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EXTENDED PRODUCER RESPONSIBILITY (EPR) AND E-WASTE MANAGEMENT: Institutions, Prices and Costs.

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To my dearest mum Lucia who gave me the life, love and light to carry on my way.
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Abbreviations

CdC RAEE: “Centro di Coordinamento per Rifiuti da Apparecchiature Elettriche ed Elettroniche” (Italian National Clearinghouse)
CdR: “Centri di Raccolta” (municipal collection points)
CPR: Collective Producer Responsibility
EEE: Electric and Electronic Equipment
EoL: End-of-Live
EPR: Extended Producer Responsibility
ERP: European Recycling Platform
EU: European Union
E-waste: waste from electronic goods
IIIEE: The International Institute for Industrial Environmental Economics
IPR: Individual Producer Responsibility
LdR: “Luoghi di Raggruppamento” (retailer collection points)
MS: Member State
NIE: New Institutional Economics
OECD: Organisation for Economic Co-operation and Development
PAYG: Pay As You Go
PLI: Price Level Index
PoM: Put on Market
PPP: Polluter Pay Principle (in the first article)
PPP: Purchasing Power Parities (in the second article)
PRO: Producer Responsibility Organisation
RFIT: Radio Frequency Identification Technology
TC: Transaction Cost
TPO: Third Party Organisation
WEEE: Waste Electric and Electronic Equipment
WEEE Directive: Directive n. 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment
WG: Waste Generated

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1 Introduction

1.1 E-waste and EPR

E-waste describes waste from electronic goods such as computers, cell phones and television. WEEE refers to Electric and Electronic Equipment (EEE) entering the waste stream after their use and it includes also non-electronic goods such as refrigerators and ovens. However, these two group of waste are becoming less distinctive as some electrical equipment incorporate programmable microprocessors (Robinson, 2009). During this dissertation, the two terms are used interchangeably, and they refer to the wider category.

On one hand worldwide, there are different legal definitions of e-waste and WEEE and several approaches to tackle the issue. On the other hand, the concern and attention over this stream of waste is largely shared. The reasons behind this special consideration dedicated to e-waste is due to various reasons: quantity and its growth, hazard content and precious metals, transboundary movements, wide range of products.

The latest estimation of the e-waste annually produced in the world is provided by StEp Initiative (2014). According to this study, in 2012 there were 48.9 million tonnes of e-waste produced worldwide, equivalent of 7 kg per inhabitant. Moreover, this research predicts an increase by 33% by 2017 reaching 65.4 million tonnes. According to OECD (2008), e-waste represent 1-3% of the global municipal waste. Widmer and colleagues (2005) estimates that e-waste may contribute to 8% of the municipal waste in rich countries. Another important aspect of WEEE refers to its content. This stream of waste includes valuable substances (gold, copper, silver etc.) as well as highly toxic substances (cadmium, mercury, lead, arsenic, selenium, hexavalent chromium and flame retardants that generate dioxins when burned) (Widmer et al., 2005).

Therefore, e-waste requires special handling and recycling methods in order to avoid harmful effects on human being and the environment (Robinson, 2009). Proper recovery techniques are required. WEEE can be recovered through disassembly, component reuse, bulk recycling, and energy recovery (Nnorom et al., 2008) Regarding the issue related to Transboundary Movements, in 1989 the “Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal” was adopted in order to face toxic trade scandals where industries from the developed world dumped hazardous waste in developing countries and Eastern Europe. This multilateral treaty came into force in 1992 and to date it includes 180 parties (Khan, 2014). Finally, WEEE is a category of waste that assumes different definition and it can include several type of EoL products. The wide range of goods and their components that end up in the e-waste stream make the management aspects even more complicated. By 2003, the European Union, South Korea, Japan and some American States had already an e-waste law in place (Kahhat, 2008). The most comprehensive law is the European Directive that include ten categories of e-waste: large household appliances (such as refrigerators, washing machines and clothes dryers; air conditioner appliances etc.); small household appliances (vacuum cleaners, irons, toasters, scales etc.); IT and telecommunications equipment (mainframes, laptops, printers, telephones and cellular telephones etc.); consumer equipment (radio sets, TV sets, musical instruments etc.); lighting equipment (luminaires, lamps); electrical and electronic tools (drills, saws, sewing machines, etc.); toys, leisure and sports equipment (video games, coin slot machines etc.); medical devices (radiotherapy equipment, dialysis, analysers etc.); monitoring and control instruments (smoke detector, thermostats etc.); automatic dispensers.

According the OECD Report (2001), many governments have reviewed their policy options in order to face the increase of waste in general. One of this environmental policy approach is the Extended producer responsibility (EPR). This policy approach places the responsibility of the post-

consumer stage of certain goods, such as WEEE, on producers.
EPR policy, on one hand, shifts the physical and/or economical, total or partial responsibility toward producers and away from municipalities. On the other hand it provides incentives to producers to incorporate environmental considerations in the design of their products (OECD, 2001).
This new policy approach was created nearly from scratch by the German Minister of Environment and it was included in the Ordinance on the Avoidance of Packaging Waste in 1991. In this Ordinance, producers are required to "take-back" the discarded packaging, shifting the waste management responsibility from consumers, to material producers, product manufacturers and retailers (Lifset, 1993). After this first application in Germany, EPR is applied to packaging and other products in most of the world's industrialized countries (Fishbein, 2000). More precisely, EPR is nowadays implemented to packaging, lubricants, batteries, electronic waste (Massarutto, 2014) and vehicles.
The first official definition of EPR was presented by Thomas Lindqvist in his report in 1992 (Lindqvist, 1992) when some European countries (Austria, Germany, The Netherlands, Switzerland, and the Scandinavian countries) were dealing with policy instrument to improve the management of end-of-life products. Moreover, Lindqvist defined that "The Extended Producer Responsibility is implemented through administrative, economic and informative instruments. The combination of such instruments determines the precise form of the Extended Producer Responsibility".
According to Lifset and colleagues the "Management of end-of-life electronics—WEEE—is one of the most prominent uses of EPR around the world." Since the European Directive on WEEE in January 2003, other countries have debated and experimented EPR applied to WEEE (Lifset et al., 2013). Therefore, any study on e-waste management cannot be separated from the EPR policy principle when and where it is applied. This is especially true in the European context where the first Directive (2002/96/EC) on waste electrical and electronic equipment (WEEE) was introduced on the 27th January 2003. This Directive introduced the policy principle and made producers responsible for the end-of-life or their products. Therefore, the two terms E-waste and EPR are closely linked and the EPR policy principle becomes the framework and the e-waste stream one of the possible content.

1.2 Research questions

This Ph.D. thesis addresses three questions among several potential enquiries in the field of EPR applied to e-waste management. We need to consider that WEEE is one of the main concern within the environmental issue, for the reasons explained before. Most of the investigations, either research papers, books or reports, deal with the issue in technical terms. The great majority of researchers belong to the engineering field, some to the area of biology, chemistry and geology. The economist and business studies are still limited.
For these reasons, the first question we address ("do INSTITUTIONS matter?") faces the issue in general economics terms and aims, with the support of a wide literature review, to understand if EPR can be a possible solution to externalities from e-waste.
The second query starts from a broad question: "who pays" for e-waste management after the introduction of regulations that include EPR policy? Within this large inquiry, there are specific aspects to consider. In fact, several actors are involved in dealing with e-waste: consumers, municipalities, retailers, producers, compliance schemes, national clearinghouses, collection facilities, transporters and recycling facilities. We limit our investigation on the economic responsibilities shared between producers and consumers. In theory, producers recover their take-

back costs either as part of the product price or as visible recycling fee (Clift, 2006). However, only a few studies address this issue. Some of them face the problem in theoretical term. One of these researches, estimates the price increase in general terms but it does not provide evidence on the computation (Commission of the European Communities, 2000). The other two studies, focus on specific products and their markets (printers and lighting sector) but they don't present the details of the computation. Our research question can be revised in "Do consumers pay an higher PRICE for EEE after the introduction of the WEEE Directive that includes the EPR principle?"
The last question refers to the study on efficiency and COSTS incurred by the operators. We concentrate our attention on Producer Responsibility Organizations (PROs) that are established by producers to manage all the waste services and administer the finance of these operations (Mayers et al., 2013). Even if PROs are central players in EPR schemes, detailed research on PROs is still limited. We question why producers create PROs to comply with the law and we assess their internal costs as well as the way they charge the consortium members.

1.3 Hypotheses and Methods

In this section we briefly present the hypotheses and the methods applied in the three articles. Specific and detailed information can be found in each article.
In the first article the hypothesis is that institutions play in important role in dealing with externalities from e-waste. If externalities are a problem of insufficient defined property right (Coase1937,1960) then it is necessary to intervene changing the property rights themselves. Following the definition of the New Institutionalists, institutions are the rules of the game and organizations are the players (North, 1992). Property rights are institutions. Consequently, we assume that it is possible to force internalization of externalities when the rules (property rights) are changed. In this respect the hypothesis is that EPR changes the property rights because it shifts the responsibility for the end-of-life management of goods, appointing producers responsible for it.
The method used is a wide literature review on EPR applied to e-waste with a desk computer research. We used the Scopus research engine to investigate the two important aspects of EPR: 1/ the shifting of responsibility upstream toward the producer and away from municipalities; 2/ the provision of incentives to producers to incorporate environmental considerations in the design of their products. We investigated additional resources issued by governmental institutions, European Institutions, private institutes of research, NGOs etc. Moreover, we conducted the literature review on the New Institutional Economics. In total we investigate something like 370 articles.
In the second article, the hypothesis follows the pattern found in literature in theoretical articles as well as in the few case studies. Producers try to recover their costs of e-waste management totally or partially increasing the price of their products. This is supposed by several authors that addressed the issue. However, there are only few cases that investigate and quantify the effect of the financial responsibility of EoL into the prices of EEE. However, these few cases are limited in their scope and they do not report how the estimation of price increase was conducted.
Therefore, we hypothesize that the prices of EEE, increase after the introduction of the WEEE Directive that includes the EPR principle. More precisely, we speculate that the consumer prices of EEE have increased after the introduction of the producers' financial responsibility. Moreover, we provide the results of such estimation presenting a new method. This is an innovative method that utilizes geometric mean computations with PLI data (PLI=Price Level Index) applied to six categories of products, called basic headings, out of 226 used by Eurostat. These categories of EEE products are sampled every year in each Member State and they are not proxy data but actual data. Afterword, we look for the starting date of the financial obligation for producers. This information was requested directly to the national Ministers of Environment in each State. Then, we compute

the "PLI ratio (R)," for all MSs, i.e. the ratio between the price of each basic heading with the price of the same basic heading in the previous year. Then we calculated two geometric mean of the PLI ratios. The first subset (subset "V") presents the "average" of all the relative price variations after the WEEE Directive came into force. In fact, "V" is the geometric mean of the PLI ratio for each MS related to the year when the WEEE Directive came into force in that state. Therefore, there are 24 ratios in this first subset (all EU states except Netherlands, Belgium, and Sweden that had already an internal law on e-waste). Afterwards, we compute the second geometric mean "U" of all PLI ratios namely, the ratios of all years (and of all the states), when (where) the WEEE Directive did not come into force. Finally, we compute the ratio V/U between the first geometric mean V (variation years of 24 states: 24 ratios) and the second geometric mean U (no variation years, all states: 111 ratios) and we named it the "geometric mean ratio". This ratio means that we confront the EEE price variation when the WEEE Directive come into force with respect of the EEE price variation when the Directive did not apply. Therefore, we take the EEE price when the WEEE Directive did not come into force as a unit of measurement, V/U is the relative price of that EEE when the WEEE Directive came into force. For example, this geometric mean ration is equal to 1.01293 for the category "major household appliances" which means that the price of this EEE group of products increased on average by 1,29% in the European States after the introduction of the WEEE Directive. We repeated this computation for the other 5 categories. Furthermore, we compute the t-test to prove the statistical significance of the results.

The third article's hypothesis is that producers create producer responsibility organizations (PROs) in order to achieve these legally-imposed targets with minimal transaction costs (Dubois, 2012) and to reduce production costs. The method we used is the single case study of one PRO also known as "compliance scheme". First of all, we conducted some interviews to few key players of the EPR e-waste system during 2012 and 2013: the national clearing house (CDC RAEE, Milan, Italy), two local recyclers (SPHERAE Srl, Gorizia, Italy , BOZ SEI Srl, San Vito al Tagliamento, Pordenone, Italy;) and one municipality (Comune di Tavagnacco, Udine, Italy). These meetings, especially the first two, provided an important understanding of the system. We also attempted to compare two national compliance schemes namely ERP ITALIA SRL and ERP UK Ltd. They are two branches of the same company named ERP (European Recycling Platform) established in 2002 by four producers of EEE (HP, Sony, P&G and Electrolux). This is the only pan-European compliance scheme operating on e-waste in Europe nowadays. However, after the first short meeting with the CEO of ERP UK ltd in London in summer 2013, was not possible to obtain the information necessary to proceed with the research. Whereas, we received full support and information from the Italian branch of ERP. In fact, we conducted a semi-structured long interview at the company's premises followed by several contacts. These contacts together with the documentation they provided, were valuable source of information for the case study. We then investigated the theoretical background of the transaction costs economics in order to evaluate the compliance scheme within this theoretical perspective. We studied the existing methods available in literature in order to assess the compliance schemes. We selected and used a method applicable to assess a single PRO that deal with e-waste. This method was developed by Fredholm (2008) and it is the only one that classifies the indices in sub categories and that provides a structure that support the comprehension of the scheme. Moreover, we provided a classification of the ERP ITALIA SRL internal costs following Remedia's scheme (2012). The research also highlighted how the compliance scheme charges its members as this is an important aspect of the functioning of the PRO.

2 Articles

2.1 Extended producer responsibility and e-waste management: do institutions matter?

The first version of this paper was presented at the Third International Conference on Degrowth in Venice, in September 19th -23rd 2012. The conference is organized by Associazione per la Decrescita, Spiazzi, IUAV, Universitá di Udine, Cittá di Venezia, Arci, Kuminda and Sesterzo and co-organized by Research and Degrowth (R&D).

This current version of the paper was presented at the Second International Conference on Integrated Urban Solid Waste Management (IUSWM) held in Pisa, Italy, on June 26th -27th 2013. The conference is organized by Sant'Anna School of Advanced Studies, Pisa, Italy.

The paper is part of the conference proceedings and it is under review by the Journal of "Economics and Policy of Energy and the Environment" Franco Angeli Editions.

Extended producer responsibility and e-waste management: do institutions matter?

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Abstract—

WEEE (waste from electrical and electronic equipment, known also as e-waste) is the fastest growing category of waste with 50 million tons generated worldwide each year and it increases at a rate of 3-5% per year (Onyenekenwa et al., 2011). In Europe e-waste issue has been tacked with a specific directive named WEEE Directive (Directive 2002/96/EC). This directive includes a policy principle known as Extended Producer Responsibility (EPR). This research relates New Institutional Economics framework to EPR. More specifically, we investigate how the European regulation on e-waste (that includes the EPR principle) changes the institutional settings according to different options available. One of these options regards the individual producer responsibility choice versus the collective producer responsibility alternative.
This article also presents a case study on how the introduction of WEEE Directive in Italy has changed the financial, physical and informative responsibilities for producers and municipalities. One important result is that the target of collection of e-waste set at 4 kg per habitant per year by the Directive, was reached in 2010. We conclude highlighting that the recast of the European Directive in 2012 redefined the collection targets of e-waste and Italy will face a big challenge in order to reach those new goals.

Keywords-component; PPP, Extended Producer Responsibility, EPR, e-waste, WEEE Directive, New Institutional Economics.

I. INTRODUCTION

The relevant issue of negative externality (pollutions) coming from the e-waste management imposed organisations such as OECD and the European Union to deal urgently with the problem in theoretical and applied ways. OECD defined in 2001 the polluter pay principle (PPP) as a principle which ensures that polluters bear the expenses for the environmental impacts that they generate, rather than them being borne by society. EPR approach (within the PPP) is defined by OECD as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. There are two related features of EPR policy: (1) the shifting of responsibility (physically and/or economically; fully or partially) upstream toward the producer and away from municipalities, and (2) to provide incentives to producers to incorporate environmental considerations in the design of their products. The European Union in particular, converted these principle in regulation in 2003 with the Directive n. 2002/96/EC known as WEEE Directive (WEEE waste from electric and electronic equipment). The European member States have transported the Directive in different years. Moreover, there are divergences between the State transposition of the Directive because it is not a single market Directive.
The first goal of this article is to provide a literature review on the extended producer responsibility (EPR) approach applied to e-waste within the theory framework of the New Institutional Economics (hereafter NIE). The main question is to understand weather institutions (defined by North in 1992 "the rules of the game") can play an important role in dealing with the externalities stemming from the end-of-life management of electric and electronic products.
The New Institutional Economics appears to be particular suitable to investigate such kind of issues as it asserts that changes in property rights could force actors to internalize negative externalities (Delmetz, 1967).
The second goal is to investigate the European context where before the introduction of EPR, recycling of municipal waste did hardly reach a share of 5-10% (Massarutto, 2006). The shifting of responsibility for achieving recycling targets on producers and retailers has rapidly boosted recycling records in all European countries, quickly reaching unprecedented figures (up to 30-50% of total waste flows). The figure for single materials is even more striking; recycling rates of 60-90% have been achieved for waste such as oil, batteries and electronic equipment (Massarutto, 2007).

The article has the following structure: after the introduction the is a section dedicated to the NIE and the policy solutions to externalities. Then the methodology is presented followed by a paragraph dedicate to the Pollution Pays Principle. A special section is dedicated to the financial mechanisms of EPR and another one to the individual versus collective responsibility (and green design). Then, the Italian case is presented followed by the discussion and conclusion paragraph.

The main findings are that externalities indicate the presence of transaction costs (Dahlman, 1979) and they can be considered as a problem of insufficiently defined property rights (Coase, 1960). Institutions, such as property rights, can reduce transaction costs. More specifically, EPR redefines property rights by shifting responsibility toward producers, and it can play an important role in the process of internalization.

II. New Institutional Economics and policy solutions to externalities

We begin our discussion going back briefly to the concept of externality defined by Arthur Pigou in his well-known book "The Economics of Welfare" (1920, pg. 183). An externality is defined as a "divergence between social and private net product". More precisely "here the essence of the matter is that one person A, in the course of rendering some service, for which payment is made, to a second person B, incidentally also renders services or disservices to other persons (not producers of like services), of such a sort that payment cannot be extracted from the benefited parties or compensation enforced on behalf of the injured parties." Pigou proposed to curb pollution by imposing a tax in order to equal the private net product to the social net product. On the other hand, in case of positive externality the equivalence could be assured by a subsidy (Andersen, 1994).

Coase (1937) departs from this idea of externality developing the concept of transaction costs which is fundamental for the new rising theory called "New Institutional Economics" (NIE). Additionally, his work of 1960 contains the critical response to Pigou's idea of externalities. (Paavola et al., 2005). These two pioneering papers from Ronal Coase together with the works of North became the building blocks of NIE (Menard et al., 2012).

Regarding the issue of externalities, Coase's alternative approach was to consider them as a problem of insufficiently defined property rights. Therefore, an economically efficient transaction can be achieved between the parties involved only when property rights have been defined (Andersen, 1994). Coase himself states that "the right to do something which has an harmful effect is also a factor of production" (1960). Other authors that belong to the NIE school developed furthermore the concept. Demsetz (1967) and Dahlman (1979) expressed similar views. Demsetz states that an harmful or beneficial effect converts into an externality when the cost of internalization is too high. He suggests that the process of internalizing (usually with a change in property rights) enable these effects to bear on all interacting persons. "A primary function of property rights is that of guiding incentives to achieve a greater internalization of externalities." (Demsetz, 1967)

Dahlman (1979) argues that "market transactors are unable to make the emitter of an externality internalize the costs of his actions because the cost of carrying out the actual transaction is greater than the expected benefit". Ultimately, externalities indicate the presence of some transaction costs (Dahlman 1979). Moreover, according to North (1992), "the costs of transacting arise because information is costly and asymmetrically held by the parties to exchange". The same concept is expressed by Bromley (1991) when he states that without transactions costs there could not be externalities. This author expressed another important concept: the transactions costs are borne mainly by those not protected by rights.

On this basis, new institutional scholars devoted a substantial effort to identify the possible policy solutions to externalities.

For Dahlman (1979), Pigou's policy implications are strong and simple. When the markets are not able to reach an optimum in the presence of externalities, the government must intervene with either taxes or subsidies on the emitter. In fact, the solution he proposed to deal with externalities was to internalize them into the price system by a tax (later called "Pigovian tax"). The institutional form he suggested to deal with the market failure was the Government. No alternative institutional innovation forms were provided (Glachant et al., 2008). However, the computation of the Pigovian taxes implies the knowledge on the production and utility functions in order to describe the allocation of the competitive equilibrium. It also implies that it is clear who the emitter and the recipient of externalities are (Dahlman, 1979).

Coase uses an "argument from absurdity" to deal with externalities. In order to support that the initial assignment of property rights does not matter (given possible volitional bargains) as the rights will go to the highest bidder and the efficiency will be reached anyway, Coase adopts two (strong) assumptions. The first assumption is that the costs of transactions are zero. The second assumption is that the wealth effects of alternative rights assignments (and ultimate allocation) are zero. This is called the Coase theorem that Bromley (1991) renamed as the Coase tautology. Coase himself acknowledged that the results stemming from these strong assumptions are not relevant to the real world (1960). Therefore, the initial endowment of resource (property right and wealth positions) and transaction costs do influence the ultimate distribution of welfare across member of society. North (1992) states that the crucial connection between institutions, transaction costs and neo-classical theory was provided by Coase (1937; 1960). His theory can be synthesized in this matter. When it is costless to transact the efficient markets of the neo-classical paradigm are obtained. On the other hand, when it is costly to transact, institutions matter. Institutions, and specifically property rights, are crucial in the efficiency of markets (North, 1992). This author in the same article reports that "institutions are the rules of the

game of a society whereas organizations are the players". More formally, institutions are the humanly-devised constraints that structure human interaction (North, 1992). Therefore, for Coase what matters is not the source of the externality (emitter) but if an higher-valued output is achieved by changing the liability assignments and the ownership rights on the parties involved. As a consequence, any government action is feasible (not just tax rates) (Glachant et al., 2008). Dahlman (1979) concludes his article stating that institutions fulfill an economic function by reducing transaction costs and they should be considered as a variable inside the economic scheme. For this reason we can say that Coase "opens the door for an economic theory of institutions". Since Coase's contributions economists regards property rights as factors of production. Bromley (1991) adds a corollary to this idea: property rights are also policy instruments.

In this article we investigate EPR as a policy instrument that assigns the financial and /or physical responsibility for the EoL products to producers so that, the producers are force to internalize waste management considerations into their product strategies (Kalimo et al., 2012).

III. Methodology

This literature review on EPR applied to e-waste is a desk computer research carried out using Scopus research engine. The research covers a period from 1960 to January 2012. The main goals of this literature review was to summarize the state-of-art regarding EPR applied to e-waste with a special focus on the two goals of this principle. As reported earlier EPR has two aims: (1) the shifting of responsibility upstream toward the producer and away from municipalities, and (2) to provide incentives to producers to incorporate environmental considerations in the design of their products. Therefore we investigated the financial mechanisms that characterize EPR and the links between EPR and green design. The keywords used in the research are divided into the following logical categories: EPR and e-waste; EPR and cost; EPR and Green Design. For each category a set of keywords have been identified and synonymous or similar words were taken from the relevant papers in the field. The keywords used are the following:

- EPR and e-waste (or WEEE or electrical and electronic waste);
- EPR and green design (or design for environment);
- EPR and cost (or economic aspects or financial mechanism or economic mechanism or financial aspects or financial mechanisms).

Moreover, in the above exploration EPR was also searched by synonymous or similar concepts like: Extended Producer Responsibility; Individual Producer Responsibility; Collective Producer Responsibility; product take-back. Searching the previous items in articles Keywords, titles and abstract 105 papers on EPR and e-waste 36 articles on EPR and green design and 76 articles on e-waste and cost were found.

In order to provide a broader picture on EPR policy applied to e-waste, additional resources where taken from the main actors in the field like international organisation, independent researchers and other field specific institutions. These are the organisations and institutions considered: OECD Organisation for Economic Co-operation and Development; EEA European Environment Agency; EPA Environmental Protection Agency - US; European Commission; Environmental Assessment Institute - EAI; DEFRA Department for Environment Food and Rural Affairs - UK; Friends of The Earth International; StEP Solving the e-waste problem - UN Organizations; United Nations Environment Programme - UNEP; European Environmental Bureau - EEB; Greenpeace International; The International Institute for Industrial Environmental Economics - IIIEE; Institute for Environmental Strategies - Ökopol; Risk & Policy Analysts - RPA; INFORM Inc.; Social Innovation Center - INSEAD; Perchards; Individual Producer Responsibility works - IPR Works; European Topic Centre on Sustainable Consumption and Production – EIONET; Swedish Environmental protection Agency – Swedish EPA; The Institute for Prospective Technological Studies (IPTS) and Resources For the Future. Moreover, additional papers and reports where investigated through citations found in the previous documentations.

The results of the research are then classified and discussed in the following paragraphs: Polluter-pay principle (from command and control to market based instruments); EPR and financial mechanisms; individual versus collective responsibility (towards green design incentives).

IV. Polluter-pays principle (PPP): from command and control to market based instruments

If the main question is whether "victims" (receptors) or "polluters" (emitters) own the property rights to use the environment we can say that PPP states that the victims have the rights to use the environment and the polluters have the duties to prevent pollution or pay for additional pollution inflicted on the victims. In fact, as reported in the UN Glossary (1997) the polluter-pays principle is "the principle according to which the polluter should bear the cost of measures to reduce pollution according to the extent of either the damage done to society or the exceeding of an acceptable level (standard) of pollution".

PPP can be implemented with two approaches: command and control (CACs) and market-based economic instruments (EIs). Both approaches target the same reductions in environmental harm, they require the same institutions and they both aim at shifting the costs and responsibilities of pollution back to the polluters (UNEP, 2004). Governments can endorse "command and control" perspective adopting instruments such as environmental taxes, technology subsidies etc. or use "market-based approaches" like emissions trading programs and EPR (Gupta et al., 2011).

According to the UNEP study (2004), EIs provide more advantages compared to CACs. First of all, EIs thanks to the more secure property rights, allow managers to take on a longer time horizon or they may earn revenues that can finance the government's management of resources more effectively. Finally, many EIs require less public sector management and oversight than CACs. As we reported earlier, EPR principle follows the "polluter pays" principle and aims to legally bound manufactures and importers for the treatment and disposal of post-consumer products (King et al., 2006).

The EPR concept has developed within three general trend in environmental law and policy making. One of this is the shifting from command and control towards economic and informational tools (Kalimo et al., 2012). However, there is no one-way-fits-all implementation of the EPR instrument. Lindhqvist in his work in 1992 defines the responsibility in different types: liability, economic (financial) responsibility, physical responsibility, informative responsibility and ownership. According to Massarutto (2007) the allocation of responsibility among collectors, municipalities and industrial recycling systems can vary, and the resulting incentives are very different.

V. EPR AND FINANCIAL MECHANISMS

EPR allocates the physical and/or financial responsibility for the environmental externalities of products to the producer. In this paragraph we analyse the financial mechanism of EPR. We structure this section in three parts: A) financial responsibility; B) visible or hidden levies; C) time of fee collection.

A) Financial responsibility

Back to the year 2001, OECD report on EPR dedicated a section on "who pays" for the waste management system. The potential actors involved in the product chain are: raw material suppliers, producers; importers; suppliers; distributors; retailers; consumers; waste managers; waste haulers; waste sorters; recyclers; resellers; Producer Responsibility Organisations (PROs); and municipal government. Nevertheless, the idea behind EPR is that the financial burden, traditionally taken by municipalities and financed by taxpayers, is shifted to those who profit from the products.

EPR policy should incentive producers to absorb social costs from waste treatment because the policy recognises the ability that producers have to alter products to prevent and minimize waste management costs. Product pricing could then incorporate any unavoidable costs. Producers and consumers would pay for the social costs, in place of taxpayers. According to Seufert and colleague (2012) the market structure and elasticity of demand and supply determine how the abatement costs move from producers to consumers and the if a residual pollution cost still exist this is borne by the victims of pollution.

Atasu and co-authors (2011), report that EPR programs typically results in net costs to producers or consumers: take-back costs reduce profitability for producers and can impact consumers resulting in higher prices. Moreover, the cost efficiency in product take-back would benefit operators (collectors, transporter and recyclers) by increasing their margins. One key actor in this supply chain is the consortiums of producers called PROs. Producers created these associations to comply with the directive. As reported by Massarutto (2007) they provide excellent solution for internalizing externalities and reducing transactions costs. However, they gained a strong market power and this can be exploited against municipalities or it can generate discrimination in the internal market against goods manufacturers. Similar view is reported in Mayers (2007). He points out that PROs play a pivotal role in EPR implementation as they are an important interface for organizing financial transactions, collections, and communications among governments, producers, waste companies, retailers, and municipal authorities. Nevertheless, some producers have raised concerns regarding the relatively high level of fees they charge and the result in large accumulated financial reserves (Mayers, 2007).

As argued in Lepaws (2012), literature on e-waste assumes that the mere presence of legislation premised on EPR achieves the internalization by manufacturers of costs for e-waste management. In this respect little attention is paid on the division of responsibility among actors. Most of the times, it is taken for granted that manufactures are forced to internalize cost of disposal. However, this is not always the case as it has been argued that whether increased costs for producers can be passed along to consumers will depends on producers` market power and consumer demand elasticity (Sachs, 2006). Similar view is shared by Gottberg and colleagues (2006). They use a case studies from the European light sector to claim that EPR is unlikely to stimulate eco-design because the demand for such products is relatively price inelastic and the regulation affects all producers equally. Therefore, the larger part (if not all) the costs of waste management were carried out by customers. This is also due to the fact that additional costs only amount to one-two percent of the total product price. Another case studied by Khetriwal and colleagues (2007) reports that in the Swiss system the consumers bear the full costs of recycling fees for EEE.

A recent research (Favot et al., *in press*) provides statistical evidence on the price increase for EEE in Europe due to the WEEE Directive introduction which includes the EPR principle. This study has been conducted for all 27 European member States for six large categories of EEE including a vast majority of products which are the targets of the WEEE Directive. The data are provided by Eurostat. The result is in line with the previous but limited case studies and with the theory. The paper gives evidence on the price increase of electrical and electronic products sold in Europe after the introduction of the Directive and it computes an average price rise of 2.19%

Based on the available literature, there is some evidence that producers and customers are more involved in financing the e-waste management costs under EPR principle. This results in a lighter burden on municipalities and therefore taxpayers.

However, there is more research needed to understand how the different types of responsibility are shared between actors.

B) Visible or hidden levies

An important question within the financial mechanism is weather the levies are visible or hidden. A visible advance recycling fee is explicitly mentioned in the price of the product as an additional component. Vice versa, hidden or inbuilt fee is included in the price of the product without any information on the value of the fee (Khetriwal et al., 2007). It seems there is no consensus among scholars about this relevant issue. As an example, according to Quinn and co-authors, (2006) producers include cost of waste management into the product price involving consumers who pay directly for the waste management to purchase eco-friendly products. The authors argue that only visible levies make producers financial responsible of waste management of their EoF products. In fact, incorporate the levy in the production costs means to producers that waste management costs are like any other cost of production. Therefore, producers can reduce them by product redesign. Such system can also encourage DfE (Design for Environment). Khetriwal and colleagues (2007) believe that visible fees make the system transparent, create awareness on consumers, avoids retailers or recyclers to charge additional money for taking back the waste, and create a level playing field for manufacturers and retailers so they cannot undercut recycling fees.

C) Time of fees collection

Moreover, within the financial mechanism the recycling fee can be collected either at the time when the product is purchased or when it is disposed of. If we consider that the system is mainly financed by consumers, they are more willing to pay at the purchase time rather than when they want to dispose the product that is worthless. This advance financing mechanism is more secure (from a collecting point of view) and it also avoids illegal disposal (Khetriwal et al., 2009). The same article includes a consideration on the disadvantage of early fee. In theory, eco-friendly design products are penalized because the fee reflects the cost to recycle previous manufactured products. Therefore, no consideration is given to eco-friendly products. On the other hand, a pre-disposal fee would reflect better the actual cost of disposal of EoL product. Again, these considerations would need more applied research.

VI. INDIVIDUAL VERSUS COLLECTIVE RESPONSIBILITY: GREEN DESIGN INCENTIVES

When the EPR policy is adopted, there are several implementation choices to be taken by policy makers and these affect producer responses and therefore the success/failure of EPR policy (Atasu et al., 2011).

Regarding the application of EPR program, an important distinction has to be made between individual producer responsibility (IPR) and collective producer responsibility (CPR). Toffel (2003) claims that the distinction between individual and collective responsibility has critical importance to achieve the goal of creating incentive for producers to prevent pollution and waste through changes in product design, engineering, and manufacturing. He points out that only individual producer responsibility can drive these design changes. The same view is shared by authors such as Atasu and co-author (2012), van Rossem (2008), van Rossem et al. (2006a, 2006b) Lifset and Lindhvist (2008), Sachs (2006), Tojo (2004) and Walls (2006). According to these researchers strong design incentives come from the individual responsibility while practical solutions come from the collective responsibility.

CPR requires producers to be jointly responsible for the collection and recycling of all products mixed between producers and share the associated costs based (for example) on sales volumes. In this case, it is crucial to work out how those collective costs are allocated among manufacturers (Plambeck et al., 2009). IPR is a policy tool that incentives producers to take responsibility of the entire life-cycle of their own products. The logic behind IPR is that producers can reap the full benefits of any design investment they made (Atasu et al., 2012).

The Directive 2002/96/EC on waste electrical and electronic equipment states (art. 8) that each producer shall be responsible for financing of the collection, treatment, recovery and environmentally sound disposal of new WEEE (those put on the market after 13 August 2005) from his own products. This is also referred as individual financial producer responsibility. However, the directive states that the producer can choose to fulfill this obligation either individually or by joining a collective scheme. Moreover, they are responsible for financing the historical e-waste by one or more systems to which all producers contribute proportionately.

The original vision of EPR was, therefore, individual rather then collective producer responsibility but the final version of the directive gives either option to producers to choose the system. The response by industry to the policy was the creation of producer responsibility organizations (PROs) that manage collection and processing relevant products with a preference for collective EPR systems (Lifset et al., 2008). Throughout Europe, there are more than 260 PROs (Mayers, 2007). Collective systems allow scale economies. Cost allocation among producers is weight-based and is managed at best by sampling the collected products (Atasu et al., 2009). On the other hand, Atasu (2012) reports that the choice between operational cost-efficiency in CRP and superior recovery cost reduction (thanks to improved product design) under IPR is not clear cut from an economic welfare perspective. This author refers to a trade-off between IPR and CPR. He argues that CPR could provide better operational cost-efficiency; IPR can lead to superior recovery costs due to design changes from manufacturers. Toffel (2003), claims that many companies and trade associations think that only individual responsibility provides these incentives. In fact, the European Recycling Platform (pan-European take back scheme between EEE producers) and other major EE

producers say that in order to invest in product recoverability producers need control over final treatment of their products.
(Özdemir et al, 2012). This vision is supported by other studies like Mayers and colleagues (2011, 2012), Castell and colleagues (2004), Webster and Mitra (Webster et al., 2007) and Smith (in OECD, 2005). For Özdemir and co-authors (2012) collective responsibility does not give any incentive to producers for product recoverability improvement. Vice versa, these incentives are supported by individual responsibility. This scheme leads also to close-loop supply chains where components from EoL products can be reused in the new products.
Once a responsibility model is selected, a decision on the extent of physical and financial responsibility placed on the producer (and others) is needed. There are several choices and combinations of physical and financial responsibility that can be initiated (OECD, 2001). According to Tojo (2004), individual financial responsibility means that producers initially pays for the end-of-life management of his/her own products. The author defines individual physical responsibility when 1) the distinction of the products are made at minimum by brand, and 2) the producer has the control over the fate of their discarded products.
Here we intersect physical and financial responsibilities with individual e collective responsibility. The result is the following:

Table 1: intersection physical/financial responsibility and individual/collective responsibility

	INDIVIDUAL FINANCIAL responsibility IF	COLLECTIVE FINANCIAL responsibility CF
INDIVIDUAL PHYSICAL Responsibility IPh	IPh&IF responsibility = pure IPR	IPh&CF responsibility mix (Not interesting)
COLLECTIVE PHYSICAL Responsibility CPh	CPh&IF responsibility mix (Interesting)	CPh&CF responsibility = pure CPR

IPR: individual producer responsibility;
CPR: collective producer responsibility
Source: Our elaboration

Supporters of collective systems stress their efficiency because they allow building economies of scale and they are more consumer oriented as they take into consideration consumer habits (consumers bring e-waste to one specific place). Defenders of individual system stress the problem of free riders in collective system. Nevertheless, the most important characteristic of individual system is that companies get feedback on their products and help improving product design and producers could charge recycling fees reflecting investment in better design (Khetriwal et al., 2007). Individual responsibility would promote design changes more than collective responsibility (Tojo, 2004). Therefore, running a collective system capable of charging individual producers based on the effective product recycling costs (CPh&IF) can bring economies of scale as well as incentives to invest in design changes for improved recovery. In fact, it is interesting to see, as declared in the INSEAD report (Dempsey, 2010), that IPR does not necessary require separate and individual collection systems. Brand-based approaches can be implemented by collectively organised recycling systems. For example the Japanese system for televisions, refrigerators, washing machines and air conditioners uses a common "recycling ticket centre". This allows traceability of individual waste through the recycling chain. Producers pay recyclers depending on the number of products treated. In the Netherlands ICT, printers and telecommunication equipments are visually identified by brand. The producers pay recyclers a monthly invoice based on the weight of the recycled products. Moreover, there are new technologies in evolution for sorting and segregation of WEEE by brand that will allow IPR implementation (Dempsey, 2010).
Sander and co-authors (2007) state that the design incentives (and we can say more broadly the green design incentive) come from the fees differentiation paid for EoL management. In fact, charging producers for their e-waste based on quantity and weight can be improved to take into account specific characteristics of the product treated. Therefore, the cost allocation for e-waste management among producers within the same collectively-organised producer compliance systems is a key issue for achieving the green design goal of EPR principle. IPR is more important for WEEE rather than for example packaging. A fee per tonne of packaging by material type is sufficient to raise financial incentive for producer to reduce the packaging use as well as to use more recycling materials (Mayers et al., 2012). This is not applicable for WEEE where the allocation of treatment and recycling costs among producers is central. As reported by Huisman and coauthors (2007) environmental improvements and highest cost-efficiency can be achieved by rearranging "the product oriented scope" to a "treatment category oriented scope".
In France there is an attempt of such approach that boots the design for recyclability as PROs charge a penalty for e-waste which require special treatment. However, the limitation regards the not-agreed method of calculating the fee adjustment (Mayers et al., 2012). In the same articles Mayers and coauthors (2012) propose a financial methods to charge producers for their e-waste based on treatment costs of WEEE. In O'Connell et al. (2013) radio frequency identification technology (RFIT) are used for brand or model recognition. Mayers (2007) stresses that an important question that producers should ask themselves regarding EPR for WEEE is not how to implement individual responsibility for their products but how they can secure financial advantage from their improved designs. In the more recent article Mayers and his colleagues (2012) go further saying that the design for end of live is encouraged when the producers' EPR costs are close to the recycling and treatment costs of their own products.

Same view is shared by S. Smith (in OECD, 2005) stating that when producers are individually responsible for managing the waste from their products they would also reap the benefits of their innovation in terms of reduced waste management costs.
As a consequence, this would give incentives to firms to devote resources to innovation of this sort. In this respect individual responsibility is considered necessary to achieve changes in the design phase by both scholars and producers (The European Recycling Platform, 2012).
In conclusion, individual producer responsibility play an important role in reaching the second goal of EPR: providing incentives to producers to incorporate environmental considerations into the design of the product. According to Lindhqvist and Lifset (1998 and 2003): without the (design) incentives, the core rational for EPR is lost.

VII. ERP AND THE ITALIAN CASE

In order to understand if institutions matter in e-waste management, we analyze how the EPR is applied in the Italian context and which are the results achieved after the introduction of the WEEE Directive in Italy.
The European Directive is not a Directive on single market. Therefore, each Member State had some freedom to apply more bounding regulations. The Italian parliament transported the WEEE Directive in 2005 with the Legislative Decree n. 151/2005, followed by other decrees that establishes the national register and the national clearinghouse (coordination centre for WEEE i.e. CdC RAEE). The financial responsibility on producers was operative from 1st of September 2007 even thought this second part of 2007 was still a transitory phase.
We analyse the Italian country case with the scheme provided by Lindhqvist (1992). This author identified three types of responsibilities: financial responsibility; physical responsibility and informative responsibility. The extension of the responsibilities to manufacturers varies between EPR programmes (Tojo, 2004). Financial responsibility means that producers cover all or part of the costs of collection, recycling or disposal of their products. Physical responsibility involves the physical management of the products or the effects of the products and informative responsibility related to supply information on the environmental properties of the products (Lindhqvist, 1998).
Regarding the financial responsibility, in Italy each producer is obliged to join a collective scheme to finance the transport, treatment, recovery and disposal of old WEEE (put on the market before 13 August 2005) from household. There are nowadays 17 multiple competing compliance schemes organised on a collective basis For new household WEEE (WEEE put on the market after 13 August 2005) producers are responsible for the transport, treatment, recovery and disposal for the WEEE corresponding to the products they placed on the market. The Decree specifies that producers can fulfil this requirement either individually or joining a collective system. Therefore, producers are not required to provide financial guarantee for their own individual future waste. This compromises the link between e-waste management costs and eco-design (European Commission DG Enterprise and industry, 2008) as previously discussed. Producers are also responsible for professional historic and new WEEE and they can fulfill this obligation either individually or collectively. For new equipment, producers are fully responsible whereas they are responsible for the treatment of old professional WEEE only when they supply a new equipment. Otherwise, the financial responsibility remains with the waste holders. In this case, they sign an agreement for waste management with authorized companies or with municipal collection centers for the hand over.
The physical responsibility of dealing with e-waste in the Italian context, starts with consumers as waste holders. They are in charged of handing over WEEE to municipal collection points or retailers (in specific circumstances). In Italy one-to-one obligation for retailers started during the year 2010 and it means that retailers are obliged to withdraw an old equipment when a similar one is bought. Retailers transport e-waste to the municipal collection centre (centri di raccolta i.e. CdR) or to “meeting points” at retailers (luoghi di raggruppamento i.e. LdR). Municipalities have the duty to organize “collection centers” for citizens and retailers. Municipalities must ensure the proper operation of the systems for separate collection of WEEE from private households. With the Decree n. 65/2010, retailers are responsible of collecting e-waste from households when the customer buy a new equivalent equipment (known as one-to-one). Whereas, for professional e-waste producers or third parties acting on their behalf must manage individually or collective adequate systems for separate collection. Producers can use municipal collection centres within an agreement at the producers' own expense (Institute for European Environmental Policy, 2009).
From these collection and meeting points compliance schemes (also known as PROs) pick them up and deliver to the treatment facilities accredited by the CdC RAEE (the national clearinghouse). The treatment plants are then responsible to carry out the treatment of e-waste in accordance with the minimum requirements set out between CdC RAEE and the recyclers’ associations. In Italy, the deadline to reach the quantitative targets of collection (4 kg per inhabitant per year) was postponed from 31/12/2006 to 31/12/2008 and the result was reached only during the 2010.
Informative responsibility relates to the duty that producers have to supply information on the environmental properties of the product he is manufacturing (Lindhqvist, 1998). This information is included on the label showing crossed-out dust bin symbol that producers must attach on the equipment. The meaning of that label is that such product when reach its end-of-life cannot be disposed of in the ordinary bins but needs to be separately collected. Moreover, producers must inform consumers how to collect the e-waste including the possibility of returning the product to the retailer when a new equipment is bought. Additionally, the producer must inform users on the potential effects on the environment and humans due to dangerous components of such products together with

information on the meaning of the crossed-out dust bin symbol. Finally, the consumer has to be informed on the sanctions in the event of illegal disposal of waste.
Producers have also obligations towards the recyclers and reuse centres. For the new equipment puts on the market, the producer must disclose information regarding reuse and treatment options for such products within a year of the entry into the market.
The display of the visible fee is authorised until 13/2/2011 and for a specific category of products up to 13/2/2013. The time of fee collection coincides of the purchase of the EEE.
The recast of the WEEE directive (2012/19/EU) redefines the collection target for the Member States in the near future. Still up to 2015 the collection targets of household WEEE and professional WEEE is set at the minimum of 4 Kg/ inhabitant per year. Then, from 2016 to 2018 the collection rate is set at 45% of the average weight of EEE placed on the market (PoM) in the three preceding years. From 2019 onwards, the collection rate can be either 65% of PoM or 85% of WEEE generated (WG). A recent study on the WEEE generated in Italy (Ecodom, 2011) the household EEE put on the market between 2008-2011 amounted to 18.5 Kg/inhabitant (including professional EEE). Therefore, 65% of PoM is 12/kg per inhabitant. If we consider that the household WEEE generated in 2011 amounted to 16.3 Kg / inhabitant, 85% of WG is 13.8 Kg/ inhabitant. Either goals are far reaching from the 2011 result of 4.29 kg/ inhabitants.

VIII. DISCUSSION AND CONCLUSIONS

In this paper we analyse the concept of Extended Producer Responsibility as a policy approach applied to waste from electric and electrical waste (e-waste or WEEE). This principle has been included in the European Directive n. 2002/96/EC also known as WEEE Directive. Our aim is to present a literature review on EPR applied to e-waste within the theoretical framework of the New Institutional Economics (NIE). Moreover, we analyse the Italian case study after the introduction of the Directive. The NIE acknowledge the existence of transaction costs (Coase, 1960) and it recognizes that an harmful or beneficial effect converts into an externality when the cost of internalization is too high (Demsetz, 1967). Bromley (1991) expresses the idea that without transactions costs there could not be externalities. According to the NIE, institutions fulfill an economic function by reducing transaction costs. Moreover, institutions can be considered as a variable inside the economic scheme (Dahlman, 1979). North (1992) sees institutions, and specifically property rights, as crucial elements in the efficiency of markets.
Before the introduction of the WEEE Directive that includes the EPR principle, the level of e-waste collection and treatment was very low. For example in 2007 only 1,9 kg of e-waste were collected from households (CdC Raee, 2008). According to the NIE perspective, this was due to the presence of transaction costs that prevent the internalization of externalities due to high costs. EPR changed property rights among actors shifting responsibility physically and / or economically towards producers. As we know from Demsetz, (1967) property rights change, play an important role in the process of internalization of negative externalities.
After providing the theoretical framework of the NIE in order to deal with externalities, our contribution is a literature review on EPR applied to e-waste. We disclose three important areas of interest: 1) EPR and financial mechanisms; 2) EPR as an approach of the polluter-pays principle; 3) individual and collective responsibility and their impact on green design.
Furthermore, we analyze the Italian case and we study the financial, physical and informative responsibility as defined by Lindhqvist (1998). Regarding the financial and physical responsibility the Italian producers of EEE organize themselves in 17 compliance schemes known as PROs. Producers have opted for collective responsibility. On the other hand, the informative responsibility remains in the hands on the single producer. In conclusions, based on the theoretical contribution of NIE and the Italian case study we can assert that institutions matter in dealing with externalities coming from e-waste. One proof of this is that the goal of 4 kg /inhabitant/ year of e-waste collection was achieved after the introduction of the WEEE Directive. This Directive in fact includes the EPR principle which redefines the property rights among the actors involved.

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WEEE Directive. Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE).

2.2 A Statistical Analysis of Prices of Electrical and Electronic Equipment after the Introduction of the WEEE Directive.

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A Statistical Analysis of Prices of Electrical and Electronic Equipment after the Introduction of the WEEE Directive

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Summary

In January 2003, the European Union (EU) issued a directive on e-waste (waste from electrical and electronic equipment; WEEE) to deal with increasing quantities and the included hazardous components. The WEEE Directive is based on the principle of extended producer responsibility, which shifts the responsibility for end of life of products away from municipalities toward producers. This led some researchers to state that, in theory, the costs of waste treatment are passed on to consumers in terms of higher prices. This work addresses two fundamental questions: (1) Did the introduction of the WEEE Directive increase consumer prices of electrical and electronic equipment (EEE)? and (2) how much is this price increase? We carry out, for the first time in the literature, a quantitative research on price variation of the vast majority of EEE sold in the EU after the introduction of producers' financial responsibility. The panel data include 972 price level indices, namely, six categories of EEE for 27 member states for six years. The main result is that the average variation of the prices for each category of EEE investigated actually increased and the variation was between 0.71% and 3.88%, depending on the specific category of EEE. The average increase of 2.19% is in line with the previous studies that estimated the impact of the WEEE Directive up to a 3% increase of the product price. The t-test performed on the data shows a good statistical significance, which strengthens the relevance of the results. Finally, future directions for research are included.

Introduction

Waste electrical and electronic equipment (WEEE) is the fastest growing waste stream in the European Union (EU): It produced 8.3 to 9.1 million tonnes in 2005 and is expected to produce up to 12.3 million tonnes of WEEE by 2020 (Commission of the European Communities 2008). In 1996, in one of its resolutions, the European Parliament asked the Commission to present a proposal for priority waste stream, such as e-waste, based on the principle of extended producer responsibility (EPR). EPR was defined by T. Lindhqvist as "an environmental protection strategy to reach an environmental objective of a decreased total environmental impact from a product, by making the manufacturer of the product responsible for the entire life-cycle of the product especially for the take-back, recycling and final disposal of the product" (Lindhqvist 1992). In practice, the term has mostly been used to describe "post-consumer" responsibility, after products have been discarded at the end of their useful life. Moreover, in its report in 2001, the Organisation for Economic Co-operation and Development (OECD) defined one of the features of EPR: the shifting of responsibility (physically and/or economically; fully or partially) upstream toward the producer and away from municipalities. One result of the European Parliament resolution is that the EPR principle was set up for WEEE at the community level

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with the Directive 2002/96/EC (known as the WEEE Directive; European Union 2003). To date, after the WEEE Directive was transposed in each member state (MS), it is still unclear how much of the financial burden has actually been shifted from municipalities to producers. Indeed, even if the directive placed the financial responsibility of e-waste management on producers (collection, treatment, recovery, and environmentally sound disposal of WEEE), it is not fully known if producers actually bear these financial costs or if they pass them on to consumers. In fact, producers can either absorb these additional costs or increase the product price to take them into account. So far, research available on the subject has stated that, at least in theory, the producers try to recover (totally or partially) the waste management cost through product pricing (Fishbein 1998; Mayers 2007; Mayers et al. 2012; Lee 2008; McKerlie et al. 2006; Atasu and Van Wassenhove 2012; Widmer et al. 2005; Gottberg et al. 2006; Magalini and Huisman 2006, 2007; Toffel 2003; Lifset and Lindhqvist 2008; Massarutto 2008).

Empirical studies addressing this issue in quantitative terms refer either to the cost of end-of-life (EOL) management expressed in Euros per tonnes of processed e-waste or in terms of the percentage of costs compared to revenues. Only in a very few cases do these researchers investigate and quantify the effects of EOL costs into price increases. One example of this kind of estimate of price increases in electrical and electronic (EE) goods following the WEEE Directive implementation can be found in the "Proposal for a directive of the European Parliament and of the Council on waste electrical and electronic equipment" (Commission of the European Communities 2000). This proposal estimates in advance the average price increase as 1% for most electrical and electronic equipment (EEE) and up to 2% to 3% for some product categories, such as refrigerators, televisions and other monitors. A second important study by Mayers (2001) estimated an increase in electronic product prices between 4% and 7% based on research conducted on printers. Finally, Gottberg and colleagues (2006) examined some case studies in the European lighting sector and they found out that the additional costs, as a result of the financial obligations included in the WEEE Directive, only amount to 1% to 2% of the total product price. To sum up, it is important to note that the available case studies are very limited in number.

More specifically, the first and second studies we have just mentioned (i.e., the "Proposal" by the Commission of the European Communities 2000 and the work by Mayers 2001) did not report how the computation of the estimation of price increase was carried out. The third research by Gottberg and colleagues (2006) investigated eight case studies on companies in the lighting sector on the basis of both qualitative and quantitative data. However, the study does not provide details on such computation.

As in the previous cases that we have briefly mentioned, earlier research on the topic is very specific and scholars have provided valuable results because of a focus on detailed, controllable data (as in the cases of studies examining printers or the lighting sector). Instead, our study aims at inquiring and providing generalized findings on the issue. In other words, even though we do not rely on specific information as in earlier research, we intend to summarize the overall data in a single, representative, and relevant parameter, such as the average price increase. Both approaches complement each other, but they are equally important because, together, they can shed light on the issue.

The goal of this research is to show whether EPR implementation in European MSs have resulted in a rise of prices of large quantities of EEE. More precisely, we investigate whether the consumer prices of EEE have increased after the introduction of the producers' financial responsibility. Further, if this is the case, we wish to provide an estimate of such increase for different categories of EEE.

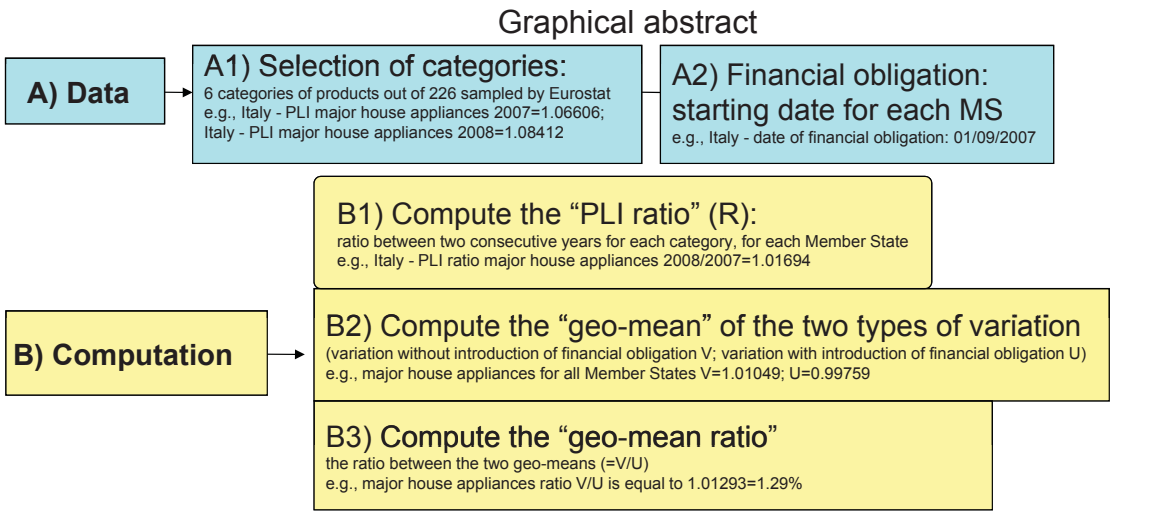
A graphical abstract (see figure 1) summarizes the phases of this research and includes data selection, computation, and results.

Materials

In this article, we analyze the relative price of some EEE by using the data provided by Eurostat (i.e., the purchasing power parities; PPP) for each year from 2003 to 2008 and for each MS. The PPPs, as defined by Eurostat, are simply relative prices that show the ratio of the prices in national currencies of the same good, service, or product group in different countries.

Following the Eurostat-OECD manual, PPPs are calculated in three stages. The first is at the product level, the second at the basic heading level, and the third at the aggregation levels. Within a single country, the products are priced at the elementary level. Then, to calculate PPPs, each country provides the prices of a selection of products chosen from a common basket of specifically defined goods and services, which are then broken down by groups (basic headings). These basic headings are the building blocks of Eurostat-OECD comparisons. At this level of aggregation, expenditures are defined, products are selected, prices are collected and edited, and PPPs are first calculated and averaged. The basic heading is the lowest level of aggregation for which final expenditures are estimated by participating countries. Following, once again, the Eurostat-OECD manual, PPPs, among other uses, can be employed to trace changes in relative price levels over time, as required by our research.

We select six categories, called basic headings, of the 226 categories of products used by Eurostat. The selection is carried out by considering the categories that include EEE whose prices are computed each year in each MS. Therefore, some categories of EEE are excluded either because their data are proxy data or because their prices are sampled every other year. This information was provided directly by Eurostat. Moreover, when the category selected in the first stage includes some non-EEE, we carry out a case-by-case consideration on the importance of such products. Then, we consider only the category where EEE corresponds to the vast majority of the items included. The result is that six important categories of EEE are selected and they enclose a large part of the EE products sold in the



Category of EEE	*Geometric mean ratio*	*Percentage of increase*	*p-value*
Major household appliances whether electric or not	1.01293	1.29%	0.0975
Small electric household appliances	1.01263	1.26%	0.1062
Equipment for the reception, recording, etc.	1.03884	3.88%	0.0190
Photographic and cinematographic equipment, etc.	1.03691	3.69%	0.0699
Information processing equipment	1.02312	2.31%	0.1227
Electric appliances for personal care	1.00711	0.71%	0.1810
Average increase in consumer price of EEE	1.02185	**2.19%**	

Figure 1 Graphical abstract. PLI = price level index; MS = member state; R = PLI ratio. V refers to the geometric mean of all the relative price variations after the WEEE Directive came into force; U refers to the geometric mean of all the relative price variations when the WEEE Directive did not come into force.

European market, including, for example, fridges, washing machines, dishwashers, dryers, air-conditioners, vacuum cleaners, televisions, radios, compact disc (CD) players, personal computers, visual display units, printers, and other small house appliances. We briefly report that there is no link between the Eurostat categories and the ten categories listed in the WEEE Directive. Moreover, Eurostat reports that the prices are inclusive of all taxes and fees.

The Eurostat data we work with are PPP converted in Euros and rescaled so that the geometrical mean of the prices of the 27 MSs as a whole (EU27) is equal to 1. In this way, we obtain a directly comparable ratio among counties, which is called the price level index (PLI), an index that expresses the price level of a given country in comparison to others.

The geometric mean is relevant each time several quantities are multiplied together (as opposed to the arithmetic mean used when several quantities are added up).

For example, suppose you have a quantity X that first increases by 10%, then the result increases by 50%, and then again the result decreases by 30%. Because those numbers translate into *multipliers* of X, respectively, by 1.10, by 1.50, and finally by 0.70, if we want to find the average rate of variation, we need to use the geometric mean, that is, $\sqrt[3]{1.10 \cdot 1.50 \cdot 0.70} = 1.0492$. In other words, the quantity X has been increased, on average, by 4.9%. Every time there are a number of factors multiplied together, then the "average" factor is the geometric mean. The example of interest rates is probably the most widely used application of this in everyday life.

In the case of PLI, the numbers that Eurostat provides for a category of EEE for each year, for example, Austria A = 1.02 and Belgium B = 0.87, translate into the ratio between the prices in those countries: R = 1.02/0.87 = 1.17241 (if we take the Belgian price as the unit of measurement, then the Austrian price would be 1.17241). Thus, working with quantities that are factors (R = 1.17241 in the above example, that leads to A = B · R), the geometric mean is the most suitable one to work with.

For our research, we select and analyze 6 of 226 basic headings:

1. **Major household appliances whether electric or not (05.3.1):** Refrigerators, freezers, and fridge-freezers; washing machines, dryers, drying cabinets, dishwashers, and ironing and pressing machines; cookers, spit roasters, hobs, ranges, ovens, and microwave ovens; air-conditioners, humidifiers, space heaters, water heaters, ventilators, and extractor hoods; vacuum cleaners, steam-cleaning machines, carpet-shampooing machines, and machines for scrubbing, waxing, and polishing floors; and other major household appliances, such as safes, sewing machines, knitting machines, water softeners, etc.

2. **Small electric household appliances (05.3.2):** Coffee mills, coffee makers, juice extractors, can openers, food mixers, deep fryers, meat grills, knives, toasters, ice cream makers, sorbet makers, yogurt makers, hotplates, irons, kettles, fans, electric blankets, etc.
3. **Equipment for the reception, recording, and reproduction of sound and picture (09.1.1):** Television sets, video cassette players and recorders, and television aerials of all types; radio sets, car radios, radio clocks, two-way radios, and amateur radio receivers and transmitters; gramophones, tape players and recorders, cassette players and recorders, CD players, personal stereos, stereo systems and their constituent units (turntables, tuners, amplifiers, speakers, etc.), and microphones and earphones.
4. **Photographic and cinematographic equipment and optical instruments (09.1.2):** Still cameras, movie and sound-recording cameras, video cameras and camcorders, film and slide projectors, enlargers and film-processing equipment, and accessories (screens, viewers, lenses, flash attachments, filters, exposure meters, etc.); binoculars, microscopes, telescopes, and compasses.
5. **Information processing equipment (09.1.3):** Personal computers, visual display units, printers, and miscellaneous accessories accompanying them; computer software packages, such as operating systems, applications, languages, etc.; calculators, including pocket calculators; typewriters and word processors. Includes: telefax and telephone-answering facilities provided by personal computers.
6. **Electric appliances for personal care (12.1.2)** : Electric razors and hair trimmers, hand-held and hood hair dryers, curling tongs and styling combs, sunlamps, vibrators, electric toothbrushes and other electric appliances for dental hygiene, etc.

Notice that we consider also the basic heading "Major household appliances whether electric or not" because, as reported previously, the large majority of these items are electric equipment excluded from a small part of the subcategory "cookers" that includes gas/convection oven and the gas/oil panels. Therefore, the final panel data include six different categories of EEE, 27 MSs, and six years (from 2003 to 2008). In total, we use 972 PLIs in our research, each one made up of thousands of pieces of data collected on each EEE and each MS and presented by Eurostat. We do not take into consideration the PLI variation of EEE for three states (Netherlands, Belgium, and Sweden) because they already had introduced a national law in force before the European Directive was issued. Those national laws already forced the producers to bear the financial responsibility for WEEE management for most EEE. Therefore, we use the data of these three states as comparative data.

The following step in this phase is to collect the date when the financial responsibility started on producers in each MS. Notice that this date does not necessarily coincide with the date when the WEEE Directive was adopted by law in the MS. This is because of the fact that, in most of the MSs, some decrees were necessary. Therefore, we investigate the actual date of the beginning of the financial obligation in each MS.

Method

So far, the research on EPR applied to WEEE is mostly theoretical. It asserts that the prices of EEE increase after the EPR introduction. There are a few exceptions that present quantitative research. However, they do not provide references to the method used.

This article uses a novel approach because it employs a geometric mean method with PLI data to explain the influence of EPR introduction on EEE price variation. The data were provided by Eurostat, and prices are expressed in PPPs. The method used by Eurostat to calculate PLIs for basic headings is the Èltetö-Köves-Szulc method (Eurostat 2006). The original data were not provided; therefore, this research uses secondary data. Moreover, Eurostat does not provide indicators of variability because, as reported in the manual, it is not possible to calculate precise error margins for PLIs or for the real final expenditure levels and comparative price levels derived from them.

We aim to asses the effect of the introduction of producer financial responsibility of WEEE management on EEE prices. The hypothesis is that producers increased EEE prices when the financial obligation was introduced. Notice that what matters in this research is simply the *relative* variation of prices from year to year, not their absolute level. Indeed, suppose that in 2006 Austria introduced the WEEE Directive and that in the same year the overall price of a specific EEE decreased throughout the EU market, for example, from 100€ to 80€, so it was reduced to 80% of its original price. If, in Austria, the price went down to just 85€ (to 85% of its price), this means that, in relative terms, the price in Austria actually increased as compared to the EU overall price. This fact is summarized by the ratio 85/80 = 1.0625, which is a factor greater than 1, that is, a relative price increase. In this way, we disregard the overall variation of prices in the EU of any category of products (resulting from any common factors throughout Europe, for example, inflation) and focus on relative increase in a specific country.

We use the PLIs of the 27 MSs for each product category. For each basic heading, our computation compares the PLI for each MS at the time when the WEEE Directive came into force in that country, with the PLI of the same basic heading in the same state the year before the introduction of the directive (as in the previous example). First, we compute, for all years and for all MSs, the ratio between the price of each basic heading with the price of the same basic heading in the previous year. In other words, the comparison is calculated by taking PLI at time t+1 divided by PLI at time t. We call this the "PLI ratio (R)," which is denoted as follows:

$$R = \frac{PLI(t+1)}{PLI(t)}.$$

Then, we repeat the same computation for all groups of products. These ratios quantify the relative change in prices between two consecutive years for each year and for each MS. For example, for the household appliances in Italy, this PLI ratio 2008/2007 is equal to 1.016940 (PLI 2007 = 1.06606; PLI 2008 = 1.08412). This means that, in Italy, there was a relative increase by 1.69% between 2007 and 2008 for that category of products. As explained previously, this does not mean that the price necessarily increased in absolute terms, but that only the PLI did.

Notice that we conventionally assume that the year of the beginning of financial responsibility falls in the current year if the obligation started in the first six months. Instead, we shifted the financial obligation to the following year if it started in the second half of the year. For example, in Italy, the financial obligation for producers started on September 1, 2007. Therefore, we consider 2008 as the year when this obligation has a full impact on consumer prices. This derives from the consideration according to which the financial obligation produced its effects in the year when producers were, for most of the time, affected by the obligation. We report in table 1, as an example, the computation for heading 1: major household appliances whether electric or not.

Because we are interested in the variation of prices after the WEEE Directive came into force, for each basic heading, we split the set of all the above PLI ratios into two separate subsets. The elements of the first subset, denoted by I, are given by the PLI ratio for each MS related to the year when the WEEE Directive came into force in that state. Therefore, there are 24 ratios in this first subset I (all EU states except Netherlands, Belgium, and Sweden, as discussed previously). In table 1, these numbers are reported in bold. The second subset Y includes all the other ratios, namely, the ratios of all years (and of all the states), when (where) the WEEE Directive did not come into force.

This fact is crucial and it is worthwhile taking some discussion to gain a better understanding of its importance. As we have already discussed, our goal is to isolate the effect on prices following the implementation of the WEEE Directive, but one of the main problems is related to the issue of "interference" on prices caused by country-specific factors, such as technology, labor market, taxation, and so on. We could tackle this issue of interference on prices by either normalizing all the data or by applying a purely statistical computation. We choose this second option and, as in the evaluation of the effects of a medical treatment, we make use of both a "treatment" group (ratios of countries and years with implementation of the WEEE Directive) and a control group (ratios of countries and years with no implementation of the WEEE Directive). In this way, because the only common feature of the first (treatment) group is the implementation of the WEEE Directive and because the other above-mentioned factors are randomly distributed over years and countries (i.e., their average is zero), if a statistically significant variation of prices arises, then it is a result of the implementation of the WEEE Directive.

Now, we compute the *geometric mean* of the ratios of both the first subset (we denote this mean by V) and the second subset (we denote this mean by U):

Let $I = \{R^*_1, R^*_2 \ldots R^*_{24}\}$ and $Y = \{R_1, R_2 \ldots R_{111}\}$. Then,

$$V = \sqrt[24]{\prod_{i=1}^{24} R_i^*} \quad \text{and} \quad U = \sqrt[111]{\prod_{i=1}^{111} R_i}.$$

Therefore, V represents the "average" of all the relative price variations after the WEEE Directive came into force, and what really matters here is the adjective "relative." An even more precise example may be useful. Suppose that, for a specific category of EEE in 2005, Austria had a price of 90€, and in the rest of the states the same price was, on average, 100€ (indeed, in general prices vary from state to state). Therefore, the ratio between the two was 90/100 = 0.9. It could be that in 2006, when the WEEE Directive came into force in Austria, the average price of that EEE dropped in all the states to 80€ (for some reasons we are not interested in). One would expect that the same price would drop in Austria to 80€·0.9 = 72€, so that the ratio is left unchanged. If instead, together with the WEEE Directive, we find that the price in Austria was 76€, then the ratio would be 76/80 = 0.95, that is, in relative terms, the price actually increased in Austria. This would be better expressed by the ratio 0.95/0.9 = 1.0555, which tells that, in relative terms, Austria had a price increase for that specific EEE of 5.55%.

Finally, we compute the *geometric mean ratio*, that is, the ratio V/U between the first geometric mean V (variation years of 24 states: 24 ratios) and the second geometric mean U (no variation years, all states: 111 ratios).

The result is the geometric mean of the EEE price variation when the WEEE Directive came into force with respect to the EEE price variation when the WEEE Directive did not come into force, the latter being considered a kind of "normal condition." In other words, taking the EEE price when the WEEE Directive did not come into force as a unit of measurement, V/U is the relative price of that EEE when the WEEE Directive came into force.

For example, for the category "major house appliances," this results in V = 1.01049; U = 0.99759. Therefore, the ratio V/U is equal to 1.01293. This means that, on average, in Europe where the directive applies, the consumer price for the major house appliances category increased by 1.29% when the financial responsibility was introduced (see table 2).

Finally, we need to test the statistical significance of the results obtained. Specifically speaking, what we need to determine is if the two sets of data I and Y are significantly different from each other, that is, if the average increase is the result of an external factor (the WEEE Directive) and not a random consequence of a casual splitting of the data into I and Y. To accomplish this task, we perform a t-test.

Before proceeding with the t-test, another crucial issue needs to be taken into account. On the one hand, we are working with numbers (PLI ratios) that are multipliers that produce the

Table 1 PLI ratios for the category major household appliances whether electric or not

Member state	*2004/2003*	*2005/2004*	*2006/2005*	*2007/2006*	*2008/2007*
Austria	1.00179	0.98591	**0.98347**	1.00283	1.03087
Belgium	0.99527	0.99282	0.92274	0.98432	1.00485
Denmark	1.01725	1.01143	**1.05676**	0.99672	1.01786
Finland	1.01341	0.99212	**1.06508**	0.98866	0.98713
France	0.98691	0.98921	1.02791	**0.99422**	0.98234
Germany	0.99527	0.98010	**1.07483**	0.98864	1.00537
Greece	**1.00852**	0.99842	0.93977	0.99925	1.01326
Ireland	0.98385	0.97769	**1.02401**	0.96051	0.97988
Italy	1.02116	0.99983	0.95952	0.96449	**1.01694**
Luxembourg	1.02055	1.00013	**1.00530**	1.00575	1.00448
Netherlands	0.99229	1.00634	1.09094	0.98638	0.98514
Portugal	1.00933	0.98490	**0.97918**	1.03248	1.01587
Sweden	0.98911	0.95230	1.04240	1.00922	0.95424
UK	1.02219	0.98187	0.92477	**1.01608**	0.86506
Bulgaria	1.00245	0.98415	1.06898	**0.99614**	1.04443
Cyprus	0.96898	**0.99348**	0.95163	0.95980	0.98991
Czech Republic	0.95617	1.00746	**0.97740**	0.98941	1.10060
Estonia	0.96932	0.95786	**1.09910**	1.00735	0.99400
Hungary	1.01360	**0.98583**	0.96684	1.05295	0.99917
Latvia	0.98934	0.94602	**1.12005**	0.95378	0.96034
Lithuania	0.96280	0.95088	**1.01008**	0.97018	0.98789
Malta	1.02911	1.05254	1.02890	**0.99249**	1.02326
Poland	1.00158	1.12842	**0.90279**	1.00901	1.06835
Romania	1.02754	1.16924	0.86406	**1.05135**	0.91966
Slovakia	1.02868	1.01000	**1.04968**	1.06770	1.04876
Slovenia	0.99569	0.99642	**0.92940**	1.02003	1.03129
Spain	1.00322	0.99272	**0.99046**	1.01042	0.99591

Note: Bolding indicates the PLI ratio related to the year when the WEEE Directive came into force in that state.
PLI = price level index.
Data source: Data derived by reprocessing Eurostat table data (Konijn 2012).

Table 2 Geometric mean ratio for major household appliances whether electric or not

Variable	*Value*
V: geometric mean of the PLI ratios when/where the WEEE Directive came into force	1.01049
U: geometric mean of the PLI ratios when/where the WEEE Directive DID NOT come into force	0.99759
V/U: geometric mean ratio	1.01293

Note: V refers to the geometric mean of all the relative price variations after the WEEE Directive came into force; U refers to the geometric mean of all the relative price variations when the WEEE Directive did not come into force.
PLI = price level index.
Data source: Data derived by reprocessing Eurostat table data (Konijn 2012).

geometric average. On the other hand, the t-test is performed on summands, because it uses arithmetic averages and related standard deviations. Our mathematical solution to this obstacle is given by the use of the logarithm, because it is a function that "transforms" multipliers into summands according to the following formula:

$$\ln(x \cdot y) = \ln(x) + \ln(y).$$

In our case, we obtain:

$$\ln\left(\prod_{i=1}^{24} R_i^*\right) = \sum_{i=1}^{24} \ln(R_i^*) \quad \ln\left(\prod_{i=1}^{111} R_i\right) = \sum_{i=1}^{111} \ln(R_i),$$

that is, a product that is transformed into a sum, and which, therefore, the t-test can now be applied to.

Hence, for each basic heading, we compute the logarithm $\ln(R_i)$ for each ratio R_i (of the 135 PLI ratios) and we split the logarithm $\ln(R_i)$ again into two subsets $\hat{I}$ and $\hat{Y}$ (obtained from I and Y):

$$\hat{I} = \{\ln(R_1^*), \ln(R_2^*) \ldots \ln(R_{24}^*)\} \text{ and}$$
$$\hat{Y} = \{\ln(R_1), \ln(R_2) \ldots \ln(R_{111})\}. \quad (1)$$

Then, we perform the t-test on the sets $\hat{I}$ and $\hat{Y}$ (of the logarithms of the elements of I and Y). We set the one-tail option because we are interested in an increase, not just a simple variation (increase or decrease) from the average. Finally, we set the threshold equal to 0.1 for the p-value. For example, the t-test for the category major house appliances results in the p-value $p = 0.0975 < 0.1$. Note that it can be easily proven that the base of the logarithm does not affect the t-test.

Table 3 Geometric mean ratio, price increases, and p-values for the six categories of EEE

Category of EEE	*Geometric mean ratio*	*Percentage of increase*	*p-value*
Major household appliances whether electric or not	1.01293	1.29	0.09750
Small electric household appliances	1.01263	1.26	0.10620
Equipment for reception, recording, etc.	1.03884	3.88	0.01900
Photographic and cinematographic equipment, etc.	1.03691	3.69	0.06990
Information-processing equipment	1.02312	2.31	0.12270
Electric appliances for personal care	1.00711	0.71	0.18100
Average increase in EEE consumer price	1.02185	**2.19**	

EEE = electrical and electronic equipment.
Data source: Data derived by reprocessing Eurostat table data (Konijn 2012).

Results

Our results show that in the exact year of the introduction of the WEEE Directive, the impact of such a directive on consumer relative prices of each of the six categories of EEE translated into an overall price increase. More precisely, the price increases emerged when the national law obliged producers to finance waste management costs on WEEE, as table 3 shows.

Major house appliances increased by 1.01293 (t-test p-value = 0.0975), small electrical households appliances increased by 1.01263 (t-test p-value = 0.1062), equipment for the reception, recording, and reproduction of sound and pictures increased by 1.03884 (t-test p-value = 0.0190), photographic and cinematographic equipment and optical instruments by 1.03691 (t-test p-value = 0.0699), information processing equipment by 1.02312 (t-test p-value = 0.1227), and electric appliances for personal care by 1.00711 (t-test p-value = 0.1810). These increases (1.29%, 1.26%, 3.88%, 3.69%, 2.31%, and 0.71%) result in an "average" (geometric mean) rise of 2.19%.

These results are in line with the studies carried out before and after the introduction of the WEEE Directive. Studies carried out before the introduction of the directive estimated the average price increase resulting from the WEEE directive implementation of 1% for most EEE and up to 2% to 3% for some product categories, such as refrigerators, televisions, and other monitors (Commission of the European Communities 2000). Mayers (2001) estimated an increase in electronic product prices between 4% and 7% based on a research conducted on printers. Another case study in the lighting sector (Gottberg et al. 2006) finds that additional costs resulting from the WEEE Directive only amount to 1% or 2% of the total product price. Finally, Mayers and colleagues (2012) reported that the impact of the WEEE Directive on the potential profitability of producers is estimated to range up to 3% of product price.

With regard to the statistical significance of the results, we notice that:

1. The relative prices of each of the six categories increased.
2. Three categories showed that the increase is statistically significant, because p-values for the t-test are below 0.1, where 0.1 can be considered a reasonable threshold.
3. The p-values of two categories are very close to 0.1, that is, 0.1062 and 0.1227.
4. Only one category (electric appliances for personal care) has a p-value equal to 0.1810, which is not completely satisfactory.

In general, the overall computation shows a good statistical significance, which strengthens the relevance of our results.

Discussion and Conclusions

This research aims to fill a gap in the literature by answering the question of whether the introduction of the WEEE Directive (and the embedded EPR principle) increases the price of EEE for consumers (Atasu and Van Wassenhove 2012). This research also quantifies such variation of prices for a large quantity of EEE sold in the European market. The research to date stated that, in theory, producers try to increase the price of products to recover EOL management costs. However, most case studies quantify such financial responsibility in terms of management costs of waste. Only in a few cases does research estimate the financial responsibility in terms of increases in the price for consumers.

This research provides some statistical evidence based on a large panel of data on the increase in consumer price of EEE in Europe resulting from the WEEE Directive introduction, which includes the EPR principle. This study has been conducted for all 27 European MSs for six categories of EEE, including a vast majority of products that are the targets of the WEEE Directive. The data used are secondary data provided by Eurostat and expressed as PPPs and transformed into PLI. The research method uses the geometric mean with 972 PLI data. This is a new approach in this field.

The results are the following: major house appliances increased by 1.29%; small electrical household appliances increased by 1.26%; equipment for the reception, recording, and reproduction of sound and pictures increased by 3.88%; photographic and cinematographic equipment and optical instruments by 3.69%; information processing equipment by 2.31%; and electric appliances for personal care by 0.71%. These increases result in an average rise of 2.19%. Finally, the t-test performed on the data shows a good statistical significance, which strengthens the relevance of our results. The findings are in line with the theoretical approaches as well as the few case studies presented in the literature. Therefore, this research shows that the WEEE Directive (when the financial responsibility was introduced) had an economic impact on consumers. This answers the question of whether or not EPR costs may

result in higher prices for consumers (Atasu and Van Wassenhove 2012). From the point of view of policy makers, this could be a first step to assess the distributional incidence (i.e., who ultimately pays) of the burden of environmental taxes. This is called final incidence, as reported on by Turner and colleagues (1998). However, it is out of the scope of the current research to investigate the relationship between the costs incurred by producers and the price increases for consumers. Therefore, future studies could take into consideration the difference in the price increase of the six categories. This could be done by investigating the actual costs for the waste management of each specific category. More precisely, it would be interesting to study the costs incurred by the producers to deal with WEEE Directive obligations for specific products and compare these costs to the rise in consumer prices. This would disclose whether or not the costs contracted by producers were totally or just partially shifted on consumers. Therefore, future research should aim to identify the cost structure of EPR implementation and its impact on stakeholders (Atasu and Van Wassenhove 2012). Future research could be carried out by using the same method with other products for which the EU issued a directive, including the EPR principle, such as packaging and vehicles. Moreover, the results could be tested by using other data sets provided by other institutions besides Eurostat.

Finally, another further development of our work could test whether the effects of the WEEE legislation on the prices had relevant consequences also in the subsequent years after the introduction of the directive.

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2.3 Why manufacturers of EEE create producer responsibility organizations to comply with the WEEE directive? The case of ERP Italia SRL with focus on costs.

This first version of the paper was presented, together with the other two articles, at the "EWAS E-waste Academy – Scientists Edition 2013". This summer school gathered twenty selected researchers worldwide to discuss the e-waste problem. It was organized in Geneva (Switzerland) on December 1st -11th 2013 by the StEP Initiative. StEP "Solving the E-waste Problem" is an initiative of various UN (United Nation) organizations with the overall aim to solve the e-waste problem. It is an address project of the UNU-ISP (United Nations University Institute for Sustainability and Peace).

Why manufacturers of EEE create producer responsibility organizations to comply with the WEEE directive? The case of ERP Italia SRL with focus on costs.

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Abstract

This paper investigates the role of producer responsibility organizations (PROs) created by producers to comply with the WEEE Directive. Despite the crucial role played by PROs in Extended Producer Responsibility (EPR) schemes, case studies that describe and evaluate national PROs is still very limited. A crucial aspect of evaluating the efficiency of PROs is the inclusion of transaction costs. This paper provides indications on how PROs deal with physical, informative and financial responsibility giving evidence on the reduced transaction costs involved in operating a collective PRO in comparison to individual scheme. The ERP ITALIA S.R.L. case study is used to investigate the issue, and it is one of the PROs operating in Italy and the only pan-European compliance scheme. This will allow future comparative studies with the other branches of ERP across Europe.

1. Introduction

The Extended Producer Responsibility (EPR) is a policy principle that is the basis of the European legislation regulating packaging, end-of-life vehicles, batteries and waste of electrical and electronic equipment (WEEE). The WEEE Directive is the result of a long developing process started in April 1998 as a part of the shift in the European environmental legislation from process to product (Castell et al., 2004). Eventually, the first issue of the Directive was published in January 2003.
After more than 10 years, several scholars advocate that a great amount of work on the topic is still needed. Massarutto (2014) draws a balance on the EPR promises and results: green design; recyclability by "closing the loop"; improvement of the overall efficiency. We can assert that the green design goal and waste prevention have not proven to deliver what expected, especially for electric and electronic products (Atasu et al., 2012; Rotter, 2011; Khetriwal et al., 2009; Yu et al., 2008; Gottberg et al., 2006; Castell et al., 2004). The "public good" aspect of recyclability prevents the incentive for the producer to design devices easy to recycle (Palmer and Walls, 1999). Therefore, several scholars share the idea that the drive for eco-design is effective only if producers are responsible for their own products (i.e. individual producer responsibility) (Castell et al., 2004; Lifset et al., 2013). However, this solutions carries important transaction costs. The view that the green design is a missing achievement, is shared by several authors: Lifset et al., (2013); Özdemir et al, (2012); Mayers and colleagues (2011 and 2013); Webster and Mitra, (2007); Smith in OECD, (2005) and Toffel (2003). On the other hand, the shifting of responsibility for achieving recycling targets on producers and retailers has facilitated recycling in all European countries (Massarutto, 2007). Moreover, the WEEE collected in Europe has been recycled at rates between 80 and 95% (Rotter, 2011).

Finally, the overall efficiency of the solutions adopted within the EPR scheme is still an open question (Massarutto, 2014). Any form of intervention by government or non-government to address market failure must be efficient i.e. the benefits must be greater than the costs. The net benefit of such intervention is critical to calculate especially for the costs and within these, the inclusion of transaction costs (Coggan, 2010).
It is widely recognized that PROs are one of the key players of the network design of EPR. However, their role is still controversial (Lifset et al. 2013; Mayers, 2007; Massarutto, 2007, Palmer and Walls, 1999). First, there is no clear agreement on the outcome they could reach (Mayers, 2007; Massarutto 2007). Second, previous research on detailed operations of PROs is quite limited (Lifset et al., 2013; Mayers et al., 2013).
We follow this call for a more fine-grained understanding on the efficiency of the solutions adopted within EPR schemes as well as the need for empirical research on one of the key players in the EPR scheme. Therefore, we focus in this paper on a producer responsibility organization (PRO), its responsibilities as well as its efficiency issues.
According to Mayers (2007) in Europe there were 10,000 producers and more than 80,000 European municipal authorities at the time when the article was written. A new subject (PRO) was created in order to deal with the potential complexity of the numerous entities in the field. In fact, as early as 2007, in Europe there were 130 PROs established to deal with WEEE.
On this basis, this research has two objectives. First it investigates the critical aspects of one producer responsibility organization operating in Italy: ERP ITALIA S.R.L. Then it underlines the transaction costs involved in operating a PRO. The paper is organized as follows. After this introduction, we provide a theoretical background followed, in section three, by the presentation of the case study. We focus on the responsibilities and the transaction costs that this scheme faces. In the last section we draw some conclusions and we call for more empirical research on PROs. This could start a discussion on the best practices adopted in Europe following the WEEE Directive implementation.

2. Theoretical background

According to Goulder (2008) the inability of the market to address externalities from pollution is the market failure that seems more central to environmental issues. Coase (1960) within the New Institutional Economics considers externalities a problem of insufficient defined property rights. The theory of New Institutional Economics (NIE) asserts that the change of property rights could force actors to internalize externalities (Demsetz, 1967).
There are several environmental policies that address the externality issue. One of these is the Extended Producer Responsibility principle, a general concept that gradually replaced the product take-back approach (Walls, 2011). EPR policy principle does change property rights among actors. In fact, EPR aims at shifting of responsibility (physically and/or economically; fully or partially) upstream toward the producer and away from municipalities (OECD, 2001). According to Buitelaar and Needham (2007) 'Property rights are rules and therefore according to the usual definition, institutions. Changing property rights deliberately so as to achieve certain effects is, therefore, purposeful institutional change'. Coggan (2010) citing Furubotn and Richter (2000, pages 2-3) states that "property rights reduce uncertainty and hence transaction costs in interactions between agents". In this respect we can cite the work of Vatn (2009) where he reports that NIE is focused very much on studying how different institutional systems economize on transaction costs.
Transaction costs have several definitions by several authors such as Coase (1960), Demsetz (1967), Barzel (1985) and Allen (1991). We use Allen's definition as it is particularly well suited for environmental and natural resource policies as many failure issues stem form incomplete property rights (McCann et al., 2005).
According to Allen (1991), property rights and transaction costs are fundamentally interlinked, and they can be considered two sides of the same coin. In his definition property rights are "the ability

to freely exercise a choice over a good or service" and transaction costs are "the costs establishing and maintaining property rights".
Changing property rights and appointing producers responsible for the end of life products (EPR principle) have created several positive aspects. EPR is the fundamental policy principle included in the European directive on WEEE. Massarutto, (2014) points out that one of the advantages of the EPR system is the capacity to collect and allocate financial resources necessary to fuel the system.
But why producers have created collective systems to comply with the directive?
According to Fleckinger and co-authors (2010) producers created associations (known as PROs) because bearing the responsibility may be very costly for individual producers. In fact, according to Sachs (2006), individual schemes are affected by substantial transaction costs. Similar view is share by Massarutto (2007) reporting that PROs represents an excellent solution to internalize externalities and reduce transaction costs. Moreover, Gottberg and colleagues (2006), classified the business costs of EPR in transaction costs, collection, recycling and miscellaneous. Transaction costs' key components are: identifying appropriate solutions and contractual partners; negotiating and managing contracts, reporting. According to Dubois (2012) producers create producer responsibility organizations (PROs) in order to achieve these legally-imposed targets with minimal transaction costs. Furthermore, individual producer operated systems may not be cost effective due to loss of scale economies as they should set up and individual logistic system to collect their products and facilities to recycle them (Atasu, 2012).
On this basis, it is quite natural to investigate the PRO approach to ERP requirements in terms of responsibilities, production and transaction costs.
McCann and co-authors (2005), specify seven typologies of transaction costs (TC) associated with public policies namely (1) research, information gathering; (2) enactment of enabling legislation, including lobbying and public participation costs; (3) design and implementation of the policy; (4) support and administration of the ongoing program; (5) contracting costs; (6) monitoring/detection and (7) prosecution/inducement/conflict resolution costs. According to this study, all of these costs are incurred also by stakeholders more specifically in our case, by producers and their organizations.
However, empirical measurement of transaction costs is problematic (Musole, 2009). He divides the studies on measurement of transaction costs in two categories: "objective approach" (with a neoclassical approach) and "subjectivist approach" (with a new institutionalist approach). This second approach founded in the seminal work of Coase (1960), measures transaction costs by proxies such as uncertainty, asset specificity, opportunism, etc. In this way "these heuristic devices measure the relative efficiency of alternative institutional/property rights arrangements or contractual choices" (Musole, 2009). In this respect our analysis follows the NIE view adopting a subjectivist approach. According to Buckley and colleague (1997) it is difficult to measure and assess TC as "the most important of them exist not in reality, but in realities that have been avoided, in worlds that have not come to be". Therefore, our analysis considers transaction costs in collective compliance schemes in comparison to individual compliance schemes that are not been established at least in Europe.
In general terms, the management of take-back schemes can be carried out by third party organization (TPO) also known as "compliance schemes" (StEP, 2009).
The StEP report presents two different approach to TPOs: own-branded TPOs and non-own-branded TPOs. The solution adopted in most cases (like in Italy) by producers is the second approach, where the compliance schemes collect and treat a share of e-waste arising in the country regardless of their brand. As reported before, according to Atasu A. and Van Wassenhove L. (2012) there are no individual producer operated systems in Europe because they may not be cost effective
The few cases of producers taking care of their own-branded products at EoL (or individual producer responsibility) are developed only in the B2B (business to business) sector. Xerox, Kodak and Ecò (Canon) are examples of companies adopting such solution in B2B. Regarding the individual producer responsibility in the B2C (business to consumer) sector, there are limited cases

such as HP and DELL Computer who encourage the take-back of their products (Van Rossem et al., 2006). However, this solution applies only to a portion of their products and therefore these producers also adhere to a PRO to fulfil their obligations.
To summarize, WEEE PROs are a central as well as controversial players in the EPR scheme. Nevertheless, they have been studied and compared only in few works. In this current paper we analyse one of the operating collection systems. We draw attention on how it fulfils its responsibilities and how it deals with transaction costs in comparison to a potential individual solution. We present how the ERP ITALIA S.R.L. complies with the economic responsibility, physical responsibility and informative responsibility as described by Lindhqvist (1992, 1998). Furthermore, we analyse the production costs if ERP ITALIA compliance scheme as well as the way this PRO charges its consortium's member.

3. The case of ERP ITALIA SRL

This company is part of a broader organization named ERP (European Recycling Platform) established in 2002 by four producers of EEE (HP, Sony, P&G and Electrolux). It developed the idea of setting the first pan-European compliance scheme in response to the European Union's groundbreaking directive to promote e-waste collection and recycling (Shao et al., 2009). ERP works in 16 states and has 2403 members in the world. So far, it has collected 2 million tons of e-waste (ERP, 2013 web site). ERP ITALIA S.R.L. was established in 2006. It is l.t.d company with one shareholder i.e. ERP SAS France. Also ERP ITALIA S.R.L has four "founding members" which make up the board in charge of the decisions; 35 "European members" and 2300 "local members" and it employs 12 people. In 2012, ERP ITALIA S.R.L. collected 12.63% of national e-waste.
The goals set at heart of the new organization in 2002 were:

1. stimulate market forces and competition among take back systems for a cost effective implementation of the WEEE Directive;
2. achieve scale economies to ensure competition and efficiency in recycling;
3. keep low overheads;
4. reduce market price for the highest quality available on the market;
5. support IPR (Individual Producer Responsibility)

(ERP ITALIA S.R.L. – corporate profile, Marc 2013)
ERP ITALIA S.R.L. operates in Italy where a national clearing house (CdC RAEE) was created in accordance to the Italian regulation. It is owned by the 17 Italian WEEE PROs. In 2012 ERP owned 1/9 of the national clearing house. The primary role of the CdC RAEE is to ensure the same market conditions to all members. It defines annually the market share of each producer and it determines which collecting spots are assigned to each PRO, on the basis of an algorithm.
The Italian branch of ERP has never been investigated while the UK branch has recently been studied (Mayers, 2007; Butler, 2009; Shao et al., 2009; Mayers et al., 2013).
Following the idea that one of the major strengths of case study is the opportunity to use different sources of evidence (Yin, 2003 page 97), our study is based on qualitative and quantitative primary and secondary data. We used a wide range of sources: reports, studies, company presentation, on line publication, company web site, brochure, as well as balance sheets (including "explanation notes"). Moreover, we used information on ERP ITALIA S.R.L. provided directly by the national clearing house (CdC RAEE) and by research papers that discussed the corporate headquarters and the English branch of ERP. Furthermore, a semi-structured interview was used in the meeting in order to gain in deep knowledge and specific details. The content of the interview was disclosed to the company before the meeting. This semi-structured long interview was held at the company premises in July 2013 and it involved two key employees. Besides, the draft document of this paper was submitted for approval to the financial officer of ERP. We discussed some important points of

the draft document over the phone. These additional inputs were used to review and improve the paper.
In order to understand better the case study, we also carried out a long interview (with Cdc RAEE) and a short meeting (with ERP UK) at their premises. Moreover, additional interviews were held with two Italian WEEE recyclers and one Italian municipality for the same reasons explained before. Moreover, data triangulation was used to address the potential problem of construct validity (Yin, 2003 page 99). The Italian regulation that implements the WEEE Directive was also studied (decree n. 151/2005 and following application decrees).

4.2 Physical responsibility

In Italy producers can fulfil their physical obligations (collection, treatment and recovery) either individually or joining a collection system according to the national regulation that implement the WEEE directive (decree n. 151/2005). The solution adopted by all Italian producers is to join a PRO. More precisely, all the 17 existing PROs are collective organizations. ERP ITALIA S.R.L is one of these. Moreover, in Italy the national clearing house (CdC RAEE) is established by law together with other institutes that manage the system (Ministerial decree n. 185/2007). Each collection system has to register to the CdC RAEE and its main task is to ensure uniform and homogeneous conditions to the collective systems.
Having a national clearing house reduces transaction costs related to (4) support and administration of the ongoing program as well as (6) monitoring/detection costs as the CdC RAEE is the body in charge of reporting to the central government.
Moreover, CdC RAEE determines the market share of each PRO which is proportionate to the amount of EEE put on the market in the previous year by the producers associated to that specific PRO. PROs have to collect e-waste from the assigned collection points when they require the intervention. The national clearing house assigns the national collecting sites to each PRO using a complex algorithm which incorporates several variables. The variables taken in consideration are: the quantity of WEEE collected in each collection point, the physical allocation of the collection point, the ease to reach the collection point and so on. Compensations on quantities collected are made the year after by reassigning the collecting points to the producers. In this way there aren't fee compensations between producers.
Based on these assumptions, ERP ITALIA S.R.L states that PROs do not compete on e-waste collection, since the collection activity is decided by CdC RAEE but they compete on the services provided to the customers. In this respect transaction costs related to (1) research and information gathering are reduced for the collection phase. This is quite different from the situation in the UK, for example, where ERP- UK (like the other British PROs) has to sign agreements with a sufficient number of collection points in order to reach the amount of e-waste collected that fulfil the responsibility of the members of the system (Mayer et al., 2013). In this respect, for producers enrolled in an Italian collective PROs, transaction costs related to e-waste procurement is significantly reduced also thanks to the role played by the national clearing house. Moreover, if we consider that an individual responsibility organization should collect and treat a share of its own e-waste by setting a separate collection and treatment route, this would create considerable transaction costs such as (1) research, information gathering; (5) contracting costs; (6) monitoring/detection and (7) prosecution/inducement/conflict resolution costs.
In Italy there are two different types of collection points: retailers collection points ("Luoghi di raggruppamento – LdR") and municipal collection points ("centri di raccolta – CdR" or "ecopiazzole comunali"). By law CdR must accept the e-waste from the local LdR. However, if the LdR is too big for the local CdR then PRO collects e-waste directly from the retailer and it transports it to the recycler. In order to make the system more efficient, PROs recognize a per ton compensation to collection sites when they reach certain standard of collections such as well

separated collection points for each e-waste category or when collection quantities reach a threshold for each collection mission requested from the collection site to the PRO. These compensation fees are regulated by a deal set by CdC RAEE and the national association of municipalities.
Producers do not have property rights on e-waste, nor PRO. The property of the e-waste belongs to the CdR or LdR when is discharged by end users and it is then owned by recyclers when it reaches their premises. PROs don't have the property on e-waste: they offer a service to pass them from the collection points to the recycler points.
When the CdR or LdR collect enough e-waste, they contact the CDC RAEE. Then CDC RAEE contact the collection scheme that has in charge that specific collection point. In this way, possible changes due to the reassignment of collection point to another PRO do not create a disservice to third parties. Typical transaction costs such as (1) research, information gathering are reduced.
CDC RAEE established a "maximum time of intervention" i.e. the maximum time from the moment in which the subscriber (either CdR or LdR) requires the intervention and the moment in which the PRO withdraws the WEEE from the collection point. In 2012 ERP ITALIA S.R.L reached on average 98.38% of the target. Then each PRO establishes a deal with transporters and recyclers to perform the operations. ERP ITALIA S.R.L has few contracts with companies that transport and recycle the e-waste. These agreements reduce transaction costs if compared to an individual producer organisation in charge of finding, collecting and treating its own products. Several transaction costs are reduces such as (1) research, information gathering (5) contracting costs; (6) monitoring/detection; (7) prosecution/inducement conflict resolution costs.
Moreover, PRO provides the contractors with a stable flow of e-waste and with contractual conditions fixed for few years.
This situation reduces the problem of hold-up for the recyclers and it allows long term investments.
The recyclers have to be accredited as enterprises of the treatment of WEEE by the CdC RAEE in accordance with its technical specification. The accreditation is based on a specific audit conducted by third-party certifiers which are selected and approved by the CdC RAEE. In 2013 (CdC RAEE web site) there are 113 waste treatment plants. Each of them is accredited for one or more of the five groups of WEEE (R1-R5 following in the Italian legislation). According to the data provided by ERP ITALIA S.R.L, the recycling performance (including energy recovery) reached 90% in 2012.

4.3 Financial/economic responsibility

Producers are responsible for financing of collection, treatment, recovery and environmentally sound disposal of WEEE. As for the physical responsibility, the legislation allows to fulfil this obligation either individually or by joining a collective scheme (WEEE Directive). The Italian regulation (decree n. 151/2005) concedes the same options to producers.
ERP (European Recycling Platform) founders claim that ERP contributed in changing the paradigm in European e-waste recycling by breaking with the monopolistic mentality and introducing competition among PROs (Shao et al., 2009). This allowed ERP to reduce average take-back costs significantly (Atasu, 2012). According to Mayers and Butler (2013), EPR was founded by producers in order to have more control and lower costs in the delivery of take-back services for WEEE.
In order to investigate the reduction of average take-back costs and therefore the improved efficiency, we analyse the internal costs of the PRO. We assess the cost structure of ERP ITALIA S.R.L. in the last three year (2010-2012). Following the Remedia's scheme (2012), we classify the costs in the following categories: treatment costs, logistic costs, performance bonuses (provided to collection points), communication costs and structure costs (including national clearing house).

COSTS	YEAR 2012	%	PER TON	YEAR 2011	%	PER TON	YEAR 2010	%	PER TON
Treatment costs	€ 1,887,389	23.59	€ 62.76	€ 3,158,423	26.79	€ 85.42	€ 3,241,142	30.98	€96.77
Logistic costs	€ 3,505,152	43.81	€ 116.55	€ 5,865,642	49.76	€158.64	€6,019,265	57.53	€179.72
Performance bonuses	€860,421	10.76	€28.61	€ 1,052,545	8.93	€ 28.47	€799,386	7.64	€23.87
Communication costs	€56,987	0.71	1.89	€ 0	0	€ 0	€0	0	0
Structure costs	€1,690,087	21.13	56.20	€ 1,712,107	14.52	€ 46.30	€ 402,493	3.85	12.02
Total costs	**€8,000,036**	**100**	**€266.02**	**€ 11,788,717**	**100**	**€ 318.83**	**€10,462,286**	**100**	**€ 312.38**

Table 1: Cost classification for ERP ITALIA S.R.L. during years 2010,2011 and 2012

Structure costs= tot WEEE production costs – (treatment costs + logistic costs + performance bonuses + communication costs).

2010: 33,492,450 kg collected by ERP; 13.65% ERP share of national collection rate
2011: 36,975,227 kg collected by ERP; 14.22% ERP share of national collection rate
2012: 30.073.569 kg collected by ERP; 12,63% ERP share of national collection rate

The break-down information on treatment and logistic costs in 2010 and 2012 have been provided directly from the ERP. Total treatment and logistic costs decreased over time for two main reasons: the company became more efficient and the value of the metal recovered from e-waste increased. More specifically, in 2012, ERP managed to reduce these costs thanks to the new business model that allows ERP to select contractors in the market instead of having one single contractor as in year 2010. In fact, while up to the first part of 2011, the general contractor was in charge of the selection of suppliers and the pick-up activities, from the second part of 2011 ERP internalized these activities with an appropriate internal structure. This new business model explains the increase of the structural costs and mainly it clarifies the decrease in the cost per ton of e-waste managed by the consortium.

On the other hand, the cost allocation under collective systems is a crucial aspect of EPR design (Lifset et al., 2013; Atasu, 2012 and Fleckinger, 2010). It can influence its efficiency as well as the incentives to waste prevention. Therefore, we analyse in detail how this compliance scheme works out the cost allocation among its members.

According to Forslind (2009), the EPR program can be implemented with two different financial schemes: pay-as-you-go (PAYG) or "insurance system". The PAYG is based on the costs incurred when the products reach their End-of-Life. With the insurance system, producers pay one contribution per product sold (Put on Market - PoM) and this will cover the costs of the end-of-life management when the product is dismissed.

First of all, ERP ITALIA S.R.L. loads the operation costs on its members. They can adopt one of these two options: the "collected and treated" (also known as PAYG tariff) and PoM tariff. ERP promotes the first option. Second, according to the managers of ERP ITALIA S.R.L., the costs paid by their members are as low as possible and they charge producers only the actual costs.

These costs are classified by ERP ITALIA S.R.L. in: 1) membership fee (i.e. general costs); 2) registration fee (i.e. cost for the local government); 3) operation costs (i.e. compliance costs).

There are two options for the "membership fee" (1): "local membership" and "European membership". On one hand, the "local membership" is defined in each Member State and in Italy it is about €200 for customers that have to treat up to 5 tons of EEE. For the customers that have more than 5 tons of EEE, the membership fee is proportionate to the quantity of EEE put on the market (PoM). This fee covers the functionality costs of PRO and for its fixed costs. On the other

hand, the “European membership” works in the same way but the agreement covers at least three European Countries.
Moreover, the “Registration fee” (2) are used to register the producer to the national system. In Italy for example these fees include: €16 for the stamp duty; € 168 for the government tax and concessions for the revenue agency; €30 for the secretarial duties at the Chamber of Commerce. The “operation costs” i.e. the compliance costs (3) can be computed in two ways: a) PoM put on market and b) collected and treated. The PoM tariff is set either by units or by kg of product put on the market.
The “collected and treated option", charges the costumers for what it is really collected that year and it is computed by multiplying the quantity times the unit costs. The advantage of PoM is that the customer pay a predefined amount of money. The disadvantage of such system is that members have to paid in advance. On the other hand, for the compliance scheme, the problem using this systems is to fix the appropriate fee, in order to cover all the costs without accumulate financial reserves.
One collective scheme for almost 2340 producers in place of thousands of single producer organisation, allows to determine the fees once for all the members reducing transactions costs such as (1) research, information gathering; (4) support and administration of the ongoing program; (5) contracting costs; (6) monitoring/detection and (7) prosecution/inducement/ conflict resolution costs.
ERP ITALIA S.R.L. prefers to charge members according to the “collected and treated” way. In order to compute the “collected and treated” tariff, ERP ITALIA S.R.L. multiplies the PoM tariff (fee per ton) by the expected rate of return. The PoM tariff is a fixed tariff computed per ton per each of the five WEEE groups (R1-R5). The expected rate of return is: tons of WEEE collected in year t+1 divided by tons of EEE sold in year t . Example tons of EEE sold in 2012 = 10,000; tons of WEEE collected in 2013 = 12,500; expected rate of return 125%.
Then ERP ITALIA S.R.L. shares the costs between producers based on their market share of the previous year. For ERP ITALIA S.R.L. this is the correct application of art 10 and 11 of DM 151/2005 as producers pay in function of their market share of the year before. ERP ITALIA S.R.L. points out the problem of setting the right tariff and get the financial sheet balance. This was especially difficult when the systems was set up. According to ERP ITALIA S.R.L., the tariffs applied to its members are the lowest possible and there are no reserves set aside.
It is very important to point out that these two ways that PRP uses to compute the fee and charge the consortium’s members do not include any incentive to eco-design. Design incentives come from the fees differentiation paid for EoL management (Sander, 2007). ERP ITALIA S.R.L. does not apply any individual producer responsibility as there is any cost sharing system based on the actual cost contribution of the EoL product.
In fact, the European Recycling Platform (pan-European take back scheme between EEE producers) and other major EE producers say that in order to invest in product recoverability producers need control over final treatment of their products. For Özdemir and co-authors (2012) collective responsibility does not give any incentive to producers for product recoverability improvement. This vision is supported by other studies like Mayers and colleagues (2011, 2013), Castell and colleagues (2004), Webster and Mitra (Webster et al., 2007) and Smith (in OECD, 2005).
Nowadays, individual operating systems can be very expensive and brand sorting activities too costly.

4.4 Informative responsibility

It is much easier to verify whether the targets have been respected at the macro level rather than at individual level. In this respect, when responsibilities and costs are shifted to collective actors like PROs, that are easier to control, the incentive to comply is strengthened (Massarutto, 2014) and

transaction costs are reduced. As reported by Atasu and colleagues (2012), regulators need to take into account costs of monitoring and controlling take-back systems. In this respect, the Italian law delegated this duty to the CdC Raee that must collect and process the information provided by the 17 PROs. This reduces the transaction costs, if we compare a solution that involves a myriad of individual PROs established by individual producers. It reduces (1) research, information gathering; (2) enactment of enabling legislation, including lobbying and public participation costs; (4) support and administration of the ongoing program; (6) monitoring/detection.
On one hand, CdC RAEE has a national call centre where municipal and retailer collection points can submit requests for waste collection and citizens can address general information. In this way any change in the allocation of collection point to a PRO does not create disservices to the users. This reduces transaction costs for the actors involved such as (1) research, information gathering. On the other hand, the national clearing house gets information and controls the system as well as provide equal possibilities to all parties involved. As reported before, producers pay a fee to the chamber of commerce. It keeps the public registers of producers (www.registroaee.it). Each producer and PRO has to enrol in this public register. Moreover, producers have several declarations to fulfil such as PoM (quantity of EEE put on market) during the previous year, by the 30th of May; the quantity of e-waste collected by PRO on behalf of its members and the percentage of e-waste recovery (using a form called MUD "single model statement"). Usually ERP ITALIA S.R.L. is also in charge of declaring the PoM on behalf of its members as an additional service. In this way ERP ITALIA S.R.L. can also check the volumes of the PoM by its members reducing (6) monitoring/detection cost. In case of differences in volumes, ERP ITALIA S.R.L. can conduct an audit to the producer.
ERP ITALIA S.R.L. declares a complexity of documentation required by the Italian central government. Moreover, the requirements are different in each member state. A statement by the European commission acknowledges that improvements under the Directive are necessary in order to harmonize the national registration and reporting requirements. Member States' registers for producers of EEE will be integrated more closely. Moreover, the Commission will adopt a harmonised format to be used for the supply of information. Consequently, administrative burdens are expected to decrease (Potočnik, 2012) together with transaction costs such as (1) research, information gathering; (4) support and administration of the ongoing program; (6) monitoring/detection.

5 Evaluation of ERP ITALIA S.R.L.

In 2011, the United Nations University and its "StEP Secretariat", issued a green paper on e-waste indicators (Gossart, 2011). Among the studies reported in this green paper to evaluate e-waste policies, we select the methods that are applicable to single PROs that deal with e-waste.
First of all, Khetriwal and co-authors (2009) assess and compare the two largest Swiss WEEE PRO, namely SWICO and SENS, based on material and financial flows. Fredholm and colleagues (2008), compare national PRO recycling systems (SWICO in Switzerland, El-Kretsen in Sweden and ICT Milieu in the Netherlands) analysing the system architecture, the content as well as the PRO performance. The IPTS technical report by Savage (2006), includes an evaluation and comparison of the compliance schemes namely Recupel (Belgium), ICT Milieu (the Netherlands), NVMP (the Netherlands), El Kretsen (Sweden), El Retur (Norway) and SWICO (Switzerland) focusing on collection targets and recycling rates. Fredholm's scheme is the only one that provides a structure and it classifies the indices in sub categories that support the comprehension of the scheme. This is the reason why we adopt this framework to evaluate our case study. The data is provided by the PRO where not otherwise specified and it refers to the situation in 2012 because this is most recent available information.

ERP ITALY SRL 2012			
System Architecture	**Product scope**	All categories (R1-R5)	**Yes**
	Collection methods	Retail Store Take-back	**Yes**
		N of non-retail collection points	**3,672***
	Financial structure	Who finance the system?	**producers**
		Sale Ban against non-registered manufactures?	**No**
Context	**Population**	Population (million)	**59,433,744***
		Population density (per sq km)	**198 #**
	Area	Area of jurisdiction (sq km)	**Not applicable**
	Wages	Average recycling wage (€/hour)	**-**
	Timing	Date each program began operating	**2006**
Performance	**Estimated annual costs (financial)**	Collection and processing (€/t)	**179.31**
		System management (€/t)	**56.20**
		Total annual cost (€/t)	**266.02**
		Amount of R1-R5 WEEE collected (kg)	**30,073,569***
	Annual quantities (environmental)	Amount of R1-R5 WEEE (Kg per person)	**4.00***

Table 2: ERP ITALIA S.R.L. evaluation according to the Fredholm's scheme.
* CdC RAEE data; # Istat data

6 Conclusions

After 10 years from the WEEE Directive publication it is widely recognized that PROs (producer responsibility organizations) play a central role in EPR schemes (Lifset et al. 2013; Mayers, 2007; Massarutto, 2007, Palmer and Walls, 1999). Despite this fact, empirical investigations on EPR implementation and on the influence of PROs is still limited. This fact has raised several calls to extend our knowledge on these aspects (Walls, 2011; Atasu et al., 2012; Khetriwal, 2009; Mayers et al., 2013). This paper answers to this call first of all by providing evidence on how ERP S.R.L. ITALIA works and how it complies with the physical, economic/financial and informative responsibilities.
Indeed, PROs play a pivotal role in EPR implementation as they represent an important interface to organize the financial transactions, collection activities, and communications among governments, producers, waste companies, retailers, and municipal authorities.
As reported by Massarutto (2014), centralized transactions through PROs allow coordinated and harmonized separated-collection activities and sorting activities. Furthermore, this centralized organization offers long term agreements, a more stable market, a reduced hold-up risk. Finally it encourages specific investments in the recycling industry as well as it counterbalances its market power. Such centralization, coordinated by PROs, reduce transaction costs if compared to a multitude of individual producer organisations. In accordance with the classification proposed by McCann and co-authors (2005), PRO schemes, if compared to individual schemes, reduce (1) research, information gathering costs; (3) design and implementation of the policy; (4) support and

administration of the ongoing program; (5) contracting costs; (6) monitoring/detection and (7) prosecution/inducement/conflict resolution costs.
Furthermore, we emphasize the importance of the financial mechanism. More precisely how PRO allocates the costs among its members as well as the composition of internal costs of ERP S.R.L. ITALIA. Moreover, we point out that ERP S.R.L. ITALIA as a collective organization, can reduce transaction costs if compared to setting up an individual organization for each producer. This is the reasons why producers have not set up individual organizations in B2C to comply to the WEEE Directive. Additional research is needed in order to provide insight of the functioning of other PROs. Moreover, further investigation on PROs will allow interesting comparisons on the adopted solutions.

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3 Results

In this section we provide a short overview of the results as they are better explained in each article. During the literature review conducted for the first paper, it became clear that the core issue of this research is the EPR policy principle while WEEE is a specific stream of waste to which the principle is applied. Nevertheless, e-waste is a peculiar stream of waste for its characteristics that we explained in the introduction (complexity, hazard substances, precious metals, variety). Therefore some consideration, especially associated to the second goal of EPR namely the green design, assume higher importance for EEE. The wide investigation conducted on the topic, reveals that the first goal of EPR principle has provided good results. EPR appoints producers of EEE responsible for the management of their end-of-life products. This policy principle changes the institutional setting and it forces the internalization of the externalities of waste.

Shifting the responsibility of EoL management of e-waste from municipalities to producers, achieved favourable outcomes. We can define these as the take-back incentive (Guoiun, 2013). According to Toyasaki and colleagues (2011) "The establishment of efficient take-back schemes is widely recognized as the first step to achieving high product recovery and recycling rates". This is referred to the downstream impact of the policy (Tojo, 2004). Indeed, EPR is always associated to high increases of separate collection and recycling (Massarutto, 2014). More specifically, in the European context the WEEE Directive imposed collection, recycling, and recovery targets on all EU member countries (Atasu et al.,2009). The collection target of 4 kg per habitant per year has been reached in almost all European countries (Eurostat, 2014). Furthermore, the WEEE collected in Europe has been recycled at a rate of between 80 to 90% (Rotter, 2011). Therefore, EPR policy principle is recognized to be a valid instrument to incentive the take-back goals.

The second goal of the EPR principle, to provide incentives to producers to incorporate environmental considerations in the design of their products has not delivered what promised. These can be defined as product design incentives (Guoiun, 2013). This is referred to environmental improvements upstream (design phase) of the product's life cycle (Tojo, 2004). Manufactures have not found much incentive there (Atasu et al., 2009). This view is shared by several authors (Atasu et al., 2012; Rotter, 2011; Khetriwal et al., 2009; Yu et al., 2008; Gottberg et al., 2006; Castell et al., 2004). Nevertheless, various research share the view that the green design incentives can be achieved by the fees differentiation paid for EoL management (Sander et al., 2007). Quantity and weight tools used to charge producers, should be improved taking into consideration specific characteristics of the e-waste. Individual producer responsibility could address the green design goal but practical implementation and costs need to be considered (Walls, 2006). However, it is possible to run collective systems that apply fee differentiation, based on the actual product recycling costs. This solution would maintain the economies of scale of the collective systems and it would create design incentives to producers for better recyclability. The key aspect is found in Mayers (2007) where he stress that the crucial question for EEE manufacturers is not necessary how to implement individual producer responsibility, but how to secure financial advantage from their improved designs. In conclusion, financial mechanisms and green design goals are strictly connected.

The results of the second article are quite straightforward. EPR forced manufactures to internalize management costs of their EoL products. In theory such costs, partially or totally, are shifted to consumers with the increase of the prices of EEE. This has proven to be the case in the European context when the WEEE Directive was introduced. Nevertheless, the average price increase is limited to 2,19% ranging from 0,71% for "electric appliances for personal care" to 3,88% for the category "equipment for the reception, recording, etc.". "Major house appliances" showed an increase by 1,29%, "small electric household appliances" 1,26, "information processing equipment"

2,31% and “photographic and cinematographic equipment” 3,69%. These findings are supported by the theoretical and practical case studies available in literature.

In the third article we analyse a case study of one of the collective systems established in Italy to comply with the WEEE Directive. The national system is supervised by a national clearing house (CdC RAEE). Up to date there are 16 consortiums operating in Italy for e-waste (www.cdcraee.it). ERP ITALIA S.R.L is the only pan-European collective system. It production costs can be classified in “logistic costs” which are the more important one reaching almost 44% of the total costs in 2012, followed by “treatment costs” 24%, “structure costs” 21%, “performance bonuses” 11% ad “communication costs” less than 1%. The comparison of the last three years permitted to find out that the company became more efficient over the time due to the new business model. This allowed ERP ITALIA SRL to select contractors directly from the market instead of signing up a contract with a single supplier. Another reason for the increase of the efficiency during these 3 years, is due to the added value of the metals recovered from the e-waste that decreased the treatment costs. We also tried to include transaction costs in the analysis knowing that empirical measurement of transaction costs is problematic (Musole, 2009). The transaction costs incurred by the PRO can be compared to the costs that an individual producer responsibility organization could incurred. However, this comparison can be made only in theoretical terms as there is none individual PRO operating on WEEE in Europe.
Another paramount aspect of the compliance systems is the allocation for e-waste management costs among its members. As reported in the first article, the fee differentiation based on the actual costs of EoL management, is a key issue for achieving the green design goal. We found out that the ERP ITALIA S.R.L. charges its members on weight of e-waste and it does not apply any fee differentiation based on the recyclability of their product. In this way, producers do not secure any financial advantage from their improved designs Mayers (2007).

4 Policy implications, Limitations and future studies

Our research shows that the first goal of the EPR principle included in the WEEE Directive reached its expected results of collection and treatment targets. According to the Eurostat statistic database, the collection target of 4 kg per inhabitant per year set by the first issue of the WEEE Directive has been reached by most of the member States. However, this target was not ambitious if we consider that this represents 2 million tons per year out of 10 tonnes generate in the EU (Potočnik, 2012). This consideration has been already endorsed by the European policy makers that during the 2012 issued a recast of the Directive appointing the new ambitious target of collection rate of 85% of WEEE generated. We can assert that this enforcement path is backed up by our findings. Moreover, we can state that this result came with a limited impact on consumers because the average price increase of EEE is only 2,19%. Nevertheless, policy makes should concentrate their attention on the second goal of EPR i.e. the green design goal. Our study underline that the theoretical solution to the issue is related to the financial mechanisms. Only when producers can secure the fruits of investment in green design, they will invest in it.
Moreover, EPR applied to e-waste opens a wide range of issues that this current work cannot fulfil. First of all it is possible to investigate other application of the EPR to other national contexts outside Europe. Then it would be interesting to study the responsibilities of the other players involved in the EPR system such as municipalities and consumers. Regarding the last paper, the initial idea of comparing different branches of ERP could be implemented with more time and resources. Paramount importance for transnational producers of EEE would be detailed

comparisons of the applications of the law in different nations with special focus on their financial and physical responsibilities.

5 Conclusions

This research studies the theoretical and practical assumptions and outcomes of the EPR policy principle applied to the e-waste. The negative externalities from the end-of-life of electric and electronic products, forced organizations such as OECD and the European Union to find an urgent solution. This is the reason way in the 1990's EPR concept was incorporated in several environmental policies especially in OECD countries (Tojo, 2004). EPR is an environmental policy approach based on the polluter pay principle (PPP). This principle assures that the polluters are responsible for the environmental impact they generate i.e. for their externalities. Coase (1960) approach to externalities is to consider them a problem of insufficiently defined property rights. We endorse this perspective and we investigate the issue within the New Institutional Economics (NIE) approach. NIE claims that changes in property rights could force actors to internalize negative externalities (Demsetz, 1967). According to Kalimo and co-authors (2012), EPR assigns the financial and /or physical responsibility for the EoL products to producers. Therefore, this change of property rights force producers to internalize waste management considerations into their product strategies (Kalimo et al., 2012). The goals and their expected outcomes of EPR are two: (1) the shifting of responsibility upstream toward the producer and away from municipalities, and (2) to provide incentives to producers to incorporate environmental considerations in the design of their products. The first goal has a downstream impact (enf-of-life management) and the second goal an upstream impact (inclusion of environmental improvements in the design phase) (Tojo, 2004).
Our findings in the literature review are conducted worldwide with a special attention dedicated to the European context where the WEEE Directive is in force since 2003. This directive incorporates the EPR principle and it applies to ten categories of e-waste ranging from large and small household appliance (such as dish washing machines and irons), to IT and consumer equipment (such as laptops and TV sets), lighting equipment, electrical and electronic tools, toys, medical devices, monitoring and control instruments and automatic dispensers.
Regarding the first goal we found out that EPR has boosted recycling records in all European countries. These quickly reached unprecedented figures up to 30-50% of total waste flows while before the introduction of EPR, recycling of municipal waste did hardly reach a share of 5-10% (Massarutto, 2007, 2008). The goal of 4 kg of e-waste collected per inhabitant set by the European Directive was achieved by almost all of the member States (Eurostat, 2014). The recast of the WEEE Directive in fact revised these targets as well as other aspects. Therefore as Sachs claims (2006) the European EPR legislation has generally improved the end-of-life management.
In the second article we analysed the impact of such change of responsibility from municipalities toward producers. More precisely, we investigate with a statistical new method, the price increase of the EEE after the introduction of the WEEE Directive that includes the EPR principle. In theory producers try to recover additional costs increasing the price of their product. Nevertheless, we found out that the magnitude of this increase is limited. On average the price increase of the EEE is 2,19% in Europe after the introduction of the WEEE. These results are in line with the previous theoretical analysis as well as with the few limited case studies. Moreover, our case study is the first available research that provide evidence of the computation. Additionally, the new method can be applied to similar contexts when an external factor, such as a European Directive, comes into force

in several States. In conclusion, we can assert that the first goal has provided good results with limited impacts on the prices of EEE.
Nevertheless, the more ambitious second goal of EPR related to the green design, has not delivered what expected. The reason behind this missing achievement can be found in the "public good" aspect of recyclability. According to Palmer and Walls (1999) it prevents the incentive for the producer to design devices easy to recycle. Several researchers like Castell and colleagues (2004) and Lifset and colleagues (2013) think that the eco-design drive is effective only if producers are responsible for their own products (i.e. individual producer responsibility). However, as we saw in the third article, this solutions carries important transaction costs as well as it does not allow economy of scale typical of collective systems. These are the reasons why there are not individual producer responsibility organization in the B2C (business to consumer) market in Europe. Furthermore, this reinforces the idea that the key issue to achieve the green design goal in the EPR principle must be found in the cost allocation for e-waste management among producers that belong to the same PRO. The case study of ERP ITALIA SRL demonstrates that the fee differentiation of the EoL products is very limited. In fact, consortiums' members are charged either with the "put on the market" (PoM) option or with the "collected and treated" solution. In the first case the membership fee is proportionate to the quantity of EEE put on the market (PoM) computed either by units or by kilograms. In the "collected and treated" solution, the membership fee is computed multiplying a fixed fee per ton of each group of e-waste by the expected rate of return of the same group. This fixed levy per ton is the same fee used to compute the PoM tariff. There is a limited fee differentiation provided by the distinct levy applied to each of the five groups of WEEE as re-defined by the Italian law. However, among the five groups of WEEE there aren't any distinction of fee based on recyclability parameters. This differentiation would provide the incentives to design equipment easy to recycle. The last article provides also some clarifications of the production costs incurred by the PRO. Logistic and treatment costs are the most important ones reaching 68% of the total costs in 2012. Moreover, we found out that this consortium managed to reduce its production costs thanks to a new business model.
Additional studies are necessary to investigate the other actors of the system such as users, collectors, municipalities, retailers, recyclers. The allocation of responsibility among them, can vary, and the resulting incentives are very different (Massarutto, 2007). We can conclude stating that there are still many aspects to investigate of the EPR principle applied to e-waste. This Ph.D. dissertation provides an overall picture of the system and it contributes to the understanding of some internal mechanisms of the EPR principle used on WEEE.

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