The influence of EPR schemes on municipal waste generation and treatment within the circular economy

Buit, Yvonne

June 11, 2021

The influence of EPR schemes on municipal waste generation and treatment within the circular economy

PUBLIC ADMINISTRATION ECONOMICS AND GOVERNANCE
MASTER THESIS

YVONNE BUIT (S2776227)

SUPERVISOR: HENDRIK VRIJBURG

SECOND READER: MARION COLLEWET

Table of contents

1. Abstract

The increasing amount of waste is an important problem in our society. There are many different policies to reduce waste and to stimulate recovery and recycling, for example through a circular economy. An important policy is the one of Extended Producer Responsibility (EPR). With EPR the financial and/or organizational responsibility of products post-consumption is assigned to the producers, instead to the consumers. Previous research usually focused on the effect of one EPR scheme in one country. This thesis tries to understand the influence of EPR schemes on municipal waste generation, recovery, recycling and landfill rates by performing a cross country analysis over 33 countries. The results are inconsistent and not convincing enough to support the hypothesis. This could be the case because lack of data, or maybe the EPR schemes do not function optimally in reducing waste and landfill and increasing recycling and recovery.

2. Introduction

The current ecological footprint of the average European citizen is 4.8 hectares. If the world is divided equally, considering the environmental quality, 1.8 hectares would be available for the average person. This means that the average European citizen is consuming more than what the earth can provide. The rich, western continents are all consuming more than what the average should be (Europa Nu 2021). This results in major pressure on the environment, which could end in destruction of the planet. The world is currently mass consuming where products are easier to replace rather than being recovered or recycled. This trend of consumerism in combination with a growing population results in increasing waste. Global waste is expected to grow by 70 percent by 2050. This means that in 30 years 3.4 billion tonnes of waste generation is expected (The World Bank 2018). How waste is treated has impact on the environment. In low-income countries, the treatment of waste is a massive problem, since 90 percent of the solid waste is openly burned or disposed of in unregulated dumps. This is a problem for both environmental and public health (WASTE 2021). This growing waste is a serious problem for the environment. Therefore, it is crucial to reduce the amount of waste.

What to do about this waste problem has been up for discussion in recent decades. Which policies are efficient and contribute to solving the problem? In Europe, one of the most important actors in dealing with this problem is the European Union (EU). Their most recent policies addressing this topic are the ones that stimulate a circular economy. Within a circular economy, the focus lies on reducing waste, reuse, recycling and the recovery of materials (European Commission 2015). The definition of the circular economy differs between organizations, but these four R's are the core. Thus, moving away from the take-make-dispose pattern towards a more circular product chain and overall a better (and less) use of our raw materials (Ellen Macarthur Foundation 2012: 6). The goal is to transform the industry towards climate-neutrality and long-term competitiveness (European Commission 2020). In the Circular economy action plan, they have different goals for 2030 and 2050. The key product value chains that the EU set out are: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients. These are all very different elements that play a key role in a circular economy.

There are multiple ways to stimulate a circular economy. One aspect that is regarded by policymakers is Extended Producer Responsibility (EPR). With EPR the financial and/or organizational responsibility of products post-consumption is assigned to the producers, instead to the consumers. The goals of these programs are reducing waste disposal, resource conservation, increasing recycling and energy recovery. Thus, by doing this, more environmentally-friendly product design is encouraged (OECD 2015). The European Union Member States have implemented Extended Producer Responsibility schemes to different elements of waste: batteries, graphic paper, end-of-life vehicle(s), the oils product stream, packaging and Waste Electrical and Electronic Equipment (WEEE). The EPR schemes are implemented at different times and sometimes not even at all. This makes it interesting to see the effect of them on waste. Therefore, EPR is used in this thesis as a measurement for the circular economy.

It is important for policymakers that policies are evaluated. That way, efficient policies are developed and improved. Otherwise, the overconsumption will not reduce and the Earth is in trouble (The World Bank 2018). EPR schemes have been a topic of interest for the academic world for some time now. However, it is difficult to find a report which evaluates the EPR schemes of the European Union Member States in total. Besides the EU and the OECD, the literature mostly focuses on one EPR scheme or one specific country. For this thesis I am going to look at the influence of three EPR schemes in OECD countries on the total generation of municipal waste, the recovery rates, recycling rates and landfill rates. Municipal waste mostly consists of household waste. This is influenced by policies like deposit-refund systems that are part of the EPR schemes. The relevant EPR schemes for this are those for batteries, packaging and WEEE.

To examine the influence of the combined EPR schemes, the main research question of this thesis is: *What is the influence of (different) Extended Producer Responsibility schemes on municipal waste generation, recovery, recycling and landfill rates of European Union Member States?* To formulate an answer to this question, the current policies on waste generation, recovery, recycling and landfill need to be understood at the national and supranational level of the EU Member States. Secondly, the EPR schemes need to be understood and discussed.

The research of this thesis is going to be relevant on two levels: socially and scientifically. First of all, it is going to be socially relevant, because it evaluates current waste policy. In recent decades, environmental policies including waste, have entered the political agenda and become an urgent topic. Multiple policies and treaties have been made in the EU to treat the environment better and to reduce waste. It is important to find out which policies work and which policies do not. There are a lot of aspects and different views when it comes to waste policy. Therefore, it is important to find out what the effects of these policies are and to evaluate the policies with precision. This thesis contributes to evaluating a part of the current waste policy, which makes it relevant for society.

Next, this thesis is going to be scientifically relevant, because it contributes to the existing literature about waste generation and treatment. EPR schemes have been a topic of interest for multiple scientific researches. This means that it is not a new topic in the existing literature. However, there is a gap in the literature when it comes to evaluating the EPR schemes of different countries on waste. There are articles that focus on specific countries or specific EPR schemes, but almost none evaluate the schemes together and perform a cross country analysis. Moreover, the EU is one of the few organizations that has examined all the EPR schemes regarding waste in EU Member States, but the data was collected in 2014. Furthermore, they focused on four main issues for guidance on EPR: share of responsibilities between stakeholders; costs; fair competition and transparency and surveillance (European Commission 2014: 37). This thesis will try to evaluate the influences EPR has and therefore be an addition to the report of the EU.

The OECD is a different organization that evaluates EPR schemes with data from 2015. They provide a literature overview for reviewing EPR schemes (OECD 2015). This thesis will focus on a statistical analysis and therefore will differ from the OECD report. Furthermore, there is a need for a research that includes multiple cofounding variables (OECD 2015: 17). This thesis tries to contribute to this need by looking at three of the EPR schemes in 33 OECD countries. This way, the broader picture of multiple policies and external influences play an important role in this research.

This thesis is divided into chapters. The next chapter is the theoretical framework. First the waste problem is defined and explained. It is a very complicated problem that requires good management. The EU is trying to manage waste through waste directives and the circular economy. There is a discussion in the literature about the definition of the circular economy. Therefore, it is important to discuss this before analyzing the EU policies about the circular economy over the years. To be able to analyze these policies, theories about regulation will be discussed. After that the topic will be narrowed to waste policies within the circular economy, focusing on EPR schemes. In chapters four and five the used datasets and methodology are discussed. The datasets are based on data from the OECD with variables of municipal waste generation, recovery rates, recycling rates and landfill rates. Multiple regressions are performed to test the possible influence of EPR schemes on these variables. In chapter six the results are analyzed. Even though there are some significant results, most of them are insignificant and not convincing enough to support the hypothesis. Lastly, the conclusion follows with a discussion about further research and limitations.

3. Theoretical framework

3.1 The problem of waste

Europe is a modern society with mass consumption, which means that we manufacture more products and we are replacing them more than recovering them. This way of consuming is not sustainable, because natural resources are running out and there is already too much waste (BBC 2021). The material and energy resources of this world are not able to keep up with human activities and consumption. Nor does our ecosystem have the capacity to absorb the outflows of the production externalities (Haas et al. 2015). The waste problem has become an important part of environmental policies in the 21st century. Because of the ongoing consumerism and growing global population the amount of waste is only expected to increase (Minelgaite and Liobikiene 2019). This growing waste is a serious problem for the environment. Therefore, it is crucial to have efficient waste management policies to reduce waste generation.

The state has the entitlement to regulate problems and thus also waste. However, this is not a simple task. There are a lot of different aspects when it comes to dealing with the waste problem. Managing waste consist of many tasks, for example collection, transportation, sorting, storing, treatment and disposal. Besides these tasks there are also multiple origins of waste which makes it more complex, such as households, businesses, healthcare premises, industry and agriculture. Furthermore, there are numerous stakeholders involved like local and national authorities, but also manufacturers, packers and fillers, retailers and citizens/customers (Gastillo-Gimenez et al. 2019: 222). Both prevention and treatment are key in managing waste. Prevention is all about changing behavior through information strategies, providing financial support for beneficial initiatives and promoting actions that incentivize this behavioral change. The treatment of waste consists of four main treatment operations: landfill; recycling; incineration; composting and digestion (Idem: 222, 223). The waste hierarchy (from most important to least important) is: prevention, preparing for re-use, recycling, other recovery and disposal (Malinauskaite et al. 2017: 2019). Landfill operation is one of the worst ways to dispose of waste, because the mixture of soil and water with chemicals from the waste can lead to climate change. Another interesting part to waste management is the levels at which regulation takes place. The EU has for example as supranational organization different directives and policies when it comes to waste. But they are implemented at the national level with often regional or local authority organizations responsible for collection, treatment and disposal (Idem: 2014, 2015). The most effective and efficient way to manage waste, according to Mazzanti and Zoboli (2009), is through policy targets aimed at waste generated per capita. The EU is managing waste through different directives and policies. Over the recent years their ambition was to manage waste by stimulating the circular economy.

Definition of waste and its treatments

There are many different categories and definitions when it comes to waste and waste streams. Therefore, it is important to state what kind of waste is spoken about in this thesis. The definitions used are the same as the ones in the Waste Framework Directive of the European Union. The definition of waste includes ''any substance or object which the holder discards or intends or is required to discard'' (European Parliament and European Council 2008: Article 3). The treatment of waste is seen as any recovery or disposal operation. There are multiple ways waste can be treated, the most important ones for this thesis are: recovery, recycling and disposal. Recovery means that waste serves a useful purpose by replacing other materials which otherwise would have been used in a different particular function. Or that waste would be prepared to fulfil that function (Ibid.). Recycling is a kind of recovery operation whereby the waste materials are processed into other products, materials or substances. The last important treatment is disposal. This means any operation which is not recovery. Landfill falls under disposal (Ibid.).

There are also different categories of waste. The main focus lies in this thesis on municipal waste. The definition of the OECD and Eurostat is the same when it comes to municipal waste. According to them, municipal waste includes household waste and similar waste that is collected by or on behalf of municipalities. The waste originates mostly from households, but also small businesses, office buildings, institutions and commerce and trade. It also includes waste from the same sources and similar in nature and composition to that collected by the private sector or originates from rural areas not served by a regular waste service (OECD.Stat 2021a). The difficulty of researching multiple countries is that the definition of certain categories may vary between countries. This means that the definition of municipal waste is not the same in every country (EEA 2013: 7, 8).

Other categories of waste are divided based on what they are, like packaging waste and electronic waste. Packaging waste means any waste from all products that are used for containment, protection, handling, delivery and presentation of goods. Packaging can consist of all materials (European Parliament and Council 1994). Electronic waste is usually known as waste electrical and electronic equipment, shortened to WEEE. This includes waste from equipment that is ''dependent on electric currents or electromagnetic fields in order to work properly and equipment for generation, transfer and measurement of such currents and fields'' (European Parliament and European Council 2012). In the diagram below, the waste stream that's important for this thesis is set out. The orange parts are of interest for this thesis.

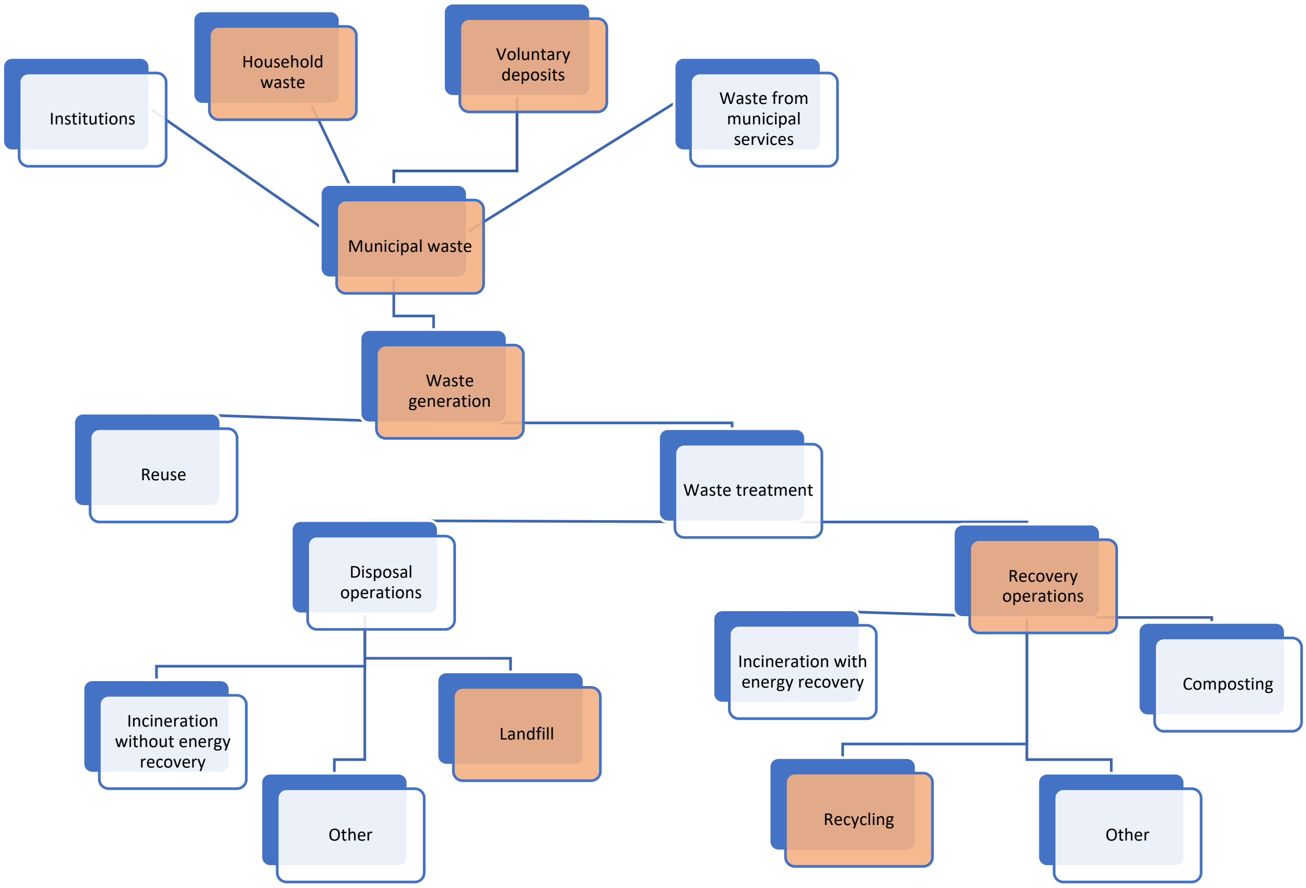

Diagram 1: Municipal waste stream

EU waste directives

In 2008 the EU presented the waste framework directive to establish a legal framework for treating waste. In this directive a waste hierarchy is presented, from most important to least important: prevention; reuse; recycling; recovery for other purposes, such as energy; and disposal. Here, the concept of Extended Producer Responsibility is introduced for the first time in EU documents (European Parliament and European Council 2008). Since waste is a big part of the circular economy, this directive certainly links to the policies regarding the circular economy. This directive was later amended, in 2018, as part of a package of measures on the circular economy (Ibid.). Goals are presented in the directive to strengthen waste prevention and there are certain measures that countries need to take on waste generation. However, these measures are vague in terms of what countries exactly need to implement. There are no concrete regulations or measurements that Member States must implement. There are a few examples of incentives introduced to apply the waste hierarchy: landfill and incineration charges and pay-as-you-throw schemes (European Parliament and European Council 2008).

The EU has waste directives on different topics, for example batteries and accumulators; End-of-life vehicles; landfill waste, packaging waste and WEEE. They consist mostly of definitions and targets to form a legal framework. They do not necessarily consist of concrete (economic) regulations that Member States must implement to realize the proposed targets. In these directives, there lies an overall focus on the Extended Producer Responsibility principle (European Commission 2021e).

3.2 Circular economy

Definitions

A way for a national government to regulate the environmental problem of waste is to stimulate a circular economy. This concept has developed since the late 1970s, but received much attention around 2016. The concept of circular economy is used by policy-makers, government agencies at supranational, national, regional and local level (Geissdoerfer et al. 2017: 759). Even though the concept is also used by academia, there is not a widely used clear definition. Instead, it is argued by authors that there are various options for defining a circular economy. Kirchherr et al. (2017) were the first ones to investigate the differences between the various definitions. There are four core principles to determine, referred to as the 4R's: reduction, reuse, recycling and recovery. However, these four principles are not the center of every definition. Many policies and definitions are centered around the third one: recycling. It is important to distinguish the different definitions, to make it clear whether a policy-maker is focusing only on recycling or on the whole package. Kirchherr et al. conclude that reduce, reuse and recycle are the most frequently used dimensions of a definition. They also conclude that the most prominent aim in 46 percent of their included definitions is economic prosperity. This means that the circular economy aims at strengthening the economy. This is followed by environmental quality in 38 percent of the definitions (Kirchherr et al. 2017: 227-229).

The closest definition of a circular economy used by the European Union is the one in the EU action plan (European Commission 2015). Here a circular economy means an economy ''where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages for Europe'' (European Commission 2015). In this definition the economic prosperity is clear, since it is stated that this kind of economy is an opportunity for competitive advantages for Europe. Furthermore, the R of reducing waste is clear to distinguish. The other elements are less clearly described in this definition, but there are elements of them in the way sustainability of products, materials and resources is described. This definition is used in this thesis.

As you can see in the definition of the EU, the concepts of circular economy and sustainability are often used in the same sentence. However, their relationship is not always clear. Geissdoerfer et al. researched the difference between the two and concluded with their similarities and differences. Based on other prominent definitions of sustainability, their definition is ''the balanced and systemic integration of intra and intergenerational economic, social and environmental performan*ce*'' (Geissdoerfer et al. 2017: 759). Their definition of the circular economy is ''a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling'' (Ibid.). They found that the relationship between the two can be seen as a subset relationship. That means that the circular economy is viewed as a condition for sustainability (Idem: 762-767).

The circular economy thus focuses on an industrial system of restoration and regeneration. This is different from the earlier linear model, where a 'take-make-dispose' pattern is dominant (Ellen Macarthur Foundation 2012: 6). This type of industry cannot ensure the same welfare level as now for future generations. Besides, the linear model has limitations. For example, losing value of materials and products, scarcity of resources, waste generation, environmental degradation and climate change (Banaité 2016: 144). There are three core principles of a circular economy, beginning with designing out waste. A goal of circularity is that waste is minimized as much as possible. Secondly, products need to be designed so that they have consumable and durable components. Consumable in the way that there are non-toxic ingredients, so that they can safely be returned to the biosphere. Durable in the way that non-consumable components are long lasting. The last core principle is that the energy that is used in the circular economy should be renewable by nature (Ellen Macarthur Foundation 2012: 7). The circularity of this system improves material productivity and can be profitable for manufacturers by reducing material inputs, associated labour, energy costs and carbon emissions. It is also beneficial for consumers, since this system is efficient and innovative (Idem: 8, 9). Within the circular economy there are two kinds of business models. The first one focuses on reuse and extending the life of a product through repair, remanufacture, upgrade and retrofits. The other one focuses on turning old goods into new resources through recycling (Stahel 2016: 435).

EU policy through the years

The supranational organization of Europe, the European Union, has a leading proponent of international action when it comes to the economy, migration, environment and other issues that call for cooperation at the international level. When it comes to the environment, the EU is committed to promoting sustainable development worldwide. Therefore, there are multiples treaties and packages that set out the goals and plans for improvement of the environment (European Commission 2021a). Over the years multiple plans and goals are developed to stimulate a circular economy and to reduce waste. Table one provides an overview of the most important policies and directives that influence the waste variables in this thesis. The initial circular economy package was developed in 2014, but the legislative proposal on waste was withdrawn and included in the package in February 2015. This was to make way for new proposals (European Parliament 2016). In December 2015 the new circular

European Union policy initiatives	Year
Directive on packaging waste	1994
Directive on the landfill of waste	1999
Directive on waste electrical and electronic equipment (WEEE)	2002
Directive on batteries and accumulators and waste batteries	2006
Waste Framework Directive: *Directive on waste and repealing certain Directives*.	2008
Closing the loop – An EU action plan for the Circular Economy	2015
Towards a circular economy – waste management in the EU	2017

Table 1: overview important policies EU

economy package was presented, called: Closing the loop – An EU action plan for the Circular Economy. This plan was fully completed by 2019 (European Commission 2021b). For this thesis this means that the effects of this whole plan cannot be observed, since our data stops in 2019. However, the early actions of this plan are expected to affect the used data.

The action plan for the circular economy is a way for the EU to develop a sustainable, low carbon, resource efficient and competitive economy (European Commission 2015: 2). To realize this, there are multiple actions necessary regarding the following topics: production, consumption, waste management, market for secondary raw materials, sectorial action, innovation and investments and, lastly, monitoring. The two most important topics for this thesis are the production process and waste management. First, the focus lies on the production process, since a large aspect of the circular economy focuses on the design of a product's life. The design of a product is important, since the ability for repair, recycling or manufacture depends on this. Therefore, repairability, upgradability, durability and recyclability of products are encouraged by the EU under the framework of the Ecodesign directive. The production process is thus important to stimulate efficient use of resources that can reduce waste generation (Idem: 3-5).

Waste management plays an important part in the circular economy. In this action plan of the EU the Commission is proposing new legislation on waste to create a long-term vision to increase recycling and reduce landfill. To realize this, long-term recycling targets are set out for important waste streams like municipal waste (Idem: 8, 9). The new waste management targets are that the share of municipal waste prepared for reuse and recycling should be 65 percent by 2030. The municipal waste landfill should be reduced to only 10 percent. And lastly, the share of packaging waste prepared for reuse and recycling should be 10 percent higher than all municipal, namely 70 percent by 2030 (European Parliament 2016: 5). Furthermore, they promote greater use of economic instruments and general requirements for Extended Producer Responsibility schemes. The EU want to improve waste management on the ground by working together with the Member States and will assist them to ensure that Cohesion Policy investments will contribute to the waste legislation (European Commission 2015: 8-11).

In 2018 the Commission adopted other initiatives to work towards a circular economy. They are a contribution to the circular economy action plan of 2015. The first of these initiatives is a proposal for a directive on the reduction of the impact of certain plastic products on the environment. The EU Strategy for Plastics in the Circular Economy is an important one. Secondly, a proposal was adopted for a regulation on minimum requirements for water reuse. Besides these, two other reports were introduced, namely a monitoring framework on the progress towards a circular economy and a report on critical raw materials (European Commission 2021b). In March 2019 a report on the implementation of the action plan was adopted. This report shows the main achievements and sketches future challenges when it comes to achieving a circular economy. The final action plan involves different policy tools to stimulate circular and sustainable products that contribute to a better environment. The finished package was presented in 2019 at a stakeholder conference (Ibid.).

It was difficult to find an objective evaluation of the EU action plan for the circular economy of 2015. This is mostly because the circular economy is difficult to quantify (PBL 2021: 245-250). Another reason why it is difficult to find an objective evaluation of the circular economy is because of the differences between the Member States. These differences result in different challenges when it comes to implementing the circular economy. The challenges a country or region faces depends on the stage of the transition towards a circular economy. Some countries have no policies regarding this topic, while others already have policies regarding waste management. For Hungary, for example, the implementation of a circular economy as such is seen as a challenge. Ireland, on the other hand, already has policies regarding waste prevention. However, for countries with multiple policies it is a challenge to bring coherence to all the measures taken by different organizations and local governments. The existing governance structure also matters, just as the political focus of the country or region (EEAC and RLI 2017: 16). Through these differences, there are several topics that are generally seen as a challenge. Consumer behaviour is one of the challenges. There is a need to raise awareness of the problem, so that a change can happen in consumption patterns. Furthermore, many countries see stopping the facilitation and promotion of a linear economy as a challenge. Implementing the circular economy is more than mitigating the effects of the current, more linear economy. Even though aspects of circularity already exist, like bike repair and sites to purchase second-hand products, a deep transition is needed including new business models, regulatory frameworks, technology, knowledge and markets for goods and services. This kind of transition implies changes in culture, structure and practices (Idem: 17). In 2017, an evaluation report of the European Parliament on waste management in the EU was carried out. They found that there are factors that hold some Member States back from achieving the set targets. These factors are: a lack of modern infrastructure, high dependency on landfill, administrative and institutional failings, a lack of political will and lack of domestic legislation and policy, a lack of awareness of waste management outside urban centers, and inefficient source separation of municipal waste (European Parliament 2017: 53). These factors overlap with the earlier differences between countries or regions when it comes to existing governance structure and political focus.

In 2020, the European Commission adopted the new circular economy action plan as part of the European Green Deal (European Commission 2021c). The effects of this new action plan will not be seen in this thesis, since the data ends in 2019. However, it will be discussed shortly to present the most current overview of the EU policies regarding the circular economy. With the new action plan, the EU tries to make the transition to the circular economy systematic and deep. They believe that it will be somewhat disruptive, so the transition has to be fair. The most important parts of the new action plan are initiatives along the entire life cycle of products. They do this by providing a sustainable product policy framework. This includes, for example, targets for product design (European Commission 2020: 19). Applying the circular economy does not only have benefits for the environment, but the EU's GDP can increase by 0.5 percent by 2030 and 700,000 new jobs can be created (IISD 2020). In the action plan, there are seven key product value chains distinguished: electronics and ICT; batteries and vehicles; packaging; plastics; textiles; construction and buildings and, lastly, food, water and nutrients (Idem: 1-12). The four core themes of this action plan are: making sustainable products the norm in the EU, empowering consumers, focusing on the lifetime of products through a sectoral lens and ensuring less waste (WBCSD 2020: 5). To keep track of the implementation, the Commission set up an implementation timetable which shows what goals need to be realized by what year. Most of the goals need to be realized in 2021 (European Commission 2021d).

3.3 Economic regulation

One way to deal with problems for the state is through regulation. Since 1980 states changed from the welfare state to the regulatory state by shifting to privatization. This brought life to multiple regulatory agencies. Instead of the state being the provider, its function becomes steering instead of rowing (Jordana and Levi-Faur 2004: 11). Because of this transition, regulation became an important part of the state. The regulator creates and enforces the regulation and the target is the entity to which the regulation applies. The government needs economic justification for intervention and thus regulation. These justifications are because of market failures and redistribution. There are four types of market failures: public good, externalities, information asymmetry and market power (Veljanovski 2010: 20-23). A public good is a non-rivalrous consumption, which means that consumption by one individual does not detract from another individual. Since non-payers cannot be excluded from this good, the competitive market may not provide this good. Externalities are an unpriced effect of activities or production for which the market does not concern itself. These effects can be positive or negative when they impose losses. Therefore, the market does not reflect the true costs and benefits of activities or productions. The third market failure of information asymmetry means there is imperfect information which can result in inefficient market outcomes. This can lead to two problems: adverse selection and moral hazard. The last market failure has to do with market power. If one or multiple firms have too much market power, the market is no longer competitive or efficient (Ibid.).

Besides economic reasons for regulation, there are also non-economic factors that provide a reason for regulation, namely redistributive goals. The most efficient outcome does not necessarily mean the fairest and most fair outcome. Therefore, the government can also have a distributive motive as justification for regulation. However, government must remember that price control driven by distributional goals often have negative effects and do not often achieve the desired redistribution. This has to do with the distortion of prices and incentives. Other sorts of policies are more efficient, such as income support payments (Idem: 23, 24).

When it comes to economic regulation, it is necessary for an efficient policy to find the right instruments for the policy-maker to use. Hepburn (2006) reviewed the literature on the questions of instrument choice. This thesis will use the insights from his research. Around the year 2000 there was a trend towards market-based instruments instead of command-and-control. With command-and-control regulations, the targets have to comply with specific standards. For example, technology or performance standards. This type of regulation could be desirable, but this requires the regulator having good quality information. Furthermore, the risk of government failure should be low and the different targets should be imposed with similar requirements to achieve the desired objective. When it comes to market-based instruments, the most essential distinction is the one between price and quantity instruments. Even though there is a distinction, prices and quantities always correspond with each other. A quantity instrument imposes a corresponding implicit price, and through a price instrument a certain quantity is desired (Hepburn 2006: 227-229).

An example of quantity instruments are targets and quotas. A cap on, for example, the maximum emissions a firm is permitted is a quantity instrument. When it comes to these types of instruments, a trading scheme is preferable. If licenses or permits can be traded they most likely end up with those who value them the most. This will also result in a more efficient outcome, since firms can trade licenses that are more compatible with their marginal costs. Some firms can reduce emissions, for example, cheaper than other firms (Idem: 229, 230). Besides quantity instruments there are price instruments that can be used to achieve a policy objective. An example of price instrument is taxes. These price schemes cannot guarantee that a certain quantity will be achieved, but it is a more indirect approach for reducing certain consumption or behavior. The logic behind this is that an incentive is created, while a quantity is more a compulsory method (Ibid.).

However, it is not always necessary to choose between the two types of instruments. It is also possible to combine the different instruments and implement a hybrid form of regulation. These types of instruments are more complex, but are often more efficient. For example, a commonly used hybrid instrument is a trading scheme with a price ceiling or a price floor. It is also of course possible to implement multiple instruments to solve one problem. This could work, but it is crucial that the policies are consistent with each other

(Idem: 230, 231). When there are multiple market failures, a policy mix is necessary according to Lehmann (2012). We do not live in a world where the market is perfect except for one problem. Often there are multiple market failures that the government has to deal with. In this case, multiple policies can reinforce each other. A policy mix is also beneficial if the first-best policy has high transaction costs. Coase (1960) was actually the first one who showed that externalities have to do with transaction costs. Transaction costs are the costs of transferring property rights. If these costs are high, for example because many actors are involved, it is more efficient to have a policy mix instead of one policy to solve the externality (Lehman 2012: 72, 73).

3.4 Existing policies regarding waste within circular economy

Over the years the literature has debated about good indicators of the circular economy (Sánchez-ortiz et al. 2020: 4, 5). There are no clear regulations implemented in all EU countries dealing with the circular economy except for EPR. Therefore, this is used in this thesis as an indicator of the circular economy. The problems regarding waste handling can be seen as a missing market. Banerjee and Sarkhel (2020) observe that waste management practices are in developed countries, which the Member States of the European Union are, embedded in market institutions. The market for waste products is important for sustainable adoption for policies like material recovery and recycling (Banerjee and Sarkhel 2020: 210, 211, 229, 230). In this market, the primary processing of the waste would be done by the households. The waste treatment firms deal with further processing and resource recovery by picking up the waste and treating it. The local governments act more like a coordinator in this market, to ensure an efficient outcome (Idem: 211, 212). Within this market, there are a lot of other principles and policies regarding waste.

Managing waste is an expensive, labour intensive and administratively demanding task. It is not a surprise that this comes along with regulatory problems. The two most important ones are pollution and dumping, which are strongly related. Policies that are price-based create a financial incentive to dispose waste illegally (Brennan 2016: 471, 472). This is relevant for industry operators, but also for households. Dumping is thus a problem for waste policy-makers. Indiscriminate dumping is a massive problem in developing countries, but also developed countries struggle with this. Indiscriminate dumping means unlawful disposal of waste in undesignated spaces. For example, open or vacant land, water or other areas.

Indiscriminate dumping can affect human health and environmental quality through exposure to biological, physical and chemical substances (Dladla, Machete and Shale 2016: 1).

An existing policy that aims at reducing waste and increasing recycling rates is called pay-as-you-throw (PAYT) or unit-based pricing. The most important goal is to increase economic pressure on the households whose waste generation and disposal behavior has the largest impact on the environment. By creating an economic incentive to reduce waste and recycle, the pay-as-you-throw system is effective (Reichenbach 2008: 2809). There are three components to this system. First, the identification of the waste generator. Second, measurement of the units, the generated waste or the obtained service, that determine the scale of the individual contribution to the disposal cost. Third, corresponding the individual contribution into a charge through unit pricing (Ibid.). There are three ways identified to distinguish unit-based pricing. The first one is based on a fee for the size of the container or for the quantities that are emptied. This is called the bin-based system (Bel and Gradus 2016: 172). The second one is the volume-based system, where special bags need to be purchased that are usually smaller than regular trash bags. This measures the volume of the waste produced, which creates a more refined system than the bin-based system. However, the households have an incentive to put as much as they can in the bags, which makes them hard to handle. With the third system the vehicle that collects the bins weighs them and matches that information with the identity of the owner. This is called the weight-based system (Ibid.). According to Bel and Gradus (2016), the weight-based has because of its refinedness the largest effect on waste quantities and is among other things therefore the most effective system.

However, this system may have high administrative costs which could nullify its welfare gain (Idem: 179, 180). The pay-as-you-throw system is based on the polluter-pays principle. In Europe there are at least seven countries that implemented pay-as-you-throw systems: Belgium, the Netherlands, Sweden, Germany, Italy, France and Austria (ACR+ 2016).

There are important limitations of this price-based system. The most important problem with PAYT or unit-based pricing is illegal dumping. If legal disposal is taxed, households and firms have a financial incentive to discover an alternative way to dispose of their waste (Walls 2011: 1; Fullerton et al. 2010: 500). Another limitation is littering. A unit-based system also encourages littering, since it would reduce their waste costs and it is very difficult to monitor. These limitations are the reason that a two-part instrument or a deposit-refund system is often suggested for managing waste in order to prevent illegal dumping and littering (Walls 2011: 1).

Deposit-refund is a two-part instrument, which means a deposit is charged at point of sale and redeemed if it is brought back (to the producer) for recovery, recycling or reuse. This way an incentive is created that leads to less illegal waste dumping and littering and to an overall waste reduction. This is mostly used for the recovery of single-use beverage containers. When customers buy a can or bottle, they pay a small deposit. If they return the container to a collection point for recycling they get that deposit back. Deposit-refund system (DRS) is proven to collect high quantities of empty beverage containers for reuse and recycling, which is essential for achieving the circular economy. It is therefore used in 10 European countries (CM consulting Inc. and Reloop Platform 2016: 5). Moreover, the refund under a DRS can encourage firms to design their products in such a way that they are easier to recycle (Fullerton et al. 2010: 503). The deposit-refund system is an example of an EPR policy (Zhou et al. 2020: 1, 2). In this case, the producers have the physical responsibility to take back their products which provide incentives to reduce waste management costs, for example improvements in the recyclability and reusability of their products. Producers are not always physically responsible for taking back their products, but they can also cover the costs of product take-back through company fees to the producer responsibility organisation (Walls 2011: 8, 9). The literature suggests that DRS under EPR principle is one of the most important economic instruments when it comes to environmental protection (Gupt and Sahay 2015: 53). This type of policy is seen as economic and market-based instruments that create a financial incentive (Pouikli 2020: 495, 496).

The EPR principle is represented in four waste directives of the EU and implemented in all EU countries. This policy instrument will be discussed in more detail later on. Out of all the goals and policies regarding the circular economy, the focus of this thesis lies on the Extended Producer Responsibility principle and schemes. The reason for this focus is because of its expected influence on municipal waste generation and treatment. With EPR schemes the producer is responsible for the collection and the (social) costs of their product at the end of its life. The social costs of treatment and disposal include the environmental damage along the product's life cycle that is not reflected in the final product price (OECD 2001: 17, 18). This way they have the incentive to design their product in a way to make it easier for treatments like recovery and recycling. That way, it is expected that the total waste generation goes down and the recovery and recycling rates go up (OECD 2015: 18).

3.5 Extended Producer Responsibility schemes

Within the circular economy packages of the EU, the Extended Producer Responsibility principle plays an important role. The goal of EPR is internalising the environmental externalities that prolong the product's life. There are two ways of doing this, first to make the producer responsible for the treatment or disposal costs of their products, including environmental costs (European Commission 2014: 10; Fullerton 2010: 504). Second, to make them responsible for the organisation of disposal and collection of their product. Thus, there is a shift of responsibility both financially and organisationally in the period from the design phase to their end-of-life. EPR involves all actors in the product value chain and can encourage a change in their behaviour, from product-makers to consumers and social economy actors (European Commission 2014: 10). This can be divided into four aims: covering the product's end-of-life costs, providing eco-design incentives, achieving resource efficiency and lastly by ensuring the high quality of recycling. This comes down to a responsibility shift from consumers and municipals to producers. EPR works as a financial and/or operational instrument by internalising treatment and disposal costs, so producers have an incentive to design products that are sustainable in terms of duration and treatment at the end of the product's life cycle (Pouikli 2020: 492-495). EPR therefore creates the incentive of a product tax or advance disposal fee to design products with less packaging that are easier to recycle. It also creates the incentive of a disposal tax or recycling subsidy in order to undertake the least costly form of disposal (Fullerton 2010: 505). The OECD defined EPR as ''an environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle'' (OECD 2001: 9). The EPR follows the polluter-pays principle (PPP). This means that the responsibility for environmental impacts of a producer's product during its entire life cycle should lie with the producer. This includes the responsibility to manage the end-of-life (Pouikli 2020: 494, 495). A list of requirements for products suitable for EPR does not exist. However, it would be necessary to track the product, since the producer is responsible for the financial costs or practical organisation of the product. The explanation of EPR follows a liability principle, where individuals are protected against harmful externalities. This means that the producer has to pay for the damage done (Kaplow and Shavell 1996: 715-723). Without doubt it is clear that EPR is relevant for a circular economy policy, since it promotes producing in a circular way with sustainable materials and designs. This will lead to a reduction of waste and on the environmental impact (Pouikli 2020: 493). There are multiple examples of specific policies that are considered as an EPR scheme or follow the EPR principle. Policies under EPR, according to the OECD, include product take-back with recycling targets, which means that producers should take back their products at the end of the product's life.

An EPR scheme is the principle of EPR implemented and is therefore defined by the EU as ''any system or scheme set up by one or several producers to implement the EPR principle'' (European Commission: 6). This can be an individual or a collective system. If it is an individual scheme, a producer organizes its own system. With a collective system several producers collaborate and transfer their responsibility to another organization, called a Producer Responsibility Organization (PRO). The danger with PROs is that 'averaging' costs of producers could nullify the efforts of certain individual producers (Pouikli 2020: 498, 499). An example of a PRO is stichting OPEN (foundation OPEN) in the Netherlands. They have been operational since March 2021 (Stiching OPEN 2021). This organization focuses on behalf of the electrical and electronic equipment producers to ensure the legal objectives of collection and recycling in the Netherlands. Having a foundation that takes care of this, ensures effectiveness and efficiency. The producers control the achievement of targets, so they accomplish their producer responsibility. There is a difference between management and implementation. Foundation OPEN takes care of the management activities to ensure that producers perform in line with their legal obligations of producer responsibility. The implementation, collecting, sorting, transportation and recycling are carried out by market operators (PV cycle 2020).

For every policy it is important to know if it is effective and efficient. For EPR schemes, this means that waste generation is reduced and the reuse, recycling and recovery rates are increasing (OECD 2015: 17). There have been multiple scientific articles that focused on evaluating one specific scheme or one specific country. The overall conclusions are that EPR schemes can significantly help reduce waste and achieve the EU waste targets (Ibid; leal Filho et al. 2019: 556). Authors like Bassi et al. even conclude that EPR policies are crucial for economic and environmental sustainability (Bassi et al. 2020: 10). However, there are definitely weaknesses and obstacles when it comes to implementing EPR schemes. For example, focusing on the EPR implementation for plastic waste streams there is a lack of binding mechanisms and a lack of incentives for enterprises to fully engage (Leal Filho et al. 2019: 556).

An economic way to measure the efficiency of a policy is through a cost benefit or cost effectiveness analysis. According to Smith (2005) the costs and benefits of EPR policies include operating cost, environmental benefits and other effects. A challenge of EPR is the heterogeneity of the programs themselves (Smith 2005). Palmer and Walls discovered through a cost effectiveness analysis that the two EPR policies they looked into are least costly and performed better than non-EPR recycling subsidies (Palmer and Walls 1997). Literature shows, according to the OECD, that multi-instrument policies are better than single instrument policies when it comes to cost-effectiveness (OECD 2015: 20).

Over the past twenty years multiple EPR schemes have been implemented in the EU Member States. During most reports and evaluations there were 28 Member States, since Brexit did not happen until January 2021. The 28 Member States have all implemented the EPR schemes on packaging, batteries, WEEE and end-of-life vehicles. Besides these four, there are also other EPR schemes that exist in some of the Member States. These are EPR schemes for graphic paper and the oils product stream (European Commission 2014: 40). According to the EU's report on guidance on EPR schemes there are four main issues relating to EPR design and implementation that have to do with the efficiency and effectiveness of EPR schemes. The first issue is the share of responsibilities among stakeholders. The stakeholders that are involved in EPR schemes are for example producers, PROs, national and local authorities, waste management industry et cetera. Since these players are involved in the EPR scheme, an organized dialogue among them is of importance to establish each partner's responsibility (Idem: 77-88). The second issue is about cost coverage and the true cost principle. This is a question about what costs are relevant and should be included in EPR schemes. The third issue is about the effect of EPR on competition and how to keep competition fair. The last issue is about transparency and surveillance of the EPR performance (Idem: 88-119).

3.6 Hypothesis

Concluding from this literature overview, EPR schemes play an important role within the circular economy policies. Within the circular economy, the focus lies on a circular product chain instead of a (more) linear one. Implementation of EPR schemes represent a shift from consumer or municipal responsibility to producer responsibility for the entire lifecycle of a product. Producers are responsible for the (social) costs and/or physical organization of taking back their product at the end of its life. This results in more sustainable design and reducing waste (European Commission 2014; OECD 2001). A part of EPR does not result in less waste, but influences the treatment afterwards. For example, the take-back from WEEE is counted within the municipal waste generation (OECD.Stat 2021a). Therefore, it will not necessarily be less if it is part of household waste or the voluntary deposits. However, the EPR schemes also create the incentive for producers to use less packaging and make their products more sustainable. This should result in less household waste, but how big this effect will be is unsure. Diagram 1 presents an overview of the various parts of the waste stream. This leads to the first hypothesis of this thesis. Following the existing literature, it can be expected that EPR schemes lead to reducing waste. Therefore, the first hypothesis expects that this will happen.

Hypothesis 1: *Implementing EPR schemes reduce the total municipal waste generated in a country*

Due to limitation of data, it is not possible to look into the effects of all the focus points of the circular economy in EU Member States. According to the EU guidelines on EPR, the order of priority is prevention, reuse, recycling and recovery. Recycling is technically a recovery-type operation. Recycling is seen as the most important recovery operation and often used separately from other recovery operations like incineration with energy recovery. Recovery operations are a goal of EPR schemes according to the EU (European Commission 2014). Since EPR schemes make producers responsible for the (social) costs and/or physical organization of taking their product back at the end of its life, they have an incentive to design their products in such a way that they are better able to be treated (OECD 2001). One would therefore expect that implementing EPR schemes results in higher recovery rates.

Hypothesis 2*: Implementing EPR schemes increases the municipal recovery rates of a country*

As stated earlier, recycling is technically a recovery operation. Therefore, it is easy to expect that if EPR schemes lead to an increase in recovery rates, it also leads to increasing recycling rates. Apart from the link with recovery operations, one could also expect that implementing

EPR schemes leads to increasing recycling rates. An important part of the circular economy is the change from a linear product chain to a circular one. The focus lies besides waste reduction on designing products that are easier to reuse, recover and recycle. By implementing EPR schemes, the producers have an incentive to design their products in such a way that they are easier to recycle, because they are responsible for the costs that are created at the end of the product's life (European Commission 2014; OECD 2001). Therefore, it is expected that the recycling rates will increase if a country has implemented EPR schemes.

Hypothesis 3: *Implementing EPR schemes increases the municipal recycling rates of a country*

The goal of EPR schemes is to stimulate producers to design their products with sustainability in mind and to increase recovery and recycling rates. If recovery and recycling is stimulated, less waste will end up in disposal operations like. Therefore, a benefit of EPR schemes is that the quantity of landfill will decrease (OECD 2001: 17, 31). In addition to EPR, there are various policies in different countries that try to limit landfill. It is therefore unsure how major the effect of EPR only will be on landfill. However, I do expect EPR schemes to affect landfill rates, because increasing recovery and recycling rates mean reducing landfill rates. Therefore, the following hypothesis is expected.

Hypothesis 4: *Implementing EPR schemes have a negative effect on landfill rates*

4. Dataset and data description

4.1 Datasets

The datasets used in this thesis are based on data of the OECD. The ‘municipal waste, generation and treatment’ dataset presents the different trends in amounts of municipal waste and its treatment and disposal. The data runs from 1975 until 2019. In the early years, data is available for a few countries only. There is more data available for more countries from about 1990, so this thesis will use the data from 1990 until 2019. The benefit of this dataset, is that there is also data from non-European countries available, which creates the option of comparing European with non-European countries (OECD.Stat 2021a).

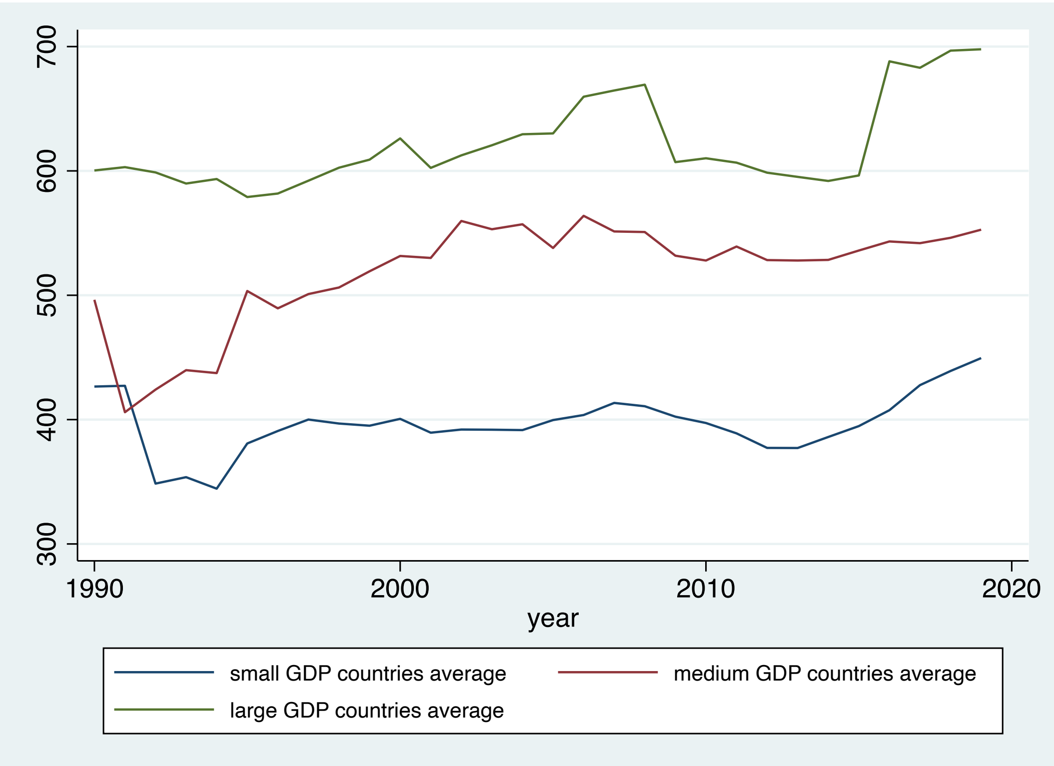

Figure 1: Comparison countries GDP

As the timespan is thirty years, it is interesting to discuss patterns in this data. Figure one shows the average of municipal waste per capita for three clusters: countries with small GDP, countries with medium GDP and countries with large GDP. Countries with a small level of GDP per capita are around 400/500 tonnes of municipal waste. Countries with a medium level are around the same level, together with a few countries around 600 tonnes. The high income countries are widely separated on the graph, although a few have very high municipal waste levels, around 700/800 tonnes. Especially for the countries with small and medium GDP the municipal waste generated become much less in the beginning of 1990s. Around 1995 the municipal waste generated increases. From the years 2000 until 2010 the municipal waste stays around the same level, while there is a slight increase from 2010 until 2020. For high income countries the municipal waste generated stays around the same level from 1990 until 2000. From 2000 there is an increase in waste until a drop around 2010. Around 2015 there is a big increase. This figure would suggest that there could be a relationship between GDP and municipal waste generation.

There are multiple variables available in this dataset. The differences between them will be discussed in order to explain the findings. The main variable is 'municipal waste generated'. This includes household and similar waste, but also bulky waste (like white goods, old furniture et cetera) and yard waste, garden waste, the content of litter containers and market cleansing waste (Ibid.). The waste included in this variable originates from households, commerce and trade, small businesses, office building and institutions (like schools, hospitals and government buildings). Furthermore, it includes waste from selected municipal services like street cleaning services. It also includes waste collected door-to-door through traditional collection and a small amount collected separately for recovery operations. This is collected by or on behalf of municipalities, collected directly by the private sector or originates from rural areas not served by a regular waste service. This variable is measured in tonnes. Since this data is absolute, it cannot be used for comparison, unless the natural logarithm is taken. The dataset of the OECD also includes a variable of municipal waste per capita. This statistic can be used in itself for comparison (Ibid.)

Within this dataset there is also much information about treated waste. The variable 'municipal waste treated' shows the amount of waste designed for recovery operations and disposal operations. The recovery operations consist of recycling, composting, incineration with energy recovery and other recovery. Recovery is defined as ''any waste management operation that diverts a waste material from the waste stream and which results in a certain product with a potential economic or ecologic benefit'' (Ibid.). This mainly refers to material recovery (recycling), energy recovery, biological recovery (composting) and re-use. Within this variable direct recycling and re-use within industrial plants at the place of generation are excluded. Disposal operations consist of incineration without energy recovery, landfill and other disposal. Disposal is defined as ''any waste management operation serving or carrying out the final treatment and disposal of waste'' (Ibid.). This means it covers the final treatment, like incineration without energy recovery or biological, physical or chemical treatment, or in final disposal like deposit into or onto land, deep injection et cetera. This is the final end of the chain. The amounts generated and the sums of the treatment methods are not necessarily the same, because treatment methods are not always mutually exclusive. The types of treatment are also included in the dataset in relation to each other through percentage. The sum of the categories does not exactly add up to 100 percent, because other recovery and other disposal treatments are not presented in this dataset (Ibid.).

Based on this dataset I created two different datasets with six dependent variables: municipal waste generated, municipal waste generated per capita, household waste generated, recovery, recycling and landfill. Each variable is in absolute numbers. Therefore, the natural logarithm is taken for each of these variables. In this way, the variables can be used for comparison. The data available differs per country. This happened mostly for one or two years at the beginning of the 1990s. Since this dataset has missing data, I created datasets with the same variables from the years 1995 to 2015. The choice to run the data until 2015 has to do with the control variables, which will be explained later on. For each dataset I made dummy variables for the three EPR schemes: batteries, WEEE and packaging. This means that a country has 1 if the EPR scheme is present in that country and 0 if it is not present in that year. This is done for EU countries as well as non-EU countries. The information about when EPR schemes are implemented comes from the 'Development of Guidance on Extended Producer Responsibility' report of the EU or the report of the OECD ''What have we learned about Extended Producer Responsibility in the past decade?'' (European Commission 2014: 41-45; OECD 2015). For a few countries the information was unclear about when exactly an EPR scheme was implemented. In those cases, extra information was sought. For the countries inside the EU the packaging EPR schemes remained unclear for Hungary. Hungary did not have an EPR scheme before or in 2017, but for the later years I could not find any information (Expra 2017). Based on this I included in the dummy that they do not have an EPR on packaging. For multiple countries outside the EU it was unclear when exactly EPR schemes were implemented. These countries are: Switzerland, Iceland, Japan, Korea, Mexico, New Zealand, Norway, Slovak Republic, Turkey, United States and China. I found for every country on the internet external information about when the EPR schemes were implemented. I included that information for creating the dummy variable. The only country I could not find any information about implementing WEEE and packaging EPR was for Mexico. Therefore, I concluded that Mexico did not implement WEEE and packaging EPR schemes. The variation between the years that the EPR schemes are implemented is shown in table 1. There is quite some variation between the years. In general, the packaging EPR schemes were implemented earlier than batteries and WEEE.

In order to estimate the relationship of interest, control variables are necessary. Control variables are part of the regression to control for other effects that could influence the dependent variable and which are also correlated to the EPR schemes. By adding them to the regression there is more chance to estimate the real effect of the main independent variable, in this case the EPR schemes. It was very hard to find literature about control variables that could explain municipal waste. Even the OECD itself reports that more research needs to be done in order to establish better control variables (OECD 2015: 18). Furthermore, it was also very difficult to find good control variables that had data for so many countries in the years from 1990 to 2019. The data was often only available from 2000 or later. These variables cannot be used, because they need to be available around the time that the EPR schemes are implemented. That is from about 1995 to 2010. At other times the data was available only until 2013. This is enough time after the EPR schemes were implemented, but it results in a lot of missing data.

Year	**Number of countries**		
	Batteries	WEEE	Packaging
<1995	2	1	7
1995-1999	4	2	9
2000-2004	8	11	10
2005-2010	16	14	0
2010<	1	2	2

Table 2: Implementation years EPR schemes

The first element for which I control is the Gross Domestic Product (GDP). The size of a country's economy matters for the level of waste it produces (Trang et al. 2017: 254). Some articles study the environmental Kuznets curve of waste. The Kuznets curve implies that there is a non-linear relationship in the shape of an inverted U between environmental output, in this case waste, and a measure of economic development, in this case GDP. This curve suggests that economic growth and development first damages environmental quality, but after a certain point economic growth and development increases environmental quality (Destek et al. 2018: 29388). However, not every paper finds the environmental Kuznets curve in their results. For example, Mazzanti and Zoboli (2009) do not find evidence for the Kuznets curve, while Arbulú et al. (2015) do find it (Destek et al. 2018: 29389). Since the results differ per article, I will include both the linear relationship of GDP and the environmental Kuznets curve. One can also use consumption expenditures instead of GDP. However, I could not find data for this variable that included every country during the time period from 1990 to 2019. Therefore, I chose GDP as measure of economic development (OECD.Stat 2021b). I expect that, in some way, GDP influences the municipal waste generation and recovery, recycling and landfill rates. Moreover, many other characteristics of a country can influence municipal waste. Population density is according to Mazzanti and Zoboli most likely to have a positive impact on waste generation (Mazzanti and Zoboli 2009: 2015; OECD.Stat 2020b). Age is another aspect that could influence waste and recycling, recovery and landfill rates. However, the relation can be positive or negative. On the one hand, people that are older could be less accustomed or committed to waste collection and recycling. On the other hand, waste collection and recycling efforts require time. The opportunity cost of time is lower for older people than younger people. The relationship can thus go both ways (Mazzanti Zoboli 2009: 215; OECD.Stat 2020c). Furthermore, I created a dummy variable to tell if a country is a Member State of the European Union or not. This shows if a country has to realize goals established by the EU. Of course, there are countries like Norway that have treaties with the EU without being an official Member State. That is a limitation of this variable that should be kept in mind. The last element to control for is environmental awareness and priority in a country. In order to capture this effect, a control of the variable environmentally related tax revenue as a percentage of GDP is added (OECD.Stat 2020a). Environmentally related taxes are an important instrument for governments to shape prices in order that the cost of a product covers the true cost. That includes for example pollution created through the production process. The categories that are included are energy products (all CO_2-related taxes), transport, pollution such as nitrogen emissions and resources. This variable does not include waste, but I hope that it gives an impression of the environmental awareness of a country (Ibid.).

Table three shows the key statistics of the variables, including the minimum and maximum values and the range in years of the available data. Especially in population density and share of the elderly population there is a lot of variation. The countries in this dataset are, except for China, all OECD countries. This results in less range in GDP. However, there is still enough range to see some effect of GDP on municipal waste, since Mazzanti and Zoboli only used European countries and found a significant effect of GDP on municipal waste (Mazzanti and Zoboli 2009: 211-226).

Variable	Obs	Mean	Std. Dev.	Min	Max	Range in years
Municipal waste	877	23224.27	45693.86	114	265224.50	1990-2019
Municipal waste per capita	849	492.75	136.28	238.14	979.93	1990-2019
Household waste	546	13130.42	24100.28	97.61	139942	1995-2019
Recovery	809	9196.46	19472.99	0	116546	1995-2019
Recycling	789	4250.88	10138.18	0	62613.90	1995-2019
Landfill	847	10047.47	24354.95	0	132612	1995-2019
Batteries EPR	945	0.51	0.50	0	1	1990-2019
WEEE EPR	945	0.51	0.50	0	1	1990-2019
Packaging EPR	945	0.62	0.48	0	1	1990-2019
EU dummy	945	0.55	0.50	0	1	1990-2019
GDP	944	29813.52	16642.03	975.50	120670.50	1990-2019
Population	912	7.67E+07	2.31E+08	267467	1.42E+09	1990-2018
Population density	813	136.84	124.21	2.66	520.92	1995-2019
Share of old population	687	16.11	2.79	10.10	28.13	1990-2018
Environmental tax	839	2.41	0.87	-1.53	5.37	1994-2019

Table 3: Key variable statistics

4.2 Limitations

There are a few limitations that need to be discussed. There might be a strong time dependency in the data. This means that the waste in time A is important for explaining the size of waste in time B. This mostly has to do with the size of the economy. I try to control for this by using the fixed effect model which will be discussed in the next chapter, but it is still good to be aware of this. As stated earlier, the need for good control variables is very important. However, it was extremely hard to find proper control variables that included this number of countries from 1990 to 2018.

This analysis is cross-country, which has not been done many times before. Since waste is often locally organized, this research is less specific and more general. Especially for larger countries this can distort the effects. However, EPR schemes and other policy is often derived nationally or supranationally. This is why I opted for a cross country analysis.

5. Methodology

Now the data and the variables have been discussed, it is time to discuss how the data is used to test the hypotheses in order to answer the research question. Based on the literature there are two important articles that try to explain waste streams. This thesis will follow their analysis as far as possible. The first article is the one of Mazzanti and Zoboli. They suggest a natural logarithm of waste and explain this with consumption expenditure, population density, urbanization, household size, elderly ratio and two policy variables. Instead of consumption expenditure, I use GDP because there was more data available with GDP than if I used consumption expenditure. Besides, other articles use GDP, thus it is a good variable to use. There were five missing countries for the variable that could be used for urbanization and the range was not from 1990 until 2019. Therefore, I did not include a variable for urbanization. However, population density could also be used as an indicator for urbanization. Population density will be used as control variable, just as elderly ratio. There was no good variable for household size that covered all the countries and years that are used. Mazzanti and Zoboli take the natural logarithm of all their variables to linearize a potential non-linear relationship. They have 25 countries in their dataset from 1995 until 2005. This is fewer countries over fewer years compared to the dataset that is used in this thesis. Using these variables, they find statistically significant influences on municipal waste generation, landfill and incineration (Mazzanti and Zoboli 2009: 211-226). These variables thus should be explaining waste.

The other article that I try to replicate is the article of Arbulú et al. (2015). They try to link waste with tourism. Their dataset consists of 32 European countries with municipal solid waste as the dependent variable. Besides tourism indicators, they used GDP, unemployment rate, education, rural population and government effectiveness to explain waste. They use, just as I will, GDP and GDP squared in order to test the environmental Kuznets curve (Ibid.). Instead of a variable for rural population I used a variable for urban population. For education there was no good variable to find for the specific countries over the timespan of 1990 until 2019. For education there was a variable, but it narrowed down the observations by a few hundred. Therefore, I decided not to use this variable. The government effectiveness variable was only available from 2002 for the countries I use. This is after many EPR schemes were implemented, so therefore it will be of no use in my regressions. They also find statistically significant results for most of their variables.

The variables in my dataset do not correspond perfectly with the variables used in the mentioned articles, but most of them overlap. That would be enough to explain municipal waste. The element that I add is the policy variable of three implemented EPR schemes and a dummy for EU membership.

To test the hypothesis of this thesis and to see the effect of multiple EPR schemes on waste, an linear panel regression is going to be performed with a cross country analysis. Most articles about EPR schemes or explaining municipal waste address the regional or national level. There is, except for the two papers above, not a lot of cross country research done when it comes to explaining waste. Therefore, it is not well-known what works best with this type of analysis and what does not. The regression used in this thesis measures the correlation between the policy and the waste or its treatment. The policies studied change at different moments in time for the various countries. Therefore, it is the goal to compare the countries at different times when their active policies, the EPR schemes, differ. That way, the effect of the policy can be measured. This approach is similar to the differences-in-differences method, where two groups are being compared which results in a time effect and a group effect. The difference is that with differences-in-differences there are two groups, the control and the treatment group, and this thesis is looking at multiple countries, thus it is more general than differences-in-differences. The linear panel regression is a cross section consisting of various countries over time. The regressions are performed on both datasets: the raw dataset and the one from 1995 until 2015. In the regression I use the fixed effects model. With this model a year and a country dummy are made to account for the institutional or explicit differences between countries and years. In this model the average effects of each country and year are held constant (fixed).

For all the hypothesis, the independent variable are the dummies of EPR schemes. For the first hypothesis, the dependent variable differs between regressions. For the first one the natural logarithm is taken from municipal waste generated in absolute numbers. Taking a natural logarithm creates a linear relationship for a relationship that might not be linear. For the second regression, the dependent variable is household waste. This variable is less complete when it comes to all the years of the countries, which could influence the results. To test the second hypothesis a third regression is performed. The total municipal waste generated is not relevant, but the focus lies at the recovery rates. Therefore, the dependent variable in the third regression is the municipal recovery rates. In order to answer the third hypothesis, the fourth regression has recycling rates as dependent variable. Finally, the last hypothesis will be tested through the fifth regression about landfill rates. The regressions are the following:

$$\log Y_{it} = \alpha_i + \rho_t + \beta_1 \log GDP_{it} + \beta_2 \log GDP_{it}{}^2 + \beta_3 \log X_{it} + \beta_4 EUdummy_{it} + \beta_5 EPRdummy_{it} + \varepsilon_{it}$$

Y = dependent variables (municipal waste, municipal waste per capita, household waste, recovery, recycling and landfill)
X = control variables (population density, share of old people and environmental tax)
EPR dummy = Packaging EPR, WEEE EPR and Batteries EPR

6. Results

In this chapter of the thesis the results are analyzed. There are two different kinds of datasets, one with raw data and one with data from 1995 until 2015. The regressions are performed on both datasets. However, the dataset with raw data will be shown in the text, since this one has the most data. The results of the other dataset are available in the appendix. The natural logarithm of variables is taken in order to establish a linear effect. The same regressions are performed but instead of the natural logarithm I divided the dependent variable by population. That way the results are per capita and become comparable between countries. Therefore, the regressions are also performed with the dependent variables divided by the country's population for the dataset with raw data. These results of the per capita regressions were consistent, so therefore the last column in the tables are the regressions performed on the dependent variable per capita. In each first regression, I try to explain municipal waste with just GDP and GDP squared, based on other existing research to this topic. After that, I include the other control variables. Further on, I include the EPR dummies: first packaging and WEEE dummy together and in the fourth the batteries dummy. The structure of this chapter is the following. Per sub-chapter one hypothesis will be tested and discussed showing the results of the regressions. Lastly, the regressions are also performed with only European countries. These results are discussed in the last paragraph.

6.1 First hypothesis: municipal waste

The first hypothesis expects that implementing EPR schemes reduce municipal waste generation. The regressions are based on two different dependent variables, which will be separately discussed, starting with the logarithm of municipal waste generated followed by household waste. In the articles of Mazzanti and Zoboli (2009) and Arbulú (2015) waste is explained with GDP and GDP squared, population density and the share of old people. In order to see if these variables explain waste for the used dataset, regressions are performed with first only GDP and GDP squared and later on with the other control variables. The results of the first dependent variable can be found in table four.

Municipal waste generated (log)

Both GDP and GDP squared are not significant in the performed regressions. The environmental Kuznets curve is not found in every article, thus it is possible that that will also be the case in this thesis. But I did expect a significant result of GDP, because figure one showed some difference between countries with small, medium and large GDP. It could be possible that there is not enough variation between the countries, since all countries, except for China, are OECD countries. However, that does not explain why Mazzanti and Zoboli find significant results with their dataset consisting of only European countries (Mazzanti and Zoboli 2009). The EPR dummies are all not significant. Also, none of the EPR schemes are significant. There is quite some variation in implementation of EPR schemes. Thus, that cannot be a reason of its insignificance. However, most countries did implement EPR schemes at some point in time. So maybe the effect would be more obvious if more countries that do not have an active EPR scheme would be part of the dataset. However, this was not possible due to available data. The EPR schemes provide perhaps not enough incentives for producers to design their products sustainably and with less packaging. If that is the case, implementing EPR schemes are not sufficient to achieve the goals of less waste through more sustainable design. Only population density is significant in the last regression. The rest of the results are not significant. There is quite some variation in the control variables. Thus, that cannot be a reason why the results are not significant. When the regressions are performed on the dataset from 1995 until 2015, there are some differences in results. The most important difference is that the WEEE dummy is significant in the third and fourth regression and all the EU dummies are significant. It is quite strange that the differences are this large, since the difference is only a few years. The coefficient for the WEEE dummy is positive, which means that implementing EPR would increase municipal waste. This is the opposite of what is expected. The EU dummy does have a negative coefficient, which means that EU membership reduces waste.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log muninicpal waste	Log municipal waste	Log municipal waste	Log municipal waste	Municipal waste per capita
Packaging EPR			0.0298	0.0294	12.84
			(0.0473)	(0.0469)	(20.42)
WEEE EPR			0.0284	0.0272	15.46
			(0.0210)	(0.0205)	(12.47)
Batteries EPR				0.00713	4.232
				(0.0248)	(11.81)

Log GDP	0.473	-1.000	-1.038	-1.045	
	(0.974)	(1.369)	(1.326)	(1.329)	
GDP					0.000657
					(0.00460)
Log GDP squared	-0.0254	0.0590	0.0604	0.0607	
	(0.0539)	(0.0703)	(0.0680)	(0.0681)	
GDP squared					1.43e-08
					(2.79e-08)
Log population density		0.263	0.233	0.228	
		(0.361)	(0.360)	(0.370)	
Population density					-2.681**
					(1.068)
Log old population		-0.284	-0.332	-0.335	
		(0.353)	(0.361)	(0.367)	
Old population					-7.430
					(7.855)
Log environmental tax		-0.0279	-0.0301	-0.0302	
		(0.0890)	(0.0873)	(0.0871)	
Environmental tax					-1.224
					(16.50)
EU dummy		-0.0659	-0.0822	-0.0824	-35.68
		(0.0502)	(0.0567)	(0.0569)	(25.71)
Constant	6.369	12.27	12.76*	12.84*	914.5***
	(4.476)	(7.249)	(7.048)	(7.149)	(248.7)
Observations	876	598	598	598	598
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.300	0.328	0.334	0.335	0.212
Number of country	33	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 4: Results municipal waste

Household waste generated

The second way that the first hypothesis is tested, is with household waste as dependent variable. Household waste is part of municipal waste, as seen earlier in diagram one. I expect that especially packaging has an influence in household waste, since producers have the incentive to include less packaging in their products. The results of the regression are shown in table five.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log household waste	Log household waste	Log household waste	Log household waste	Household waste per capita
Packaging EPR			-0.0846	-0.0839	-3.08e-05**
			(0.0543)	(0.0532)	(1.38e-05)
WEEE EPR			-0.0524	-0.0521	-1.03e-05
			(0.0590)	(0.0606)	(1.80e-05)

Batteries EPR				-0.0366	-1.59e-05
				(0.0404)	(1.48e-05)
Log GDP	-2.614**	-1.587	-1.209	-1.115	
	(0.954)	(1.322)	(1.295)	(1.289)	
GDP					5.30e-09
					(3.60e-09)
Log GDP squared	0.147***	0.0957	0.0789	0.0752	
	(0.0511)	(0.0686)	(0.0673)	(0.0669)	
GDP squared					-0
					(0)
Log population density		0.494	0.652	0.708	
		(0.473)	(0.473)	(0.449)	
Population density		0.0646	0.192	0.210	
		(0.513)	(0.512)	(0.505)	
Log old population					-1.21e-06
					(1.12e-06)
Old population					3.85e-06
					(6.55e-06)
Log environmental tax		0.254***	0.264***	0.268***	
		(0.0880)	(0.0892)	(0.0876)	
Environmental tax					2.02e-05**
					(9.28e-06)
EU dummy		0.0142	0.0409	0.0422	1.97e-05
		(0.0600)	(0.0516)	(0.0533)	(1.89e-05)
Constant	19.55***	11.77	8.625	7.754	0.000324
	(4.615)	(7.553)	(7.545)	(7.456)	(0.000201)
Observations	545	398	398	398	398
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.577	0.388	0.414	0.420	0.321
Number of country	24	19	19	19	19
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 5: Results household waste

It is interesting that in the first regression, both GDP and GDP squared are significant. However, in all the other regressions, the results are not significant. Maybe it has to do with the number of countries and observations that are in the dataset with the first regression. The coefficient of GDP is negative, which means that high income countries generate less household waste. The only other control variable that has significant results is the environmental tax. This, however, is a positive coefficient, which means that if a country spends more on environmental taxes there is more household waste. The packaging EPR dummy in the last regression is the only one of the EPR dummies that has a significant result. The coefficient is negative, which means that implementing an EPR scheme results in less household waste. This is what I expected, especially for household waste since packaging is collected there. The results of the regressions performed on the dataset from 1995 until 2015 are for the most important parts the same. The only big difference is that GDP is also significant in the last regression and GDP squared is also significant in the second regression. Based on the results of both table four and table five, I reject the first hypothesis. Even though there are some significant results, they are not convincing enough to accept the hypothesis that EPR schemes reduce municipal waste.

6.2 Second hypothesis: recovery rates

To test the second hypothesis, regressions are performed to discover the influence of EPR schemes on recovery rates. Table six shows the results of these regressions. The WEEE and batteries EPR dummy are significant in the last regression. Their coefficient is both positive, which means that implementing EPR schemes increases recovery, just as the hypothesis expected. The rest of the EPR dummies are not significant. Furthermore, there are significant results for four control variables: GDP, GDP squared, EU dummy and the environmental tax revenue. It is strange that now the first regression is the only one without significant results for GDP and GDP squared. Which is almost the opposite of table five. The coefficient of GDP is positive and GDP squared is negative. Positive means that a higher GDP level results in higher recovery rates. GDP squared is negative, which is quite strange, because the effect will become less over the years. One would expect this with waste generation, but not with recovery. The effect of EU membership is negative, which is also not expected. I would expect that EU Member States have higher recovery rates, since there are multiple policies active in the EU that stimulate recovery. But these results suggest the opposite. The environmental tax revenue has a positive effect, which means that if a country spends more on environmental taxes, the recovery rates are higher.

The regressions performed on the dataset from 1995 until 2015 have less significant results. This could be because this dataset has less observations. However, this difference is not that large for it to matter. GDP and GDP squared are in this dataset only significant in the last regression. The discussed results show some significant effect of EPR schemes, but not enough to be very convincing. Therefore, based on these results, I reject the second hypothesis that EPR schemes increase the recovery rates.

VARIABLES	(1) Log recovery	(2) Log recovery	(3) Log recovery	(4) Log recovery	(5) Recovery per capita
Packaging EPR			0.165	0.158	-9.45e-06
			(0.197)	(0.199)	(1.61e-05)
WEEE EPR			0.109	0.0960	4.18e-05**
			(0.0949)	(0.0848)	(1.73e-05)
Batteries EPR				0.0930	3.36e-05**
				(0.104)	(1.45e-05)
Log GDP	7.946	15.96**	15.69**	15.60**	
	(5.347)	(7.052)	(6.770)	(6.867)	
GDP					1.37e-08***
					(3.68e-09)
Log GDP squared	-0.289	-0.623*	-0.613*	-0.610*	
	(0.252)	(0.342)	(0.326)	(0.329)	
GDP squared					-0***
					(0)
Log population density		1.607	1.428	1.387	
		(2.387)	(2.318)	(2.337)	
Population density					7.54e-07
					(1.35e-06)
Log old population		0.855	0.596	0.525	
		(1.145)	(1.238)	(1.280)	
Old population					-2.86e-06
					(1.38e-05)
Log environmental tax		0.987***	0.964***	0.970***	
		(0.337)	(0.340)	(0.333)	
Environmental tax					1.94e-05
					(1.31e-05)
EU dummy		-0.527	-0.601*	-0.602*	-5.36e-05***
		(0.372)	(0.338)	(0.339)	(1.83e-05)
Constant	-43.14	-99.65**	-96.47**	-95.48**	-0.000166
	(28.43)	(44.62)	(43.09)	(44.20)	(0.000325)
Observations	794	568	568	568	580
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.619	0.714	0.717	0.718	0.718
Number of country	32	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 6: Results recovery

6.3 Third hypothesis: recycling rates

The third hypothesis expects that implementing EPR schemes will increase the municipal recycling rates in a country. The results of the performed regressions are showed in table seven. The WEEE EPR dummy is in every regression positive and significant. This means that implementing an EPR scheme increases the recycling rates. This is in line with the hypothesis. In the last regression, also the packaging EPR dummy is significant. However, the coefficient is negative, which would mean that implementing packaging EPR would reduce recycling. Of the control variables, GDP, GDP squared and the EU membership dummy show some significant results. The coefficient of GDP and EU membership are positive and significant. This means that being member of EU also increases recycling rates just as being a high income country. This is entirely in line with the expectations. That the EU dummy has a significant effect is not surprising, since the EU has a lot of targets and goals for its Member States when it comes recycling. A reason why only the WEEE dummy is significant, could be because of the weight of electrical and electronic waste. Since recycling is measured in tonnes, it could be that this effect is better to be seen than with packaging or batteries. It could also be, that electrical and electronic products are better qualified for recycling than batteries or packaging materials. However, this does not explain why the packaging EPR dummy is negative and significant.

When the regressions are performed on the dataset of 1995 until 2015, there are no big differences. The same results are significant and positive. It is difficult to reject of accept the hypothesis, since the WEEE EPR scheme does increase recycling rates, but the other EPR schemes do not. However, this is not enough to fully except the hypothesis, thus therefore I reject the hypothesis that EPR schemes increase recycling rates.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log recycling	Log recycling	Log recycling	Log recycling	Recycling per capita
Packaging EPR			-0.153	-0.156	-1.28e-05**
			(0.187)	(0.185)	(5.82e-06)
WEEE EPR			0.184***	0.178**	1.79e-05***
			(0.0655)	(0.0680)	(4.51e-06)
Batteries EPR				0.0410	5.96e-06
				(0.108)	(6.52e-06)
Log GDP	19.46***	13.28	13.76	13.55	
	(4.884)	(8.707)	(8.503)	(8.445)	
GDP					2.95e-09*
					(1.62e-09)
Log GDP squared	-0.866***	-0.581	-0.606	-0.597	
	(0.233)	(0.419)	(0.409)	(0.406)	
GDP squared					-0
					(0)
Log population density		-0.113	0.192	0.129	
		(2.433)	(2.399)	(2.434)	
Population density					-8.63e-08
					(5.48e-07)
Log old population		-0.132	0.0312	-0.00803	

		(1.125)	(1.209)	(1.268)	
Old population					-3.13e-06
					(3.13e-06)
Log environmental tax		-0.0939	-0.0575	-0.0638	
		(0.558)	(0.536)	(0.538)	
Environmental tax					1.44e-06
					(4.45e-06)
EU dummy		0.868*	0.893*	0.897*	5.53e-06
		(0.507)	(0.490)	(0.488)	(1.20e-05)
Constant	-101.7***	-68.06	-72.27	-70.71	4.96e-05
	(25.79)	(52.88)	(51.65)	(51.70)	(0.000104)
Observations	759	565	565	565	592
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.682	0.703	0.707	0.707	0.651
Number of country	31	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 7: Results recycling

6.4 Fourth hypothesis: landfill rates

The last hypothesis expects that landfill rates will go down if a country implemented an EPR scheme. The results in table eight show that the packaging dummy is significant in the fourth regression, but the coefficient is positive. That means that having a packaging EPR scheme increases landfill. This is the opposite of what the hypothesis expected, since an EPR should increase recovery and recycling operations instead of disposal operations. Of the control variables in the first four regressions, both GDP and GDP square are significant as well as population density. The GDP coefficient is also positive. This could be explained by that if countries with higher GDP have more waste, they would also have to dispose waste more often through landfill. The coefficient of population density is also positive. A reason for why countries that have higher population density have more landfill, is because sorting and collecting waste could be more difficult of people live closely together, in for example apartment buildings. That way recovery and recycling is harder and therefore more waste will be disposed through landfill. In the last regression, there are no results significant.

The difference between the regressions performed on the dataset of 1995 until 2015 is small. The biggest difference is that the packaging EPR dummy is also significant in the third regression. There are no other big differences between the results. Therefore, based on these results I reject the fourth hypothesis that EPR schemes will reduce landfill rates.

VARIABLES	(1) Log landfill	(2) Log landfill	(3) Log landfill	(4) Log landfill	(5) Landfill per capita
Packaging EPR			0.325	0.314*	3.07e-05
			(0.190)	(0.180)	(2.59e-05)
WEEE EPR			0.0850	0.0542	-1.56e-05
			(0.231)	(0.247)	(1.53e-05)
Batteries EPR				0.182	-1.36e-05
				(0.245)	(1.56e-05)
Log GDP	13.50**	27.54**	26.67**	26.48**	
	(5.640)	(11.38)	(10.86)	(10.72)	
GDP					-7.66e-09
					(5.43e-09)
Log GDP squared	-0.693**	-1.378**	-1.339**	-1.332**	
	(0.303)	(0.585)	(0.559)	(0.553)	
GDP squared					0
					(0)
Log population density		6.405*	5.963*	5.833*	
		(3.642)	(3.483)	(3.366)	
Population density					-7.46e-07
					(1.93e-06)
Log old population		-1.790	-2.271	-2.370	
		(1.899)	(1.943)	(1.966)	
Old population					2.94e-08
					(9.96e-06)
Log environmental tax		-0.369	-0.396	-0.397	
		(0.514)	(0.523)	(0.527)	
Environmental tax					-1.64e-05
					(2.35e-05)
EU dummy		0.288	0.148	0.142	5.50e-07
		(0.229)	(0.231)	(0.223)	(3.43e-05)
Constant	-57.24**	-153.6**	-145.6**	-143.6**	0.000533
	(26.41)	(68.75)	(65.23)	(63.71)	(0.000361)
Observations	831	598	598	598	598
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.490	0.554	0.561	0.564	0.541
Number of country	33	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 8: Results landfill

6.5 Results only EU countries

This thesis focused on purpose on OECD countries and not just European countries. That way, I hoped there would be more variation in the dataset. However, other articles do focus only on European countries (Mazzanti and Zoboli 2009; Arbulu 2015). Therefore, I performed the same regressions for the same dependent variables again, but only for European countries. The regressions are performed on both the raw dataset and the dataset from 1995 until 2015.

The results are in the appendix, but the most important differences will be discussed in this paragraph. I first discuss the differences between the raw datasets because this is the main discussed dataset in this thesis. In the last paragraph the differences with the 1995 until 2015 dataset will be discussed.

The results are overall the same, but the most important difference is seen in the regressions performed with the dependent variable municipal waste. In the first regression, GDP and GDP squared are significant and as expected. GDP is negative, which means that high income countries generate less waste. In the other regressions GDP and GDP squared are not significant. This is also the case for the results with recovery as the dependent variable. The variables GDP and GDP squared are also significant in the first regression. However, GDP squared is not significant in the other regressions in the European country's dataset, except for the last regression. Nevertheless, they are significant in the original dataset. Moreover, there are no important differences when it comes to the EPR dummies. Only the EU dummy is less significant than in the original dataset. Another difference shows in the results with landfill as dependent variable. Here the packaging EPR dummy is in the dataset with European countries significant in the third regression, while that is not the case in the original dataset. For the other dependent variables there are no important differences, only some control variables are not significant when it comes to the European countries dataset while they are significant in the original dataset.

When the European dataset of 1995 until 2015 is compared to the raw European dataset, there are no big differences when it comes to GDP, GDP squared or the EPR dummies. Only some other control variables are sometimes less or sometimes more significant in the dataset from 1995 until 2015. The only big difference is that the packaging EPR dummy is significant in the last regression when the dependent variable is recovery. However, the coefficient is negative. Which is the opposite as the hypothesis expected.

7. Conclusion

This thesis tried to answer the question: *What is the influence of (different) Extended Producer Responsibility schemes on municipal waste generation, recovery, recycling and landfill rates of European Union Member States?* To formulate an answer this thesis presented an overview of the debate in the scientific literature about the circular economy and existing policies of the European Union regarding this topic. This thesis contributes to existing literature about Extended Producer Responsibility within the circular economy by performing a cross country analysis. Existing theories explain that (financial) incentives of EPR should stimulate producers to design their products more sustainable. This could result in less waste and waste that is better to be treated. The expectations following the literature are that implementation of EPR schemes will reduce municipal waste including household waste, increase recovery and recycling and reduce landfill. To test these hypothesis multiple regressions are performed on different datasets. The main dataset is with raw data, but as a check there is also a dataset with data from 1995 until 2015 to avoid gaps in the data.

The results differ a lot between these datasets and per variable. First, waste is tried to explained with two different dependent variables: municipal waste and household waste (which is part of municipal waste). The literature uses GDP as control variable for this, but there are not a lot of significant results in this thesis. The packaging EPR dummy seems to have a negative effect on packaging, but this is only once significant in that table. When it comes to recovery and recycling, GDP seems to be most of the time significant. Also, the WEEE EPR dummy is in both tables partly significant. The batteries and packaging EPR dummy are both once significant. However, this is not convincing enough to fully accept the hypothesis that EPR schemes have a positive effect on recovery and recycling. The effect of EPR on landfill is very confusing, since the coefficient of packaging EPR dummy is negative. This is the opposite of what was expected.

Overall, there is no clear consistency between the results. The EPR dummy that seems to have the most effect is the WEEE EPR dummy. However, this is not enough to accept any of the hypothesis. Maybe the effect of EPR is not clearly seen in the results due to lack of data. However, it can also be the case that EPR schemes just do not have the big effect that is predicted by the literature. Especially when it comes to reducing waste, it could be the case that the incentives EPR creates are not large enough for producers to design their products more sustainable. The EU membership dummy does have a significant influence on recovery and recycling. That means that the focus of the EU does help for recovery and recycling. However, it also shows that more can be done when it comes to waste regulation.

Since the results differ per dataset and variable, there is a strong need for further research and ways to compare waste policies across country. It would be good to compare countries with each other, since policies are usually nationally or supranational organized. A limitation of this thesis is therefore lack of good control variables when it comes to policy indicators. Other articles also claim that the circular economy is difficult to measure. furthermore, there is a need for more research about good control variables that explain the waste stream. It would also be desirable to have more data available at one place about waste from multiple countries that are not part of OECD. For further research, it would be interesting to see how different implementation between Member States influences the results of EPR schemes.

8. Reference list

Arbulú, I., Lozano, J. and Rey_Maquieira, R. (2015). ''Tourism and solid waste gemeration in Europe: A panel data assessment of the Environmental Kuznets Curve'', *Waste Management* 46: 628-636.

Association of Cities and Regions for Recycling and Sustainable Resource Management (ACR+) (2016). ''New cross-analysis of ''Pay-As-You-Throw'' schemes in 7 European municipalities: potential and benefits under study'', Press Release, https://www.acrplus.org/images/Media_Kit/Press_Releases/2016_05_23_PRESS%20RELEASE%20_PAYT_report.pdf

Banaité, D. (2016). ''Towards circular economy: analysis of indicators in the context of sustainable development'', *Social Transformations in Contemporary Society,* 4: 142-150.

Banerjee, S. and Sarkhel, P. (2020). ''Municipal solid waste management, household and local government participation: a cross country analysis'', *Journal of Environmental Planning and Management,* 63 (2): 210-235.

Bassi, S., Boldrin, A., Faraca, G. and Astrup, T. (2020). ''Extended producer responsibility: How to unlock the environmental and economic potential of plastic packaging waste?'', *Resources, Conservation & Recycling,* 162: 1-12.

BBC (2021). ''Biodiversity & the effect of human interaction on ecosystems'', https://www.bbc.co.uk/bitesize/guides/zggqcj6/revision/3. Requested at March 24 2021.

Bel, G. and Gradus, R. (2016). ''Effects of unit-based pricing on household waste collection demand: A meta-regression analysis'', *Resource and Energy Economics*, 44: 169-182.

Brennan, C. (2016). ''The Enforcement of Waste Law in Northern Ireland: Deterrence, Dumping and the Dynamics of Devolution'', *Journal of Environmental Law*, 28: 471-496.

CM Consulting Inc. and Reloop Platform (2016). *Deposit systems for one-way beverage containers: Global overview.*

Destek, M., Ulucak, R. and Dogan, E. (2018). ''Analyzing the environmental Kuznets curve for the EU countries: the role of ecological footprint'', *Environmental Science and Pollution Research,* 25: 29387-29396.

Dladla, I., Machete, F. and Shale, K. (2016). ''A review of factors associated with indiscriminate dumping of waste in eleven African countries'', *African Journal of Science, Technology, Innovation and Development:* 1-7.

EEAC and RLI (2017). *Europe goes circular. Outlining the implementation of a circular economy in the European area*.

Ellen Macarthur Foundation (2012). *Towards the circular economy. Economic and business rationale for an accelerated transition*.

European Commission (2014). *Development of Guidance on Extended Producer Responsibility (EPR).*

European Commission (2015). *Closing the loop – An EU action plan for the Circular Economy*.

European Commission (2020). *Circular Economy Action Plan. For a cleaner and more competitive Europe*.

European Commission (2021a). ''International Issues'', https://ec.europa.eu/environment/international_issues/index_en.htm. Requested at March 30 2021.

European Commission (2021b). ''First circular economy action plan'', https://ec.europa.eu/environment/circular-economy/first_circular_economy_action_plan.html. Requested at March 30 2021.

European Commission (2021c). ''EU Circular Economy Action Plan'', https://ec.europa.eu/environment/circular-economy/. Requested at April 2 2021.

European Commission (2021d). ''Quick Reference on CEAP Implementation'', https://ec.europa.eu/environment/circular-economy/pdf/implementation_tracking_table.pdf. Requested at April 2 2021.

European Commission (2021e). ''Waste law'', https://ec.europa.eu/environment/topics/waste-and-recycling/waste-law_en#ecl-inpage-754. Requested at 4 May 2021.

European Environment Agency (EEA) (2013). *Managing municipal solid waste – a review of achievements in 32 European countries.* Luxembourg: Publications Office of the European Union.

Europa Nu (2021). ''Voetafdruk'', https://www.europa-nu.nl/id/vi92okvy7zxd/voetafdruk. Requested at March 23 2021.

European Parliament (2016). *Briefing: Closing the loop – New circular economy package*.

European Parliament (2017). *Towards a circular economy – Waste management in the EU*. Scientific Foresight Unit.

European Parliament and European Council (1994). *Directive on packaging and packaging waste.*

European Parliament and European Council (2008). *Directive on waste and repealing certain Directives*.

European Parliament and European Council (2012). *Directive on waste electrical and electronic equipment (WEEEE).*

Expra (2017). ''Extended Producer Responsibility, When and How?'', https://avfallnorge.ams3.digitaloceanspaces.com/avfall-norge-no/8_Expra_Norway-4-Dec-2019.pdf?mtime=20191211154751&focal=none . Requested at 4 May 2021.

Fullerton, D., Leicester, A. and Smith, S. (2010). ''Environmental Taxes''. In: Institute for Fiscal Studies. (red) *Dimensions of tax design: The Mirrlees review*, 423-547.

Gastillo-Gimenez, J., Montanes, A. and Picazo-Tadeo, J. (2019). ''Performance and convergence in municipal waste treatment in the European Union'', *Waste Management,* 85: 222-231.

Geissdoerfer, M., Savaget, P., Bocken, N. and Hultink, E. (2017). ''The Circular Economy – A new sustainability paradigm?'', *Journal of Cleaner Production,* 143: 757-768.

Gupt, Y. and Sahay, S. (2015). ''Managing Used Lead Acid Batteries in India: Evaluation of EPR-DRS Approaches'', *Journal of Health & Pollution,* 5 (8): 52-63.

Haas, W., Krausmann, F., Wiedenhofer, D. and Heinz, M. (2015). How Circular is the Global Economy?'', *Journal of Industrial Ecology,* 19(5): 765-777.

IISD (2020). ''European Commission Adopts Circular Economy Action Plan'', https://sdg.iisd.org/news/european-commission-adopts-circular-economy-action-plan/. Requested at April 15 2021.

Jordana, J. and Levi-Faur, D. (2004). ''The politics of regulation in the age of governance''. In: *The Politics of Regulation: Institutions and Regulatory Reforms for the Age of Governance*, 1-28.

Kaplow, L. and Shavell, S. (1996). ''Property rules versus liability rules: an economic analysis'', *Harvard Law Review*, (4) 109: 713-790.

Kirchherr, J., Reike, D. and Hekkert, M. (2017). ''Concepualizing the circular economy: An analysis of 114 definition'', *Resources, Conservation & Recycling,* 127: 221-232.

Leal Filho, W., Saari, U., Fedoruk, M., Iital, A., Moora, H., Klöga, M. and Voronova, V. (2019). ''An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe'', *Journal of Cleaner Production*, 214: 550-558.

Lehman, P. (2012). ''Justifying a policy mix for pollution control: a review of economic literature'', *Journal of Economic Surveys,* 26(1): 71-97.

Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsoe, E., Rostkowski, P., Thorne, R., Colón, J., Ponsá, S., Al-Mansour, F., Anguilano, L., Krzyżyńska, R., López, I., Vlasopoulos, A. and Spencer, N. (2017). ''Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe'', *Energy,* 141: 2013-2044.

Mazzanti, M. and Zoboli, R. (2009). ''Municipal waste Kuznets Curves: Evidence on Socio-Economic Drivers and Policy Effectiveness from the EU'', *Environmental and Resource Economics,* 44: 203-230.

Minelgaite, A. and Liobikiene, G. (2019). ''Waste problem in European Union and its influence on waste management behaviours'', *Science of the Total Environment*, 667: 86-93.

Netherlands Environmental Assessment Agency (PBL). (2021). *Integrale Circulaire Economie Rapportage.*

OECD (2001). *Extended Producer Responsibility – A Guidance Manual for Governments*.

OECD (2015). *What Have We Learned About Extended Producer Responsibility in the Past Decade? A Survey of the Recent EPR Economic Literature*.

OECD.Stat (2020a). ''Environmentally related tax revenue''.

OECD.Stat (2020b). ''Regional Demography: Population density and area''.

OECD.Stat (2020c). ''Demographic references: population age structure''.

OECD.Stat (2021a). ''Municipal waste: Generation and Treatment''.

OECD.Stat (2021b). ''Level of GDP per capita and productivity: GDP per capita levels''.

Palmer, K. and Walls, M. (1997). ''Optimal policies for solid waste disposal Taxes, subsidies, and standards'', *Journal of Public Economics,* 65 (2): 193-205.

Pouikli, K. (2020). ''Concretizing the role of extended producer responsibility in European Union waste law and policy through the lens of the circular economy'', *ERA forum,* 20: 491-508.

PRO Europe (2021). ''Switzerland'', https://www.pro-e.org/Switzerland.html. Requested at May 3 2021.

Publications Office of the EU (2020). *EU waste management law.*

PV cycle (2020). ''Foundation Open bundles all producers of EEE in the Netherlands as from 1 January 2021'', http://www.pvcycle.org/press/foundation-open-bundles-all-producers-of-eee-in-the-netherlands-as-from-1-january-2021/. Requested at 3 May 2021.

Reichenbach, J. (2008). ''Status and prospects of pay-as-you-throw in Europe – A review of pilot research and implementation studies'', *Waste Management*, 28: 2809-2814.

Sánchez-Ortiz, J., Rodríguez-Cornejo, V., Río-Sánchez, R. Del. And García-Valderrama, T. (2020). ''Indicators to Measure Efficiency in Circular Economies'', *Sustainability*, 1-15.

Smith, S. (2005). ''Analytical framework for evaluating the costs and benefits of extended producer responsibility programmes'', *Organization for Economic Co-operation and Development,* 1-57.

Stahel, W. (2016). ''Circular economy'', *Nature*, 531: 435-438).

Stichting Open (2021). ''Over ons'', https://stichting-open.org/over-ons/. Requested at 4 May 2021.

The World Bank (2018). ''Global Waste to Grow by 70 Percent by 2050 Unless Urgent Action is Taken: World Bank Report'', https://www.worldbank.org/en/news/press-release/2018/09/20/global-waste-to-grow-by-70-percent-by-2050-unless-urgent-action-is-taken-world-bank-report. Requested at March 25 2021.

Trang, P., Dong, H., Toan, D., Hanh, N. and Thu, N. (2017). ''The Effects of Socio-economic Factors on Household Solid Waste Generation and Composition: A Case Study in Thu Dau Mot, Vietnam'', *Energy Procedia,* 107: 253-258.

Veljanovski, C. (2010). ''Economic Approaches to Regulation''. In: Baldwin, R., Cave, M. and Lodge, M. (red) *The Oxford Handbook of Regulation*, 17-38.

Walls, M. (2011). ''Deposit-Refund Systems in Practice and Theory'', *Resources for the Future*.

WASTE (2021). ''Problems and solutions'', https://www.waste.nl. Requested at 31 May 2021.

Zhoe, G., Gu, Y., Wu, Y., Gong, Y., Mu, X., Han, H. and Chang, T. (2020). ''A systematic review of the deposit-refund system for beverage packaging: Operating mode, key parameter and development trend'', *Journal of Cleaner Production* 251: 1-13.

9. Appendix

9.1 Tables from dataset 1995 until 2015

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Log muninicpal waste	Log municipal waste	Log municipal waste	Log municipal waste	Municipal waste per capita
Packaging EPR			0.0314	0.0315	5.950
			(0.0350)	(0.0347)	(16.47)
WEEE EPR			0.0358*	0.0359*	16.51
			(0.0182)	(0.0184)	(11.18)
Batteries EPR				-0.000644	-0.175
				(0.0201)	(9.204)
Log GDP	0.0554	-0.964	-1.097	-1.096	
	(1.000)	(1.199)	(1.165)	(1.181)	
GDP					0.00612
					(0.00570)
Log GDP squared	-0.00289	0.0563	0.0620	0.0619	
	(0.0539)	(0.0638)	(0.0618)	(0.0625)	
GDP squared					-2.36e-08
					(3.25e-08)
Log population density		-0.0143	-0.0550	-0.0546	
		(0.334)	(0.336)	(0.346)	
Population density					-2.493**
					(0.975)
Log old population		-0.450	-0.501	-0.501	
		(0.297)	(0.305)	(0.308)	
Old population					-6.502
					(6.952)
Log environmental tax		-0.0635	-0.0627	-0.0628	
		(0.0801)	(0.0795)	(0.0798)	
Environmental tax					-3.254
					(17.21)
EU dummy		-0.108***	-0.118***	-0.118***	-51.27**
		(0.0331)	(0.0339)	(0.0338)	(20.14)
Constant	8.356*	13.95**	15.03**	15.02**	810.4***
	(4.689)	(6.271)	(6.215)	(6.390)	(241.0)
Observations	680	525	525	525	525
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.182	0.380	0.391	0.391	0.274
Number of country	33	25	25	25	25
Robust standard errors in parentheses					

***** p<0.01, ** p<0.05, * p<0.1**

Table 9: Results municipal waste 1995-2015

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Log household waste	Log household waste	Log household waste	Log household waste	Household waste per capita
Packaging EPR			-0.0524	-0.0528	-1.93e-05
			(0.0461)	(0.0463)	(1.39e-05)
WEEE EPR			-0.0189	-0.0189	-2.70e-06
			(0.0529)	(0.0536)	(1.64e-05)
Batteries EPR				-0.0188	-8.17e-06
				(0.0343)	(1.18e-05)
Log GDP	-2.739***	-1.764	-1.305	-1.224	
	(0.930)	(1.276)	(1.241)	(1.213)	
GDP					8.05e-09**
					(3.40e-09)
Log GDP squared	0.152***	0.110*	0.0896	0.0860	
	(0.0471)	(0.0631)	(0.0613)	(0.0595)	
GDP squared					-0
					(0)
Log population density		0.324	0.455	0.487	
		(0.465)	(0.480)	(0.458)	
Population density					-2.17e-06*
					(1.08e-06)
Log old population		-0.00578	0.0774	0.0879	
		(0.446)	(0.448)	(0.445)	
Old population					2.46e-06
					(5.43e-06)
Log environmental tax		0.176**	0.188**	0.189**	
		(0.0730)	(0.0769)	(0.0760)	
Environmental tax					1.83e-05**
					(6.77e-06)
EU dummy		-0.0802	-0.0832	-0.0842	-1.11e-05
		(0.0633)	(0.0659)	(0.0671)	(1.57e-05)
Constant	20.48***	13.26	9.920	9.299	0.000455**
	(4.745)	(7.909)	(8.040)	(7.806)	(0.000197)
Observations	424	347	347	347	347
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.490	0.451	0.461	0.463	0.393
Number of country	24	19	19	19	19

Robust standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Table 10: Results household waste 1995-2015

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Log recovery	Log recovery	Log recovery	Log recovery	Recovery per capita
Packaging EPR			0.0776	0.0755	-3.07e-05
			(0.239)	(0.239)	(2.12e-05)
WEEE EPR			0.0686	0.0643	3.90e-05**
			(0.108)	(0.0985)	(1.43e-05)
Batteries EPR				0.0331	2.03e-05
				(0.112)	(1.35e-05)
Log GDP	5.448	10.80	10.38	10.33	
	(7.055)	(9.925)	(9.424)	(9.518)	
GDP					1.51e-08***
					(3.28e-09)
Log GDP squared	-0.182	-0.417	-0.399	-0.397	
	(0.331)	(0.472)	(0.448)	(0.451)	
GDP squared					-0***
					(0)
Log population density		0.957	0.871	0.866	
		(3.213)	(3.149)	(3.165)	
Population density					2.21e-06
					(1.53e-06)
Log old population		0.521	0.390	0.362	
		(1.509)	(1.619)	(1.686)	
Old population		0.666	0.665	0.669	
		(0.427)	(0.409)	(0.403)	
Log environmental tax					1.67e-05
					(1.14e-05)
Environmental tax					-2.28e-06
					(1.29e-05)
EU dummy		0.317	0.300	0.301	-3.35e-05
		(0.466)	(0.491)	(0.493)	(2.37e-05)
Constant	-29.08	-65.43	-62.29	-61.89	-0.000381
	(37.76)	(62.87)	(59.79)	(60.76)	(0.000320)
Observations	626	495	495	495	507
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.481	0.650	0.651	0.651	0.671

Number of country	32	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 11: Results recovery 1995-2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log recycling	Log recycling	Log recycling	Log recycling	Recycling per capita
Packaging EPR			-0.0386	-0.0402	-1.52e-05**
			(0.147)	(0.147)	(6.90e-06)
WEEE EPR			0.157**	0.152*	1.73e-05***
			(0.0755)	(0.0743)	(4.04e-06)
Batteries EPR				0.0422	2.39e-06
				(0.0964)	(5.42e-06)
Log GDP	20.34***	10.98	11.09	10.86	
	(6.290)	(7.567)	(7.406)	(7.438)	
GDP					4.15e-09
					(2.49e-09)
Log GDP squared	-0.916***	-0.500	-0.507	-0.497	
	(0.303)	(0.375)	(0.368)	(0.369)	
GDP squared					-0
					(0)
Log population density		-0.916	-0.794	-0.860	
		(2.834)	(2.758)	(2.798)	
Population density					2.24e-07
					(6.02e-07)
Log old population		-1.240	-1.233	-1.283	
		(1.017)	(0.972)	(1.029)	
Old population					-3.71e-06
					(2.83e-06)
Log environmental tax		-0.459	-0.449	-0.455	
		(0.639)	(0.612)	(0.610)	
Environmental tax					-5.84e-07
					(4.23e-06)
EU dummy		1.446***	1.432***	1.435***	8.89e-06
		(0.362)	(0.363)	(0.360)	(1.25e-05)
Constant	-105.4***	-46.81	-47.77	-46.05	2.75e-06
	(32.85)	(48.10)	(46.89)	(47.60)	(9.84e-05)
Observations	589	492	492	492	519
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.625	0.733	0.735	0.735	0.643

Number of country	30	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 12: Results recycling 1995-2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log landfill	Log landfill	Log landfill	Log landfill	Landfill per capita
Packaging EPR			0.331*	0.319**	3.40e-05
			(0.162)	(0.153)	(2.33e-05)
WEEE EPR			0.0537	0.0201	-1.63e-05
			(0.200)	(0.216)	(1.37e-05)
Batteries EPR				0.207	-9.60e-07
				(0.213)	(1.37e-05)
Log GDP	12.83**	29.36**	27.52**	27.20**	
	(6.162)	(11.74)	(11.00)	(10.86)	
GDP					-3.75e-09
					(6.67e-09)
Log GDP squared	-0.660*	-1.468**	-1.384**	-1.370**	
	(0.338)	(0.615)	(0.580)	(0.574)	
GDP squared					0
					(0)
Log population density		7.775**	7.191*	7.057*	
		(3.717)	(3.525)	(3.422)	
Population density					-1.67e-06
					(1.72e-06)
Log old population		-1.974	-2.476	-2.594	
		(2.085)	(2.103)	(2.083)	
Old population					4.54e-07
					(9.60e-06)
Log environmental tax		-0.557	-0.561	-0.556	
		(0.497)	(0.510)	(0.514)	
Environmental tax					-1.40e-05
					(2.25e-05)
EU dummy		0.256	0.182	0.185	-2.26e-05
		(0.224)	(0.199)	(0.184)	(3.22e-05)
Constant	-54.10*	-168.4**	-154.5**	-151.8**	0.000590*
	(28.10)	(67.88)	(62.75)	(61.50)	(0.000333)
Observations	657	525	525	525	525
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes

R-squared	0.417	0.531	0.541	0.546	0.518
Number of country	33	25	25	25	25
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 13: Results landfill 1995-2015

9.2 Tables from dataset with only European countries raw data

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Log munincipal waste	Log municipal waste	Log municipal waste	Log municipal waste	Municipal waste per capita
Packaging EPR			0.0240	0.0236	9.478
			(0.0496)	(0.0493)	(21.60)
WEEE EPR			0.0197	0.0196	5.362
			(0.0220)	(0.0217)	(12.50)
Batteries EPR				0.00667	-0.208
				(0.0277)	(12.68)
Log GDP	-2.143***	-1.233	-1.280	-1.290	
	(0.765)	(1.485)	(1.437)	(1.447)	
GDP					-0.000327
					(0.00436)
Log GDP squared	0.106**	0.0688	0.0709	0.0713	
	(0.0417)	(0.0755)	(0.0729)	(0.0733)	
GDP squared					2.27e-08
					(2.73e-08)
Log population density		0.272	0.243	0.238	
		(0.375)	(0.365)	(0.377)	
Population density					-2.691**
					(1.024)
Log old population		0.000756	-0.0393	-0.0418	
		(0.432)	(0.439)	(0.442)	
Old population					1.241
					(11.38)
Log environmental tax		-0.0352	-0.0349	-0.0343	
		(0.0877)	(0.0871)	(0.0878)	
Environmental tax					-1.763
					(16.02)
EU dummy		-0.0735	-0.0855	-0.0859	-41.10
		(0.0544)	(0.0609)	(0.0613)	(26.33)
Constant	18.88***	12.58	13.08*	13.16*	793.6***
	(3.579)	(7.610)	(7.318)	(7.468)	(268.3)
Observations	724	552	552	552	552

Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.444	0.335	0.339	0.339	0.226
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 14: Results municipal waste EU raw

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log household waste	Log household waste	Log household waste	Log household waste	Household waste per capita
Packaging EPR			-0.0803	-0.0797	-2.92e-05*
			(0.0566)	(0.0549)	(1.49e-05)
WEEE EPR			-0.0636	-0.0673	-2.05e-05
			(0.0643)	(0.0649)	(1.51e-05)
Batteries EPR				-0.0406	-1.93e-05
				(0.0409)	(1.47e-05)
Log GDP	-2.919***	-1.810	-1.379	-1.244	
	(0.955)	(1.484)	(1.455)	(1.455)	
GDP					3.34e-09
					(3.56e-09)
Log GDP squared	0.163***	0.103	0.0834	0.0774	
	(0.0523)	(0.0768)	(0.0755)	(0.0752)	
GDP squared					-0
					(0)
Log population density		0.498	0.642	0.702	
		(0.467)	(0.468)	(0.452)	
Population density					-1.58e-06
					(1.15e-06)
Log old population		0.293	0.367	0.368	
		(0.621)	(0.582)	(0.578)	
Old population					8.27e-06
					(7.57e-06)
Log environmental tax		0.225**	0.226**	0.226**	
		(0.0918)	(0.0913)	(0.0905)	
Environmental tax					1.87e-05*
					(9.14e-06)
EU dummy		0.0218	0.0483	0.0511	1.19e-05
		(0.0585)	(0.0512)	(0.0532)	(1.96e-05)
Constant	20.67***	12.32	9.183	8.149	0.000342
	(4.522)	(8.015)	(8.076)	(8.107)	(0.000206)
Observations	472	366	366	366	366

Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.592	0.394	0.421	0.428	0.363
Number of country	20	17	17	17	17
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 15: Results household waste EU raw

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log recovery	Log recovery	Log recovery	Log recovery	Recovery per capita
Packaging EPR			0.134	0.129	-2.14e-05
			(0.205)	(0.206)	(1.50e-05)
WEEE EPR			0.0548	0.0556	2.29e-05*
			(0.0995)	(0.0987)	(1.21e-05)
Batteries EPR				0.0668	2.19e-05
				(0.114)	(1.46e-05)
Log GDP	13.35***	14.87*	14.57**	14.48*	
	(4.629)	(7.237)	(6.958)	(7.037)	
GDP					1.18e-08***
					(3.80e-09)
Log GDP squared	-0.558**	-0.576	-0.563	-0.559	
	(0.210)	(0.348)	(0.334)	(0.336)	
GDP squared					-0**
					(0)
Log population density		1.795	1.614	1.584	
		(2.476)	(2.404)	(2.421)	
Population density					8.17e-07
					(1.03e-06)
Log old population		2.134	1.914	1.866	
		(1.262)	(1.366)	(1.401)	
Old population					2.11e-05**
					(8.47e-06)
Log environmental tax		0.901**	0.888**	0.901**	
		(0.343)	(0.347)	(0.334)	
Environmental tax					1.76e-05
					(1.28e-05)
EU dummy		-0.514	-0.567	-0.571	-5.87e-05***
		(0.369)	(0.339)	(0.338)	(1.92e-05)
Constant	-70.77***	-97.97**	-94.90**	-94.12**	-0.000482**
	(25.36)	(45.90)	(44.18)	(45.11)	(0.000214)

Observations	682	522	522	522	534
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.685	0.737	0.738	0.738	0.794
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 16: Results recovery EU raw

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log recycling	Log recycling	Log recycling	Log recycling	Recycling per capita
Packaging EPR			-0.184	-0.185	-1.45e-05**
			(0.197)	(0.194)	(6.20e-06)
WEEE EPR			0.147*	0.148*	1.58e-05***
			(0.0789)	(0.0788)	(4.92e-06)
Batteries EPR				0.0186	4.87e-06
				(0.122)	(7.10e-06)
Log GDP	23.66***	12.71	13.28	13.19	
	(5.857)	(9.114)	(8.933)	(8.887)	
GDP					2.72e-09
					(1.69e-09)
Log GDP squared	-1.068***	-0.561	-0.588	-0.584	
	(0.283)	(0.437)	(0.428)	(0.427)	
GDP squared					-0
					(0)
Log population density		-0.204	0.156	0.129	
		(2.546)	(2.504)	(2.545)	
Population density					-1.32e-07
					(5.90e-07)
Log old population		0.289	0.551	0.536	
		(1.704)	(1.784)	(1.827)	
Old population					-1.70e-06
					(6.01e-06)
Log environmental tax		-0.213	-0.151	-0.151	
		(0.570)	(0.551)	(0.551)	
Environmental tax					1.01e-06
					(4.42e-06)
EU dummy		0.889*	0.927*	0.928*	4.95e-06
		(0.510)	(0.497)	(0.496)	(1.25e-05)
Constant	-124.1***	-65.37	-70.73	-70.06	3.77e-05
	(30.54)	(54.87)	(53.58)	(53.69)	(0.000136)

Observations	652	519	519	519	546
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.711	0.707	0.711	0.711	0.655
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 17: Results recycling EU raw

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log landfill	Log landfill	Log landfill	Log landfill	Landfill per capita
Packaging EPR			0.374*	0.354*	3.87e-05
			(0.205)	(0.192)	(2.64e-05)
WEEE EPR			0.313	0.308	-7.11e-06
			(0.187)	(0.186)	(1.66e-05)
Batteries EPR				0.316	-8.98e-06
				(0.242)	(1.79e-05)
Log GDP	15.69**	27.00**	26.28**	25.78**	
	(7.274)	(11.96)	(11.40)	(11.23)	
GDP					-6.86e-09
					(5.97e-09)
Log GDP squared	-0.797*	-1.344**	-1.312**	-1.290**	
	(0.391)	(0.610)	(0.584)	(0.577)	
GDP squared					0
					(0)
Log population density		6.092*	5.647	5.408	
		(3.513)	(3.328)	(3.159)	
Population density					-7.26e-07
					(2.17e-06)
Log old population		-1.975	-2.600	-2.716	
		(2.696)	(2.726)	(2.754)	
Old population					-9.53e-06
					(1.49e-05)
Log environmental tax		-0.264	-0.259	-0.229	
		(0.540)	(0.554)	(0.563)	
Environmental tax					-1.55e-05
					(2.46e-05)
EU dummy		0.300	0.112	0.0917	4.24e-06
		(0.250)	(0.246)	(0.231)	(3.53e-05)
Constant	-69.02*	-149.8**	-142.2**	-138.1**	0.000646

	(34.09)	(69.50)	(65.68)	(63.88)	(0.000443)
Observations	697	552	552	552	552
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.513	0.550	0.565	0.574	0.558
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 18: Results landfill EU raw

9.3 Tables from dataset with only European countries 1995 until 2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log munincpal waste	Log municipal waste	Log municipal waste	Log municipal waste	Municipal waste per capita
Packaging EPR			0.0287	0.0287	4.144
			(0.0359)	(0.0356)	(17.33)
WEEE EPR			0.0296	0.0296	6.820
			(0.0203)	(0.0203)	(11.08)
Batteries EPR				-0.000715	-3.897
				(0.0234)	(10.49)
Log GDP	-2.147**	-1.165	-1.313	-1.311	
	(0.968)	(1.279)	(1.229)	(1.262)	
GDP					0.00523
					(0.00569)
Log GDP squared	0.107*	0.0654	0.0721	0.0720	
	(0.0525)	(0.0672)	(0.0643)	(0.0659)	
GDP squared					-1.54e-08
					(3.32e-08)
Log population density		0.0242	-0.0195	-0.0190	
		(0.343)	(0.338)	(0.351)	
Population density					-2.679***
					(0.890)
Log old population		-0.210	-0.251	-0.250	
		(0.403)	(0.409)	(0.410)	
Old population					-1.136
					(11.53)
Log environmental tax		-0.0626	-0.0588	-0.0589	
		(0.0815)	(0.0821)	(0.0838)	
Environmental tax					-1.136
					(11.53)

EU dummy		-0.117***	-0.126***	-0.126***	-57.90**
		(0.0354)	(0.0362)	(0.0363)	(22.28)
Constant	18.92***	13.99**	15.09**	15.08**	761.9***
	(4.499)	(6.505)	(6.304)	(6.578)	(261.2)
Observations	567	483	483	483	483
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.277	0.382	0.390	0.390	0.280
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 19: Results municipal waste EU 1995-2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log household waste	Log household waste	Log household waste	Log household waste	Household waste per capita
Packaging EPR			-0.0464	-0.0470	-1.91e-05
			(0.0453)	(0.0456)	(1.38e-05)
WEEE EPR			-0.0259	-0.0281	-1.46e-05
			(0.0586)	(0.0579)	(1.23e-05)
Batteries EPR				-0.0204	-1.18e-05
				(0.0340)	(1.17e-05)
Log GDP	-3.127***	-1.847	-1.395	-1.280	
	(0.897)	(1.389)	(1.328)	(1.294)	
GDP					5.97e-09*
					(3.23e-09)
Log GDP squared	0.172***	0.112	0.0916	0.0861	
	(0.0456)	(0.0683)	(0.0655)	(0.0633)	
GDP squared					-0
					(0)
Log population density		0.403	0.510	0.544	
		(0.487)	(0.500)	(0.482)	
Population density					-2.63e-06**
					(1.10e-06)
Log old population		0.237	0.271	0.268	
		(0.566)	(0.526)	(0.530)	
Old population					4.64e-06
					(5.89e-06)
Log environmental tax		0.159*	0.165*	0.163*	
		(0.0788)	(0.0799)	(0.0787)	
Environmental tax					1.63e-05**
					(5.77e-06)
EU dummy		-0.0845	-0.0860	-0.0863	-1.87e-05

		(0.0680)	(0.0692)	(0.0709)	(1.63e-05)
Constant	21.98***	12.60	9.574	8.828	0.000528***
	(4.573)	(8.456)	(8.463)	(8.241)	(0.000178)
Observations	362	318	318	318	318
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.524	0.458	0.466	0.468	0.435
Number of country	20	17	17	17	17
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 10: Results household waste EU 1995-2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log recovery	Log recovery	Log recovery	Log recovery	Recovery per capita
Packaging EPR			0.0500	0.0510	-3.84e-05*
			(0.237)	(0.237)	(1.93e-05)
WEEE EPR			0.00301	0.00260	2.29e-05**
			(0.104)	(0.106)	(9.46e-06)
Batteries EPR				-0.0151	1.11e-05
				(0.116)	(1.32e-05)
Log GDP	12.58*	9.846	9.535	9.568	
	(6.535)	(9.827)	(9.297)	(9.367)	
GDP					1.34e-08***
					(3.45e-09)
Log GDP squared	-0.543*	-0.375	-0.361	-0.362	
	(0.294)	(0.466)	(0.441)	(0.444)	
GDP squared					-0***
					(0)
Log population density		1.681	1.582	1.586	
		(3.256)	(3.213)	(3.236)	
Population density					1.98e-06*
					(1.14e-06)
Log old population		2.198	2.121	2.131	
		(1.773)	(1.882)	(1.925)	
Old population					1.68e-05*
					(9.36e-06)
Log environmental tax		0.577	0.571	0.567	
		(0.440)	(0.425)	(0.405)	
Environmental tax					1.67e-05

					(1.06e-05)
EU dummy		0.338	0.334	0.334	-4.54e-05**
		(0.460)	(0.482)	(0.482)	(2.03e-05)
Constant	-64.63*	-68.18	-65.84	-66.06	-0.000591**
	(36.03)	(62.22)	(58.99)	(59.73)	(0.000232)
Observations	537	453	453	453	465
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.572	0.679	0.680	0.680	0.759
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 11: Results recovery EU 1995-2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log recycling	Log recycling	Log recycling	Log recycling	Recycling per capita
Packaging EPR			-0.0543	-0.0546	-1.63e-05**
			(0.152)	(0.152)	(7.44e-06)
WEEE EPR			0.102	0.102	1.50e-05***
			(0.0828)	(0.0831)	(3.87e-06)
Batteries EPR				0.00598	1.32e-06
				(0.113)	(5.96e-06)
Log GDP	22.82***	10.85	11.13	11.09	
	(7.119)	(7.507)	(7.427)	(7.501)	
GDP					4.05e-09
					(2.51e-09)
Log GDP squared	-1.046***	-0.500	-0.513	-0.512	
	(0.343)	(0.372)	(0.369)	(0.373)	
GDP squared					-0
					(0)
Log population density		-0.992	-0.839	-0.848	
		(2.882)	(2.818)	(2.884)	
Population density					5.37e-08
					(6.17e-07)
Log old population		-1.480	-1.381	-1.386	
		(1.580)	(1.536)	(1.577)	
Old population					-4.91e-06
					(5.80e-06)
Log environmental tax		-0.589	-0.558	-0.557	
		(0.656)	(0.637)	(0.637)	

Environmental tax					-1.05e-06
					(4.26e-06)
EU dummy		1.479***	1.469***	1.470***	9.14e-06
		(0.362)	(0.364)	(0.364)	(1.26e-05)
Constant	-117.6***	-44.80	-47.25	-47.01	4.34e-05
	(37.20)	(47.87)	(46.94)	(47.97)	(0.000117)
Observations	510	450	450	450	477
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.646	0.738	0.739	0.739	0.645
Number of country	26	23	23	23	23
Robust standard errors in parentheses					
***** p<0.01, ** p<0.05, * p<0.1**					

Table 12: Results recycling EU 1995-2015

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	Log landfill	Log landfill	Log landfill	Log landfill	Landfill per capita
Packaging EPR			0.377**	0.359**	4.00e-05
			(0.174)	(0.164)	(2.34e-05)
WEEE EPR			0.234	0.232	-9.52e-06
			(0.190)	(0.183)	(1.44e-05)
Batteries EPR				0.322	2.53e-06
				(0.210)	(1.52e-05)
Log GDP	13.65*	29.01**	26.98**	26.21**	
	(7.636)	(12.51)	(11.70)	(11.52)	
GDP					-3.19e-09
					(7.17e-09)
Log GDP squared	-0.695	-1.444**	-1.352**	-1.316**	
	(0.414)	(0.651)	(0.614)	(0.606)	
GDP squared					0
					(0)
Log population density		7.335**	6.703**	6.474**	
		(3.416)	(3.224)	(3.084)	
Population density					-1.54e-06
					(1.91e-06)
Log old population		-2.239	-2.804	-2.864	
		(3.357)	(3.414)	(3.357)	
Old population					-7.31e-06
					(1.45e-05)
Log environmental tax		-0.472	-0.442	-0.396	

		(0.519)	(0.535)	(0.539)	
Environmental tax					-1.39e-05
					(2.38e-05)
EU dummy		0.258	0.157	0.151	-1.62e-05
		(0.261)	(0.231)	(0.207)	(3.22e-05)
Constant	-59.07	-164.6**	-149.4**	-144.2**	0.000668
	(35.21)	(67.71)	(62.11)	(60.73)	(0.000418)
Observations	555	483	483	483	483
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.434	0.522	0.539	0.552	0.535
Number of country	27	23	23	23	23
Robust standard errors in parentheses					
****** p<0.01, ** p<0.05, * p<0.1***					

Table 13: Results landfill EU 1995-2015