control for this effect through the use of variables for regional and sector characteristics, economic performance, firm size, R&D, etc. For example, larger and more productive firms promote EI, and regional waste management provides further incentives. This demonstrates the inducing effect of regulatory pressure in the waste realm (Horbach *et al.*, 2012; Veugelers, 2012), given that separated collection is driven almost entirely by the regulatory framework.

Agglomeration is not significant and the interaction term is negligible from a statistical and economic perspective.

(TABLE 4 ABOUT HERE)

Tables 5 and 6 explore the implications of Results 1 and 2 using various other proxies, which are more oriented to policy. We test the role of waste tariffs (Mazzanti *et al.*, 2012) and landfill taxes, two of the pillars of waste management/policy. Estimates show that while landfill taxes are not significant, tariffs are positively correlated to ECOWA adoption.

This is as expected, for two reasons. First, landfill taxes address waste disposal and have been found not to be significant for waste generation and waste management. They are too low in the waste hierarchy to have an impact upstream in the waste and materials filieres (Mazzanti and Zoboli, 2006). Waste tariffs have a sign and effect that are coherent with the evidence in Table 4. They are at the core of waste management systems. The higher are these tariffs, the more strongly the waste system is rooted in economic incentives and oriented towards full recovery. Regional heterogeneity is high, and captures different perspectives on waste issues. Based on previous studies (see, among others, D'Amato *et al.*, 2011), we can conclude that tariffs are positively correlated to separated collection, confirming the results obtained when landfill tax is used as the policy related explanatory variable.

In relation to networking and cooperation among firms, and their impact on waste related EI (Section 2.2), with the exception of the variable *Group,* they seem not to be correlated with ECOWA. This result is not unexpected since the business group is the organizational form adopted by Italian firms that want to grow (Cainelli and Iacobucci, 2007). The results for *Group* confirm the role of firm size as one of main drivers of EI adoption. The evidence related to our theoretical predictions on the potential role of information related to innovation are less clear cut compared to the case of innovation more broadly. To sum up, the evidence seems to suggest that a dense district environment, which historically is related to the innovation oriented evolution of industrial districts through the exchange of intangible information such as knowledge and R&D spillovers (Cainelli and Zoboli, 2004), appears not to be relevant for innovation in general, which is in line with Horbach *et al.* (2012).

Overall, our results confirm that policy environments matter for EI. Market forces are not sufficient given the public good nature of EI. Our evidence shows also that both regional market forces (agglomeration) and the usual geographical factors are not significant. However, some of the policy content of regional frameworks are significant and contribute to explaining adoption of ECOWA, complementing standard firm-related' factors. In other words, in the area of waste, waste management and policies seem to matter more than firm's R&D efforts.

(TABLES 5 - 6 ABOUT HERE)

Table 7 summarizes the policy related evidence. In economic terms, separated collection, a fundamental part of waste management systems, has the biggest effect. Given the situation in Italy, this suggests the need for serious consideration of future waste management strategies. The divergence in waste system performance could exacerbate differences among Italian regions in relation to sustainability and competitiveness through the dynamic effect of innovation.

(TABLE 7 ABOUT HERE)

5. Conclusions

The paper presented a theoretical-empirical investigation of manufacturing firms' the innovation adoption decisions aimed at reducing materials use and production of waste in manufacturing. In line with the emphasis on external innovation as more important than classic drivers of innovation, such as R&D, we investigated the role of factors such as policy environments and structural regional features.

Our main results can be summarized as follows. First, firms located in regions where commitment to waste management to increase recycling (separated waste collection) is stronger are more likely to adopt innovations aimed at reducing waste and materials. We found geographical effects were not statistically significant, meaning that regional policy attitudes to specific environmental/waste issues favour firms' adoption of environmental innovations. The embedding of firms in specific institutional landscapes reinforces their propensity to innovate in the presence of other firm related factors. This result is confirmed by the evidence for waste tariff, which is statistically significant, as opposed to regional landfill tax. This is as expected since landfill taxes operate at the level of disposal (not waste reduction/recycling) and their incentive effects on waste management are often negligible.

Within this set of idiosyncratic regional factors, the endowment related to the waste management infrastructures on which separated collection is based, is economically and statistically very significant. This econometric result is coherent with the north-south divided in relation to separated waste collection in Italy.

These results are rather worrying since such management of the environment and policy effects might further reinforce the existing technological divide between firms located in different areas and increase economic and environmental differences.

Second, in contrast to much existing work on innovation, waste related innovation seem not to be sensitive to the presence of R&D and other effects related to cooperation and networking. There may be several reasons for this. In a country such as Italy, we can

interpret it as lack of focus (on average) by firms (district of firms) on environmental innovation. There are exceptions such as ceramics firms, which in some regions have adopted district based environmental management systems. Thus, networking and cooperation on their own do not seem to be strong drivers of waste related environmental innovation, at least in our setting and case study: policy commitment is necessary to explain EI.

Further research might focus on even more localized spatial effects occurring at provincial and municipal level. Original survey data would be needed for such an investigation.

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Figure 1 – Landfill taxes

Figure 2 – Separated collection of waste

Figure 3 – Waste tariff diffusion (% population covered)

Italy's regions: map and taxonomy

Note: Figures 1-3 present 2000-2005 average values by region.

Table 1 – Descriptive statistics

	Mean	*Std. Dev.*	*Description*
Ecowa*	0.252	0.434	Adoption share of innovation for reducing waste & material
Innova*	0.498	0.500	Adoption share of technological general innovation (process and product)
Relational factors			
Sentg	0.432	0.495	Information on innovation received by internal sources
Ssup	0.365	0.481	Information on innovation received by suppliers
Scli	0.284	0.451	Information on innovation received by clients

Scom	0.151	0.358	Information on innovation received by competitors
Sins	0.209	0.406	Information on innovation received by private research institutes and consultancy firms
Suni	0.078	0.268	Information on innovation received by universities
Sgmt	0.039	0.195	Information on innovation received by public research institutes
Scon	0.214	0.410	Information on innovation received at conferences
Sjou	0.144	0.351	Information on innovation received by journals
Spro	0.125	0.331	Information on innovation received by firm's business associations
Co	0.113	0.317	Cooperation activities with other firms
Firms internal factors			
Rtr	0.259	0.438	Presence of formal training for employees
Group	0.297	0.457	Membership to a business group
Lprod06	11.881	0.816	Labor productivity in 2006

R&D	0.305	0.460	Presence of R&D
'Regional variables'			
Funloc	0.125	0.331	Innovation oriented Funding provided by regional agencies
Sep-collec	15.74	11.27	Share of regional separated collection (%)
Tariff	9.05	12.94	Share of population covered by the 'new' tariff system (%)
Land	0.0014	0.005	Landfill tax level in the region (€ per kg)
Agglomeration	…	…	Economic Density variable captured by the share of district firms in a region

N. Obs.: 6,483. * dependant variables

Table2 – Factors correlated to of ECOWA

ESTIMATION METHOD	BIPROBIT			
Dep. var.	ECOWA		INN	
	Coeff.	*t-value*	*Coeff.*	*t-value*
Sentg	0.104*	1.90	1.425***	19.32
Ssup	0.116**	2.42	1.111***	13.93
Scli	0.008	0.17	0.666***	6.66
Scom	0.073	1.36	0.352***	2.46
Sins	0.187***	3.71	0.599***	5.00
Suni	0.046	0.57	-0.609***	-3.02
Sgmt	-0.059	-0.58	0.169	0.54
Scon	0.127**	2.40	0.664***	5.27
Sjou	-0.002	-0.05	-0.386***	-2.63
Spro	0.100*	1.72	0.402**	2.46
Co	0.084	1.38	0.252	1.51
Rtr	0.177***	3.75	1.189***	10.17
Group	0.117**	2.49	-0.175**	-2.38
Lprod06	0.066**	2.54	0.083**	2.20
R&D	-0.001	-0.03	0.627***	6.12
Funloc	0.023	0.44	0.216	1.62
D1-49	Ref.	Ref.	Ref.	Ref.
D50_249	0.096**	2.03	-0.013	-0.16
D250	0.393***	5.69	0.039	0.29

North_West	0.014	0.13	0.333*	1.81
North-East	0.169	1.51	0.281	1.51
Centre	0.123	1.05	0.101	0.51
South	0.170	1.40	0.171	0.87
Islands	Ref.	Ref.	Ref.	Ref.
Industry dummy	Yes	Yes	Yes	Yes
N. Obs.	6,483		6,483	
Wald test (p.value)		0.274		

*** significant at 1%; ** significant at 5%; * significant at 10%

Note: standard errors are robust to heteroscedasticity

Table 3 – Factors correlated to of ECOWA

ESTIMATION METHOD	PROBIT			
Dep. var.	ECOWA			
	Coeff.	*t-value*	*dF/dx*	*t-value*
Sentg	0.103*	1.89	0.032*	1.89
Ssup	0.116**	2.41	0.036**	2.41
Scli	0.007	0.16	0.002	0.16
Scom	0.073	1.35	0.022	1.35
Sins	0.187***	3.70	0.059***	3.70
Suni	0.046	0.57	0.014	0.57
Sgmt	-0.059	-0.58	-0.017	-0.58
Scon	0.127**	2.40	0.040**	2.40
Sjou	-0.003	-0.05	-0.0009	-0.05
Spro	0.100*	1.72	0.031*	1.72
Co	0.084	1.38	0.026	1.38
Rtr	0.177***	3.76	0.056***	3.76
Group	0.117**	2.48	0.036**	2.48
Lprod06	0.066**	2.53	0.024**	2.53
R&D	-0.001	-0.03	-0.0004	-0.03
Funloc	0.023	0.43	0.007	0.43
D1-49	Ref.	Ref.	Ref.	Ref.
D50_249	0.096**	2.03	0.030**	2.03
D250	0.393***	5.70	0.132***	5.70

North_West	0.015	0.14	0.004	0.14
North-East	0.169	1.51	0.053	1.51
Centre	0.124	1.05	0.039	1.05
South	0.171	1.41	0.055	1.41
Islands	Ref.	Ref.	Ref.	Ref.
Industry dummy	Yes	Yes	Yes	Yes
N. Obs.	6,483		6,483	
Pseudo R^2	0.089		0.089	

*** significant at 1%; ** significant at 5%; * significant at 10%

Note: standard errors are robust to heteroscedasticity

Table 4 – Factors correlated to of ECOWA

ESTIMATION METHOD	PROBIT			
Dep. var.	ECOWA			
	Coeff.	*t-value*	*Coeff.*	*t-value*
Sentg	0.103**	2.32	0.103**	2.29
Ssup	0.116**	2.52	0.119***	2.67
Scli	0.007	0.15	0.005	0.12
Scom	0.072	1.60	0.069	1.48
Sins	0.187***	3.39	0.187***	3.40
Suni	0.045	0.46	0.048	0.51
Sgmt	-0.057	-0.50	-0.066	-0.58
Scon	0.126***	2.98	0.123***	2.83
Sjou	-0.0006	-0.03	-0.0003	-0.02
Spro	0.101***	3.27	0.105***	3.25
Co	0.084	1.02	0.089	1.05
Rtr	0.178***	3.43	0.178***	3.42
Group	0.119***	2.91	0.111***	2.78
Lprod06	0.064***	2.68	0.067***	2.79
R&D	-0.001	-0.04	0.002	0.06
Funloc	0.026	0.52	0.004	0.11
Sep-collec	0.110**	2.16	0.339***	2.64
Agglomeration	…	…	0.005	1.13
Sep-collec×agglomeration	…	…	-0.002*	-1.67

D1-49	Ref.	Ref.	Ref.	Ref.
D50_249	0.097***	2.94	0.101***	2.88
D250	0.396***	9.65	0.402***	9.93
North_West	-0.216	-0.99	-0.469*	-1.81
North-East	-0.053	-0.24	-0.338	-1.31
Centre	-0.020	-0.10	-0.200	-0.82
South	0.117	0.61	0.011	0.06
Islands	Ref.	Ref.	Ref.	Ref.
Industry dummy	Yes	Yes	Yes	Yes
N. Obs.	6,483		6,483	
Pseudo R^2	0.089		0.091	

*** significant at 1%; ** significant at 5%; * significant at 10%

Note: standard errors are clustered at regional levels (20 clusters)

Table 5 – Factors correlated to of ECOWA

ESTIMATION METHOD	PROBIT			
Dep. var.	ECOWA			
	Coeff.	*t-value*	*Coeff.*	*t-value*
Sentg	0.103**	2.39	0.103**	2.36
Ssup	0.116**	2.53	0.117**	2.56
Scli	0.007	0.14	0.007	0.14
Scom	0.073	1.58	0.072	1.55
Sins	0.187***	3.41	0.186***	3.39
Suni	0.051	0.55	0.051	0.55
Sgmt	-0.067	-0.59	-0.066	-0.58
Scon	0.127***	3.08	0.126***	3.00
Sjou	-0.005	-0.30	-0.004	-0.22
Spro	0.102***	3.08	0.103***	3.09
Co	0.085	1.01	0.085	1.00
Rtr	0.178***	3.45	0.179***	3.51
Group	0.110***	2.73	0.112***	2.76
Lprod06	0.067***	2.74	0.065***	2.60
R&D	0.003	0.09	0.003	0.08
Funloc	0.005	0.12	0.006	0.14
Land	-0.174	-1.49	-0.211	-1.35
Agglomeration	…	…	-0.004	-0.28
Land ×agglomeration	…	…	-0.001	-0.40

D1-49	Ref.	Ref.	Ref.	Ref.
D50_249	0.101***	2.93	0.102***	2.89
D250	0.401***	10.12	0.405***	9.64
North_West	-0.013	-0.08	-0.103	-0.59
North-East	0.221	1.14	0.193	0.98
Centre	0.133	0.77	0.072	0.42
South	0.145	0.78	0.120	0.64
Islands	Ref.	Ref.	Ref.	Ref.
Industry dummy	Yes	Yes	Yes	Yes
N. Obs.	6,483		6,483	
Pseudo R^2	0.090		0.090	

*** significant at 1%; ** significant at 5%; * significant at 10%

Note: standard errors are clustered at regional levels (20 clusters)

Table 6 – Factors correlated to of ECOWA

ESTIMATION METHOD	PROBIT			
Dep. var.	ECOWA			
	Coeff.	*t-value*	*Coeff.*	*t-value*
Sentg	0.101**	2.32	0.100**	2.32
Ssup	0.119***	2.62	0.122***	2.79
Scli	0.002	0.05	0.002	0.04
Scom	0.075	1.61	0.073	1.53
Sins	0.189***	3.39	0.188***	3.40
Suni	0.041	0.42	0.047	0.49
Sgmt	-0.065	-0.59	-0.071	-0.62
Scon	0.124***	2.93	0.122***	2.81
Sjou	-0.004	-0.23	-0.004	-0.24
Spro	0.102***	3.06	0.103***	3.06
Co	0.085	1.02	0.087	1.03
Rtr	0.181***	3.55	0.181***	3.60
Group	0.113***	2.82	0.110***	2.73
Lprod06	0.062**	2.50	0.062**	2.52
R&D	0.005	0.13	0.007	0.19
Funloc	0.019	0.43	0.004	0.11
Tarif	0.011***	3.04	0.012***	6.51
Agglomeration	…	…	0.002	1.29
Tarif_1×agglomeration	…	…	-0.0001**	-2.46

D1-49	Ref.	Ref.	Ref.	Ref.
D50_249	0.109***	2.95	0.111***	2.98
D250	0.418***	9.46	0.422***	9.31
North_West	-0.076	-0.41	-0.114	-0.59
North-East	-0.184	-0.87	-0.087	-0.46
Centre	-0.043	-0.23	-0.055	-0.28
South	0.161	0.85	0.131	0.69
Islands	Ref.	Ref.	Ref.	Ref.
Industry dummy	Yes	Yes	Yes	Yes
N. Obs.	6,483		6,483	
Pseudo R^2	0.091		0.092	

*** significant at 1%; ** significant at 5%; * significant at 10%

Note: standard errors are clustered at regional levels (20 clusters)

Table 7 – Marginal effects

ESTIMATION METHOD	PROBIT
Dep. Var.	ECOWA

	dF/dx	*t-value*
Separated collection	0.033**	2.15
Landfill tax	-0.053	-1.48
Waste Tariff	0.003***	3.02

*** significant at 1%; ** significant at 5%; * significant at 10%

Note: standard errors are clustered at regional levels (20 clusters)

Figure 1 – Landfill taxes

Figure 2 – Separated collection of waste

Figure 3 – Waste tariff diffusion (% population covered)

Italy's regions: map and taxonomy

Note: Figures 1-3 present 2000-2005 average values by region.