

# Economic and Ecological efficiency with respect to Waste Treatment Policies: Literature Review

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## Abstract

Developed countries have undertaken far-reaching policy measures to promote recycling of municipal waste. However, the understanding of the consequences of different policy measures are often less than complete. A number of promoted waste recycling policies tend to focus entirely on environmental impacts abstracting from other important costs to society. Recycling is not a free activity. It uses resources to produce resources. Hence, it is not always definite that the marginal net product is positive. The goal of this paper is to review international literature regarding different approaches to economic and ecological efficiency related to waste treatment policies. The recycle of waste is a function of economic and non-economic influence. We consider what is meant by efficient recycling policies via examining such concepts as social optimality, cost-efficiency, non-economic efficiency in the sense of affecting behavior and eco-efficiency.

**Keywords:** social optimality, Pareto optimum, Pigou tax, cost-efficiency, non-economic efficiency, eco-efficiency, waste

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## 1. Introduction

We have been living in the time of escalating environmental consciousness. The recycle of waste takes place in almost every country because it has been economical. It is also partly a function of non-economic influences such as change in political concerns triggered by voter tastes for the cleaner environment (Alhanaqtah 2014; Fullerton & Kinnaman 2002).

Economically developed countries have undertaken far-reaching policy measures to promote recycling of municipal waste. The following waste management options are outlined in many European countries (Letcher 2020; Letcher & Vellero 2011; Rao et al. 2016; Veglio & Birloaga 2018; Worrell & Reuter 2014): reduce, reuse, recycle, incinerate and landfill (Note 1). However, the understanding of the consequences of different policy measures are often less than complete. The differences in economic costs across policies can be substantial. Referring to Baumol (1977), "Recycling is not a free activity. It uses up resources to produce resources and it is therefore not always certain that the marginal net product must be positive". Radetzki (2000) indicates that a variety of promoted recycling policies tend to focus completely on environmental impacts prescinding from other essential costs to society. Acuff and Kaffine (2013) studied least-cost policies for the reduction of waste and, in particular, analyzed the effect of deposit-refund system, recycling subsidies on upstream greenhouse gas emissions and advance disposal fees. They found out that in spite of the increases rates of waste recycling and relevant reduction of emissions, direct recycling subsidies are more expensive and generate less reduction in emissions than a deposit-refund system or advance disposal fee. Ino (2011) considered the deposit-refund policy is an ideal policy for internalizing disposal costs (the first-best-policy), analyzed a monitoring cost of firms' illegal disposal and also investigated an alternative (the second-best) policy by applying the tradable rights market with the help of which producers would to take back residuals. Eichner and Pethig (2001) used a general equilibrium model to conclude that "if recycling benefit exceeds environmental damage, the policy instruments needed for green design are a tax on the consumption good supply and a subsidy on the demand for material input". Shinkuma (2007) analyzed the optimal waste disposal policy for durable goods (Note 2). He concluded that adoption of an advance disposal fee policy results in excessive consumption and disposal compared to the social optimum. This policy can be considered as second-best in some situations, either if net disposal cost is relatively low or if repair cost is relatively high. Kinnaman *et al.* (2014) suppose that developed countries may be setting inefficiently high recycling goals. They conducted a research for Japan and found out that average social costs (Note 3) are minimized with recycling rates well below observed and mandated levels. Ek and Miliute-Plepiene (2018) analyzed implementation of food-

waste collection to measure the casual effect on the sorting of packaging waste. Even though results suggested a positive spillover effect, indirect robustness tests provided no compelling evidence that estimated spillovers are spurious. Thus, from the economic standpoint recycling policies have to pass cost-benefit and economic efficiency tests. Thus, we have to consider what is meant by efficient recycling policies.

## 2. Approaches to economic efficiency

### 2.1 Social optimality

Social optimality implies comparing marginal social costs (MSC) and marginal social benefits (MSB). The marginal costs are costs for sorting and transportation of waste, administration costs of recycling policies, etc. The marginal benefits refer to the value of recycled materials in new production. This policy aims maximizing the net benefits to society. The point where  $MSB = MSC$  would be a Pareto-optimal (Note 4) provision of waste sorted. If decision makers know MSC and MSB they can impose the tax that will stimulate an economically efficient level of sorted waste.

Finding socially optimal level of recycling is, of course, not easy. It was investigated theoretically and empirically. One set of theoretical studies derives taxes of Pigou to ensure Pareto optimum (Dinan 1993; Graves 2019; Laurent et al. 2014; Palmer & Walls 1997; Sonesson et al. 2000) while another set of studies derives optimal mixes of recycling, incineration and landfilling using dynamic models to analyze waste management options (Bovea et al. 2010; Cremiato et al. 2018; Edwards 2018; Huntala 1997; Keeler & Renkov 1994; Leach et al. 1997; Leu & Lin 1998; Lima et al. 2018; Liu et al. 2017; Powell 1996; Powell et al. 1996; Samakovlis 2001; Saraiva et al. 2017). Kinnaman and Fullerton (2000) broadly reviewed economic aspects of different waste management policies.

Food waste recycling is required since it allows to alleviate the saturation of landfills. Currently, there are very few countries implemented food-waste disposal tax. Some authors justify theoretically the social-optimal food-waste (disposal) tax along with the government incentive which includes mechanisms of Pigou and government expenditures (Katare et al. 2017; Pakhomova et al. 2019).

The “invisible hand” of markets favors the discharge of waste directly into the environment. However, levying prices for waste disposal, like Pigou tax, may provide incentives to make illegal waste discharges through “midnight dumping”. Monitoring of waste for a large variety of non-point sources can be extremely costly. Some papers consider optimal waste disposal policy when monitoring of waste disposal of individual polluters is not possible. They show that deposit-refund system may be used to equalize private and social incentives for waste collection. The optimal policy implies a tax (deposit) on the good, the use of which results in waste creation, combined with a subsidy (refund) on waste collection. Together this combination acts as an implicit Pigou tax on uncollected waste (Dinan 1993; Fullerton & Kinnaman 1995; Palmer & Walls 1997).

Some authors describe the socially optimal environmental policy via collective waste disposal activities among producers of solid, liquid and gaseous waste (Hamilton & Sproul 2013). Collective waste disposal system is an instrument which takes advantage of the economies of scale in waste treatment and disposal costs among different polluters (Callan & Thomas 2001), engage the spatial transportation of waste from areas where it is produced to areas with designed facilities to assimilate it. Such a system may be used to manage household garbage, public sewage and various types of hazardous waste. It is noteworthy that the optimal composition of waste networks as well as the implementation of coordinated waste collection are subjects that have received insufficient attention until recently.

### 2.2 Cost-efficiency

In the whole, it appears that international literature guides to rather contrasting conclusions. First, whilst some authors focus on costs in the balance sheet, others evaluate the future cost of substitution waste plants and landfills, and others examine the environmental costs of each option in accordance with a cost-benefit or a cost-effectiveness analysis. Second, why authors' conclusions vary so much is due to the specific features of the sphere examined. In each sphere there are variables affecting service costs (availability and capacity of landfills, financial incentives, labour costs, production factors). On balance, while some scholars limit analysis of costs to a particular stage in the waste cycle, others focus on the whole integrated waste management system (collection, transportation, recycling, disposal).

Determinants of costs are technology, population density, extension of the collection area, supplier's turnover, service delivery arrangements (Lombran 2009).

Noteworthy, no correlation was found between privatization and cost efficiency (Bel & Warner 2008). In fact, evidence shows that both private and publicly owned undertakings are able to maintain development (Alhanaqtah 2019; Alhanaqtah *et al.* 2019). Therefore, we may say that performance is not affected by the amount of private capital, but by the type of waste management type and the extension of service areas.

Policy is considered to be effective if it achieves a target at the lowest possible cost. This is efficiency without taking into account social optimality (Baumol & Oates 1988). Cost-efficiency is realized when the marginal costs of all possible means of achievement are equal. For example, there is the amount of waste (the recycling target) to be recycled in two regions with different marginal costs: region 1 is assumed to have a high cost of recycling waste while region 2 has a relatively low cost of recycling. The purpose is to divide the recycling target between these regions so that to minimize the cost to society as a whole. Here we have to keep in mind that the recycling target does not necessarily correspond to the socially optimal level of recycling activities. Logically, the region 2 with lower costs should recycle more than the region 1 but both regions sum up to the recycling target. In accord with Berglund (2003), “by identifying the least-cost means of meeting a particular standard or policy goal and using this cost as a benchmark case, we can estimate how much total costs can be expected to increase from this minimum level if policies that are not cost effective are implemented”.

There are several different activities that could be allocated in a cost efficient manner. One aspect of cost efficient allocation focuses on household recycling efforts. Palmer and Walls (1997) used a partial equilibrium model of waste generation and recycling to evaluate three policies targeted at reducing solid waste disposal [54]. The author concluded that a deposit-refund system is the cost-effective policy under scrutiny which was supported by other studies. Another aspect relates to a regional and global scale where countries or regions tend to minimize recovery costs given a politically set recycling goal. Here the focus is on minimizing costs of collection, input costs for firms and transportation costs (Berglund 2003). The life cycle analysis has been employed to this issue (Bernstad & Jansen 2011; Brogaard & Christensen 2016; Finnveden & Ekvall 1998; Finnveden *et al.* 2000; Hansen *et al.* 2006; Hauschild *et al.* 2013; Maria & Micale 2015; Sharma & Chandel 2017; Vieira & Matheus 2019).

### *2.3 Efficiency in the sense of affecting behavior*

Efficiency could be defined in a non-economic sense. A policy is considered efficient if it affects behavior of people in a desirable way. For example, a subsidy on recycling is reasonable if it stimulates a profound increase in recycling activities of a society. Obviously, this efficiency criterion connected with public deliberations is very different from the Pareto criterion. Here the focus is made not on a productive (or technical) efficiency but on allocative efficiency. Different policy scenarios may be accomplished by economic incentives. Nevertheless, if the public is not much responsive to economic (such as price) incentives for waste collection and recycling, other non-economic incentives (such as information campaigns, etc.) may be more efficient or, in other words, more successful in changing recycling behavior. Some research studies from the economic-psychology literature point out that motives matter, and that people undertake recycling activities for moral reasons (Ackerman 1997; Frey & Jegen 2001; Frey & Oberholzer-Gee 1997; Grodzinska-Jurczak 2006; Hornik *et al.* 1995).

Waste is a provocative issue. The appeal to shop suppresses any mention of garbage. Constant consumption is framed within a commodity culture and serves as an expression of personal freedom and choice. However, the other side of it is a freedom to discard things that still possess value. Thus, Hawkins (2006) examines beliefs and ideas that shape social behaviors around waste. In consumers' relentless efforts to buy, sell and accumulate things, they do not possess them as much as things possess its consumers (Hawkins 2006). Brown (2003) offers a remarkably new way to think about materialism.

Tucker and Speirs (2003) review factors affecting the household waste management recycling and composting behaviours. They show that negative perceptions about these activities or barriers to performing those activities are common discriminants of behaviour in those activities. They found out that there may be two distinct classes of attitudes: convenience factors such as time and effort and attitudes of predisposition such as perceptions of fly and vermin problems, waste requirements and aesthetics.

Zarine (2018) shares how Civic Response Team takes a people-first approach to change practices of dealing with the waste. Some scholars point out that where people interact for the sake of environmental change, managing relationships is of a great importance. Relationships build trust, and trust is essential for any behavioral change (Shah 2016).

## **3. Approaches to eco-efficiency**

How and to which extent the environment is used in economy over time?

The concept of eco-efficiency focuses on integrating economic and ecological dimensions of activities or processes, encouraging the creation of value with less environmental impact. This concept has three *objectives* (World 2000a):

- decreasing environmental impact by reducing to minimum different kinds of environmental pollution and facilitating the sustainable use of resources;
- decreasing resource consumption reducing to minimum material inputs and assuring closing materials loops;
- increasing the value of products and services by offering products which require fewer resources and materials, and at the same time meet consumer needs.

In order to measure eco-efficiency there are two categories of indicators: economic performance (generally include product quantities, sales, net profits) and environmental influence (generally include consumption of energy, water and materials, emissions of greenhouse gases and ozone depleting substances, packaging amounts, waste to incineration, waste to landfills and total waste produced) (World 2000b).

Importantly, eco-efficiency is not a specific concept or waste management system. It is an ecological and economic effectiveness. It shows how economic activity deals with the environment. Eco-efficiency can be described mathematically as follows (Bohne *et al.* 2008):  $\text{eco-efficiency} = \text{value added} / \text{environmental impact}$ .

Nonetheless, applying eco-efficiency to waste issues requires special reasoning. Application of eco-efficiency indicators, described by the formula above, is limited in relation to end-of-pipe treatment technologies. These technologies are designed to remove residues after they have been created. It occurs at the last step of a process and no financial benefit is expected. To deal with the challenge some scholars propose to measure the environmental cost efficiency indicators in order to describe the environmental benefits of a given technology over another per additional unit of cost (Hellweg *et al.* 2005). These specific indicators of eco-efficiency are determined on a project-by-project basis. They may vary dependent on to the available data and types of the materials and processes (Shoer & Seibel 2002).

The guidance regarding the accounting treatment of all types of waste is provided by the UNCTAD (A manual 2004). There is an example of disclosure of waste in the Table.

Table. Waste generated

Waste generated	Quality and classification						Total	
	Mineral		Non-mineral					
	Non-hazardous		Hazardous					
	Previous year	Current year	Previous year	Current year	Previous year	Current year	Previous year	Current year
<i>Open-loop reuse, remanufacturing, recycling</i>	83.8	23.8	105.7	74.0	38.0	2.1	189.5	97.8
Reuse	58.6	10.8	15.2	21.5	1.1	0.0	73.8	32.4
Remanufacturing	8.3	5.4	8.4	8.1	0.6	1.1	16.7	13.6
Recycling	16.8	7.5	82.2	44.4	36.3	1.0	99.0	51.9
<i>Incineration</i>	87.4	52.4	45.4	74.5	12.2	26.7	132.8	126.9
Low-temperature	9.2	12.2	7.3	14.3	5.7	10.3	16.5	26.4
High-temperature	75.3	9.9	19.0	18.6	5.2	9.6	94.3	28.5
Cement kilns	3.0	30.3	19.1	41.6	1.3	6.9	22.1	71.9
<i>Sanitary landfills</i>	78.2	104.5	130.4	21.2	55.6	34.7	208.6	125.7
Landfills for bioactive materials								
Landfills for stabilized materials	35.8	10.3	22.5	10.4	12.8	33.3	58.3	20.7
<i>Landfills for inert materials</i>	39.3	21.9	51.5	3.0	3.8	0.9	90.4	24.8

<i>Open dumpsite</i>								
<i>Temporary stored on-site</i>	3.1	72.3	56.9	7.9	39.0	0.5	60.0	80.2
	67.0	0.2	12.3	5.4	0.4	5.2	79.3	5.6
	14.6	42.0	46.8	55.2	1.4	0.3	61.3	97.3
Total	331.0	222.9	340.6	230.4	107.5	68.9	671.6	453.3
<i>Closed-loop reuse, remanufacturing, recycling</i>								
Reuse	-10.0	-12.0	-5.2	-3.0	-0.1	-0.2	-15.2	-15.0
Remanufacturing	-10.0	-12.0	-2.1	-2.0	-0.1	-0.2	-12.1	-14.0
Recycling			-1.5	-1.0		0.0	-1.5	-1.0
			-1.6	0.0		0.0	-1.6	
Total waste generated	321.0	210.9	335.4	227.4	107.4	68.7	656.4	438.3
Net value added							1 000	1 100
Eco-efficiency indicator "waste generated / net value added" (m.cub. / Euro)							0.656	0.438

Source: based on the data from UNCTAD.

Notes: (a) The columns "non-mineral" and "mineral" add up to 100%, while the column "hazardous" lists that amount of non-mineral waste that is classified as hazardous. (b) To store waste temporary on-site best technologies are used.

As we may see from the Table, a disclosure on waste generated consists of total waste generated in accordance with the quality and classification of the waste and applied waste treatment technologies. Then, based on this information, responsible agents develop accounting policy on waste, waste policy, targets and measures.

#### 4. Conclusion

The analysis of literature on the economic and environmental efficiency with respect to waste treatment policies shows that even though developed countries have undertaken far-reaching policy measures to promote recycling of municipal waste, the understanding of the consequences of different policy measures are often less than complete.

- Recycling is not a free activity. It uses resources to produce resources. Hence, it is not always definite that the marginal net product is positive.
- A variety of promoted recycling policies tend to focus completely on environmental impacts prescinding from other essential costs to society. Some scholars consider that developed countries may be setting inefficiently high recycling goals. Thus, from the economic standpoint recycling policies have to pass cost-benefit and economic efficiency tests.
- Socially optimal policy aims maximizing the net benefits to society. It was investigated theoretically and empirically that finding socially optimal level of recycling is not easy. One set of theoretical studies derives taxes of Pigou to ensure Pareto optimum while another set of studies derives optimal mixes of recycling, incineration and landfilling using dynamic models to analyze waste management options.
- Markets favor the discharge of waste directly into the environment. Levying prices for waste disposal may provide incentives to make illegal waste discharges. Monitoring of waste for a large variety of non-point sources can be extremely costly.
- Deposit-refund system may be used to equalize private and social incentives for waste collection.
- Collective waste disposal system may be used to manage household garbage, public sewage and various types of hazardous waste. It takes advantage of the economies of scale in waste treatment and disposal costs among different polluters, engage the spatial transportation of waste from areas where it is produced to areas with designed facilities to assimilate it.

- The optimal composition of waste networks as well as the implementation of coordinated waste collection are subjects that have received insufficient attention until recently.
- International literature guides to rather contrasting conclusions about cost-efficiency. Some authors focus on costs in the balance sheet, others evaluate the future cost of substitution waste plants and landfills, and others examine the environmental costs of each option in accordance with a cost-benefit or a cost-effectiveness analysis. Additionally, while some scholars limit analysis of costs to a particular stage in the waste cycle, others focus on the whole integrated waste management system. We explain this variance of authors' conclusions by the specific features of the sphere examined.
- No correlation was found between privatization and cost efficiency. We may conclude that performance is not affected by the amount of private capital, but by the type of waste management type and the extension of service areas.
- Efficiency could be defined in a non-economic sense: a policy is considered efficient if it affects behavior of people in a desirable way. Some research studies from the economic-psychology literature point out that motives matter, and that people undertake recycling activities for moral reasons. Educational campaigns and managing relationships is important because relationships build trust, and trust is essential for any behavioral change.
- There are eco-efficiency indicators showing how and to which extent the environment is used in economy over time. Importantly, applying eco-efficiency to waste issues requires special reasoning. It is limited in relation to end-of-pipe treatment technologies. These specific indicators vary dependent on to the available data and types of the materials and processes.

On balance, the recycle of waste takes place in almost every country because it has been economical. International literature accumulated a solid theoretical background and rich practical experience of application of different types of economic instruments to manage waste, created a large variety of economic and environmental indicators to measure the effectiveness of different policy measures.

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## Notes

- Note 1. Reduce, reuse and recycle are considered good options while incinerate and landfill are bad ones.
- Note 2. The existing literature does not differentiate between *durable* and *non-durable* goods and concludes that the social optimum can be attained by either a disposal fee policy or an advance disposal fee policy in an economy without transaction costs.
- Note 3. Social costs consist of costs to recycling households to prepare materials estimated with an original method, external disposal costs and external recycling benefits, municipal costs and revenues.
- Note 4. In accordance with V. Pareto “an efficient situation is one in which it is impossible to make one person better off without making anyone else worse off” (Pareto 2014). Sufficient to say that the Pareto efficiency criterion cannot be used to evaluate most projects because at least one person will be worse off. Instead, the Kaldor-Hicks compensation principle is suggested (Hicks 1939; Kaldor 1939).

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