The EU Waste Framework Directive - examining performances in waste management and the reasons on why it differs across countries

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Abstract:
This thesis aims to investigate the development of municipal waste management in the European Union through conducting a cross-country study over 27 countries between 2008-2020. The study uses the Waste Framework Directive, implemented in 2008, and associated Waste Hierarchy to evaluate how EU countries have succeeded to comply with the goals established by the Waste Framework Directive. In addition, various factors that promote different parts of the hierarchy are evaluated. Three two-way fixed effects regressions were run to see what variables affect recycling rates, energy recovery and waste disposal. Independent variables were added gradually which resulted in several significant variables. Our findings indicate that the most significant independent variables were government effectiveness, GDP per capita and investment in research and development. These findings suggest that efficient waste management is dependent on a country's governance, GDP per capita and policies in place. These variables are interconnected, since government effectiveness is reliant on GDP per capita making the result expected. In addition, the establishment of a deposit refund system was found significant for recycling rates - implying the importance of implementing waste related policies. Other explanatory variables showed lower significance, such as population density and tax on waste. A conclusion drawn from the study is that municipal waste management is likely to improve with higher GDP, good governance and the implementation of waste related policies.

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1. Introduction

"Any substance, material or object which the holder discards or intends or is required to discard.". This is the official description of waste from the European Commission (2021). As harmless as this description may seem, what it expresses is one of our times biggest problems. With the population and consumption of the world increasing, the global production of materials has exploded. Consequently so has the waste. On the whole, more than two billion metric tons of municipal solid waste are generated annually - a number that is expected to increase by around seventy percent by 2050. (Alves, 2023). This development is immensely affecting our environment, with waste having negative impacts on our ecosystems in different ways. (European Environment Agency, 2024).

1.1 Background

Waste generation has over the last decades increased and while waste management methods have improved they are yet not sufficient to process it all, contributing to a gap between waste generation and treatment. Recycling rates have increased but still waste is being disposed of in unsustainable ways such as inefficient incineration that contributes to air pollution or landfilling where toxins seep through the ground and contaminate the soil beneath. (Liu et al., 2015). This was acknowledged in 2024, when the European Environment Agency stated that too much waste is generated in Europe and not enough is being recycled or properly managed. At the same time the amount of waste generated in Europe is steadily increasing, creating a risk to lose valuable resources, damaging the environment and human health. However, the European Union (EU) has over the last decades taken steps in the direction of implementing more environmentally friendly waste policies. In its goal to decrease the generated waste and improve the treatment of waste, the EU has developed different legislations and directives that aim to speed up the process and make the region's waste management sustainable. (European Environment Agency, 2024).

In this study we aim to dive deeper into one of such EU directives, the Waste Framework Directive and its associated Waste Hierarchy. We will analyze how waste management has developed since the directives implementation and what factors have affected this development, with a special interest in the role of policy instruments. Within the model we will focus on three levels of waste management in the model; recycling, recovery and disposal.

1.2 The Waste Framework Directive

The Waste Framework Directive was implemented in 2008, and with goals set to be reached in 2025, 2030 and 2035. It is the EU legal framework for managing and treating waste, establishing the basic concepts and various definitions related to waste management in the European Union. It establishes the “polluter-pays” principle and the “extended producer responsibility”, with both principles stating that who is responsible for pollution and the associated cost of it is assigned to the polluting instance, i.e in production where the future waste is “created”. (Directive 2008/98/EC). With the directive enhancing the importance of waste principles and waste management policies we find it of great significance to control for these variables in our work.

The framework is a directive, meaning that it is a legislative act that establishes a goal that all EU countries must reach. However, it is up to each individual member country to decide the implementation methods in order to reach the goal, and what actions to take to comply with the framework. (EUR-Lex, 2021). This enables considerable freedom for each member country. A recent warning report from 2023 published by the European Commission shows vast differences in how far each member country has come in the implementation of the framework by measuring how close the countries are to reach the goals set up by the directive. The warning report divides the EU member countries in three groups: member states on track, member states that risk missing one target and member states that risk missing more than one target. (European Environment Agency, 2023). The mentioned targets are more closely described in sector 1.3 below. In 2022 the European commission sought to confirm and objectify the implementation problems of the Waste Framework Directive, therefore conducting a call for evidence routine where the original framework directive went through a revision. The revision went in line with the objectives that were sent out in the 2020 European Green deal and the Circular Economy Action Plan. Areas of focus were prevention, separate collection, waste oils and textiles. (European Commision, 2022). In this study, we will not include the revision of the Waste Framework Directive as we do not have enough analytical material to cover such an analysis.

1.3 The Waste Hierarchy

The Waste Framework Directive introduces a waste hierarchy that applies a priority order for waste management principles. The hierarchy is divided into five different steps - prevention, preparing for reuse, recycling, recovery and disposal. In this study, we focus on recycling, recovery and disposal. This focus is due to the availability of information. The entire waste hierarchy is described below, with special focus on the parts relevant for the thesis.

Figure 1: The waste hierarchy

Source: (European Commission, n.d)

1.3.1 Prevention

Within the waste hierarchy, prevention of waste is at the top of the funnel and the most desired option for waste management. The definition of prevention of waste is to take the appropriate measures to prevent a substance, product or material from becoming waste. Such measures are reducing the quantity of waste through increasing the life-span of products and through the re-use of products, as stated in Article 9, Chapter 1 of the directive. All member states have been obliged to establish waste prevention programs. The programmes should set out the waste prevention objectives with the aim to break the link between economic growth and environmental impacts related to waste generation. (Directive 2008/98/EC). This step will not be further analyzed in this thesis since more data and information is needed to study it thoroughly.

1.3.2 Preparing for re-use

Preparing for re-use is the second most desired step in waste management according to the waste hierarchy. According to article three in chapter 1 of the directive, it is defined as recovery operations including checking, cleaning or repairing of products and components, in such a way that the products can be re-used without further intervention or preprocessing. Member states are compelled to take measures to promote and prepare for the re-use of products, in particular through the establishment of re-use networks and implementing standards for materials used in production. (Directive 2008/98/EC). This step will not be further analyzed in this thesis because of the lack of information about it.

1.3.3 Recycling

The third step in the waste hierarchy is recycling processes. According to article 11, recycling operations is defined as any recovery operation that processes waste materials into new products, materials or substances - either for original or other purposes. According to the directive, member states are obliged to take measures in order to promote high quality recycling and set up separate collections for waste that technically, environmentally and economically meet the quality standards. Separate collections for waste should include at least paper, glass, metal and plastics. In addition, by 2025 separate collections for textile and hazardous waste should be set up by the member states. (Directive 2008/98/EC).

Chapter 1, Article 11 further highlights that by 2025, recycling activities and the preparation for re-use procedures shall be increased to a minimum of 55% of weight. By 2030 and 2035, this minimum line is to be increased to 60% and 65% of weight, respectively. These targets include a municipal waste recycling target as well as a total packaging recycling target. For the EU, the stage of recycling is important for the transition into a circular economy where high-quality resources get extracted from waste as much as possible and in an efficient way. It is also set to stimulate innovation within the recycling processes. (Directive 2008/98/EC).

1.3.4 Recovery

Recovery within the waste hierarchy refers to when it is no longer practical or possible to recycle the material so it is recovered instead and made to serve another useful purpose, mainly as fuel to generate energy, according to Annex II in the Waste Framework Directive (2008/98/EC). For this method to be used, it is required that the waste does not contain recyclates, such as recovered paper, but only other waste. The three different recovery methods measured by Eurostat (2023.b) are recycling (in the sense that non-recyclates are transformed into material that can be recycled for specific purposes), backfilling and incineration. In this paper, the focus lies on waste incineration, where waste is transformed into energy through incineration. Recovery then references the process of recovering the material by transforming it to energy. From this process two types of ash are produced as residue, fly ash and bottom ash. Fly ash is a hazardous type of residue, containing toxins and heavy metals, stemming from exhaust flue gasses, making it harder to recycle and be reused. Bottom ash is more coarse, created after combustion on the grate and can be recycled as fill material for construction work. Liu et al (2015) concluded that in 2003 Denmark had a reuse rate on bottom ash at 98 percent, which is an example of when recovery becomes recycling. This entire process requires a well functioning waste management system as incorrect waste incineration can be inefficient and release avoidable toxins that harm the environment. Liu et al. (2015) reported that in 14 European countries, 200 waste to energy facilities existed and managed 23% of the municipal solid waste.

Strengthened by the directive, incineration is only considered as recovery if it is energy efficient. When waste reaches the recovery or disposal level in the hierarchy, it will be managed under controlled conditions set up by the Waste Framework Directive. The conditions to carry out any type of treatment is that waste facilities must possess a permit from a competent authority. Article 23, chapter 5 in the directive concerns permits and registrations, touching on the subject of the requirements to treat waste. In the allocation process, the permits must specify the types and quantities of waste that is allowed treatment, the method used for the treatment, safety and precautionary measures taken and ensure an energy efficient incineration. What is regarded as energy efficient incineration is described in Annex V of the directive (2008/98/EC). In it, it is clarified that efficiency levels have to be equal to or above 60 percent for facilities in operations or permitted before 1 January 2009 and 65 percent for facilities permitted after 31 December 2008. In order to meet these demands, incineration operations have to fulfill the formula for energy efficiency.[1]

1.3.5 Disposal

The final level in the hierarchy is disposal of waste and it accounts for the waste that could not be successfully prevented, recycled or recovered. This can occur if a competent authority deem the treatment more harmful than helpful in regards to environmental protection, making it within their right to refuse to issue a permit. The guidelines to decide what waste is eligible for these treatments is that the materials have to be non recyclable to be considered. Article 29, chapter 1, highlights this as it states that member states should not support landfilling or

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Formula: Energy efficiency = (Ep-(Ef+Ei)) (0.97 (Ew + Ef))

Ep = Annual energy produced as heat or electricity, calculated through multiplying electricity by 2.6 and heat produced for commercial use by 1.1. (GJ/year)

Ef = Annual energy input to the system from fuel contributing to steam production. (GJ/year)

Ew = Annual energy contained in treated waste, calculated through net calorific value of the waste. (GJ/year)

Ei = Annual energy imported excluding Ew and Ef (GJ/year)

0.97 = Factor accounting for energy loss due to bottom ash and radiation. (GJ/year) incineration of these recyclates whenever possible. This is the least desirable outcome since no material or energy will be recovered. Incineration will no longer be energy efficient but instead damaging to the environment as the facilities release unnecessary toxins into the air. (Liu et al, 2015). The Waste Framework Directive classifies this as a “last resort” on how to dispose of waste, even prohibiting recyclable waste to be dumped in this manner. Further, the directive states that if this method should be undertaken, the waste must be disposed of through a safe operation that protects the human health and environment.

Article 13 underscores this by emphasizing that the disposal (and recovery) shouldn’t:

a) harm the water, air, soil, plants or animals.
b) disturb surrounding environment through noise or odors
c) affect places of special interest or the countryside.

1.4 Purpose

Our purpose with this thesis is to investigate how the implementation process of the waste hierarchy has developed across EU member states, with a focus on recycling, recovery and disposal operations. In addition, if there are any differences in the processes, we aim to find factors as to why some countries are able to implement the framework in a more efficient and successful way than others. This study will make a comparative descriptive analysis concerning the development of the recycling, recovery and disposal operations throughout countries. To further analyze the drivers of the potential differences in waste management methods, three fixed effects regressions will be run to investigate the relevance and significance of such factors explaining differences across countries. By conducting this study, our ambition is to provide evidence on the heterogeneity of waste management across EU countries, and on the factors that might be explaining such heterogeneity. Our ambition is that the evidence provided will be deemed relevant and assist in future research concerning effective waste management of municipal solid waste.

1.5 Research questions

The research questions of this thesis is as follows:

- *How have the performances in recycling, recovery and disposal developed in the EU countries between the years of 2008-2020?*

- *What may be statistically significant reasons as to why the performances may differ across the EU countries?*

1.6 Constraints

When analyzing the Waste Framework Directive, we have in this study chosen to focus on the years of 2008-2020. This decision was made since we could not find appropriate data on all desired explanatory variables past that time. The subject of waste management is broad and contains several different definitions and methods. To simplify this study we have chosen to focus, as mentioned above, on three levels of the waste hierarchy. We have further specified our research topic by only focusing on municipal solid waste and the associated recycling and further disposal of it.

Within the Waste Framework Directive, waste is divided into different sub categories, such as municipal solid waste, sewage and hazardous waste, hazardous waste, depending on type of waste which consequently creates different management methods. Municipal solid waste is a collection of waste mainly consisting of household waste but also waste generated from public institutions and small businesses, all collected by the municipality. (Eurostat, 2024a). Since the data available in many cases reports municipal solid waste, the focus of this study lies in the processing of this category. Thus, our analysis does not consider waste from the agriculture sector, demolition projects and other major waste pollutants.

2. Literature review

This section explains and reviews the relevant literature on the subject of municipal waste management. Earlier studies explore the link between different types of waste management and variables that may explain different performances in these sectors. The review will be organized by the literature relating to each of the three chosen steps in the waste hierarchy.

2.1 Recycling of waste

López-Portillo et al. (2021) conducted a study that found that differences in waste management could be explained by different economic indicators. In particular, investment in research and development (R&D) and GDP per capita were shown especially important for higher recycling rates. Earlier research has also explored the relationship between recycling and different types of waste policies. López-Portillo et al. (2021) studied the connection between waste treatment and waste policies in the EU - including the WFD directive. The findings were that there is certain convergence in european recycling rates due to EU policies. Another policy that is related to waste recycling is deposit-refund systems. Walls (2011) explored the system in practice and in theory, and found that the system may be able to control waste pollution in much the same way as a Pigovian tax. In addition, alternative waste disposal policies are shown to be inferior to the deposit-refund systems in theory. Another policy that has been reviewed is a waste incineration tax. Sahlin et al. (2007) conducted a study that investigates the effects of a waste incineration tax in Sweden on incentives for recycling. The findings of the study were that the incineration tax would have an effect on recycling behavior but with different impacts on different types of waste. The largest effect of the tax was to be found on biological treatment of kitchen, garden waste and packaging waste. Packaging waste includes paper, plastic (non-PET), metal and glass. In addition the magnitude of the effect depends on other variables, such as the level of the tax, cooperation between waste incinerators and technological factors. The authors observed the tax impact to be highly dependent on the size of the tax. (Sahlin et al. 2007).

Next, Pronti and Zoboli (2024) have investigated the link between recycling rates, institutional quality and trust in institutions. The explanatory variable chosen for institutional quality and trust in institutions was government effectiveness. As a result, the study could confirm the hypothesis that institutional quality and trust in institutions can influence recycling behavior. Moving on, Yamamoto and Kinnaman (2022) have found that higher rates of incineration have been found to decrease recycling rates. According to the study, this can be explained by policy makers that are found comfortable with incineration plants that operate at a low capacity in an economy that produces more waste. Starr and Nicolson (2015), found that while increased age leads to higher waste generation (through purchasing more materials) it also increased the recycling demand. Another effective policy instrument to increase recycling is the use of “pay as you throw” (PAYT) systems, where a fee is paid to dispose of one's municipal waste to a waste management system. Through a study by Rizzo and Secomandi (2024) it was shown that when imposing a PAYT system, recycling rates increased 40 percentage points while total waste per capita decreased 30 percentage points. Lastly, Best and Kneip (2011) have explored the relationship between recycling rates and environmental attitudes and behaviors - concluding that changing environmental attitudes are important for increasing recycling rates.

2.2 Recovery of waste

Yasmeen et al. (2023) discusses that when investing in waste management technologies such as waste-to-energy systems and recycling facilities, countries can change their waste management systems, making them more environmentally sustainable, operationally efficient and economically feasible. By expanding this technology, stemming from increased expenditures on research and development, solid waste management standards improve. Building effective facilities for this process will turn waste into valuable resources and reduce the impact of harmful emissions from debris disposal, as corroborated by Yasmeen et al. (2023). Moreover, the article also references government quality and concludes that countries with higher government quality are stronger economically (therefore having a higher GDP) and can implement policies more effectively.

In 2015, Liu et al. reviewed different municipal solid waste environmental standards, and the connected incinerator residues. In the article, the authors first acknowledge that improper waste incineration can release toxic heavy metal elements and later go on to discuss the policy evolution across selected countries. The countries that have high percentages of recycled and reused ash per year from incineration is higher in European countries compared to non-European countries, attributing this to more advanced waste management programs and policies. Through an Environmental Regulatory Regime Index that measures implementation and enforcement, associated institutions, mechanism and standards, they conclude that a higher score indicates higher environmental regulations- indicating that policy stringency has an impact on effective waste recovery.

2.4 Disposal of waste

As reviewed in the first paragraph under section 2.1, Sahlin et al. (2007) show that waste incineration tax had an effect on recycling rates. Consequently, a higher recycling rate in the same time corresponds to a lower disposal rate. Also mentioned in Liu et al. (2015) and Yasmeen et al. (2023),policy stringency will affect the disposal of waste as more economically affluent nations generally have a higher GDP and higher government quality. Mazzanti and Zoboli (2008) further discusses this, as incineration will increase as landfilling decreases (from an increased landfill tax). The authors also found that the levels of disposal through incineration and landfills was highly affected by the presence of waste policies and how effective governments were to fulfill policies. In the same article, the authors discussed that investment in research and development should have a positive link with disposal through incineration due to technical intensity. At the same time, the authors concluded that the link may also be opposite directed since countries that invest in research and development may use the technological skills to improve recycling facilities. Mazzanti and Zoboli (2008).

Liu et al. (2015) also concluded that what can have an effect on the disposal of waste is population density and percentage of arable land. In countries with high population density and a low percentage of arable land it was more beneficial to try to reduce the amount of waste going to landfills. To combat this, these countries tend to have higher incineration plant densities (measured in number of incineration facilities per one million people). As the literature reviewed, earlier articles and studies have discussed different factors affecting waste management in each of the steps of the waste hierarchy in the Waste Framework Directive.

Moreover, Clapp (2002) stated that there is a strong correlation between rising incomes, material consumption, waste generation and disposal. The author related this to an increasingly skewed global economic inequality, where the normative material consumption behavior is constantly being pushed further - what is normal to consume today will be seen as "little" in a year or two.

To summarize, several studies have highlighted the importance of policy implementation and policy instruments on waste management. In addition, we have in the literature found other variables that show importance for each of the steps on the waste hierarchy - such as age, arable land and population density, as well as GDP per capita and good governance. We have in this review tried to capture the big picture of factors affecting recycling, recovery and disposal of waste. At the same time, we acknowledge that other relevant literature exists.

3. Theoretical framework

This section presents relevant theories connected to the Waste Framework Directive and the associated waste hierarchy. The circular economy and polluter pays principle are relevant theories since they are promoted by the EU and mentioned in the directive. To explain potential differences between countries the Environmental Kuznets Curve is considered important. By using these theories as our theoretical framework, our aim is to analyze how well different countries are adhering to the directive and the reason they differ.

3.1 The circular economy

The circular economy is a model that dates back to the early days of modern environmental movements in the 1960 and 1970s. It aims to create a new relationship with goods and materials, leaving the traditional linear model of “make-use-dispose” behind. The focus lays on the flows of materials, with the goal to turn products that are at end of life into new resources for others. (Stahel, 2016). The circular economy model is possible to divide into two groups, the reuse of service life through repair and remanufacturing and the possibility to create new goods through recycling. In this model, consumers become reusers and creators at the same time - creating the circular model. Studies have shown that a shift to the circular economy would reduce each nation’s greenhouse gasses by 70 procent, and at the same time grow the workforce by around four procent (Stahel, 2016). The reduction of waste would at the same time enable materials to be kept in the economy and create new value due to recycling - creating a model for a sustainable economy. (Stahel, 2016). The circular economy is promoted by the EU, as well as by a number of national governments and businesses. The circular flow of the model is described to reduce environmental harm by reducing waste and increasing efficiency, and at the same time creating new jobs and economic gains. (Korhonen et al., 2018).

As the circular economy model has gained reviews, critiques of the model have occurred. Overall, the model has been criticized for not having enough foundation in theory, and that its implementation faces structural challenges. Moreover, people have found fault with the model being too chained to an ideological agenda that brings uncertain contributions to sustainable development and depoliticizes sustainable growth. (Corvellec et al., 2022). In addition, the concept of the circular economy has gained critique in that its definition has been used in a non-coherent way, with different people describing and using the concept in different ways. Findings show that the model is commonly used to describe recycling activities, but often fails to highlight that the model needs a systematic shift in the society in order to function. Additionally, definitions commonly miss to show linkages between the model and sustainable development - raising voices that aim to conceptualize the definitions so as the concept of the model does not get lost. (Kirchherr et al., 2017).

2.2 Polluter pays principle

Introduced by the Organization for Economic Co-operation and Development (OECD) in 1972, the polluter pays principle states that the expenses for pollution should be paid by the polluter. The recommendation specifically reads that "allocating costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment" (OCDE/GD(92)81). It is a principle policymakers use to internalize the negative externalities that come from the production of goods, often in the form of economic instruments. Pollution can be defined as the environmental impact emissions or harmful activities produce from production. Who is considered the polluter can be tricky to define. The polluter is partly the entity performing the polluting activity (as the producer) but it also includes those who can potentially pollute the environment where pollution has not (yet) happened (such as the consumer). To efficiently incentivize the producer to minimize pollution the cost of pollution is included when buying a product, paying indirectly for their pollution by internalizing the cost.

The European Court of Auditors (ECA) (2021) states that by adhering to this principle, the polluter pays principle serves as a foundational concept for environmental accountability, guiding the actions of member states. Chapter II, Article 8 in the Waste Framework Directive elaborates on this by introducing the 'Extended producer responsibility' that informs how Member States need to act in a way that 'producers of products bear financial responsibility or financial and organizational responsibility for the management of the waste stage of a products life cycle'. This references the steps of prevention and preparing for re-use in the hierarchy where firms change the material of their products, expand recyclable packaging and similar actions. Within the Waste Framework Directive (2008/98/EC) the polluter pays principle is adjusted so that the final, or previous, holders of waste are liable for associated costs for waste disposal or waste management. ECA recalls how this principle has since 2007 been the premise of all EU environmental policies. It is the European Commission's obligation to draft related environmental proposals that member states then have to apply and enforce internally. Member states can then implement the polluter pays instrument itself using different sub-instruments; command and control law, voluntary approach and market-based instruments, as presented by Communication and Information Resource Centre for Administrations, Businesses and Citizens (CIRCAB) (2012).

CIRCABC categorizes Command and control law as a policy sub-instrument within this economic instrument as it contains emission limit values, administrative orders and sanctions, bans and licensing procedures. Policymakers then take direct measures to limit pollution through regulation by setting environmental standards, capping pollutants and prohibiting harmful activities. The voluntary approach, even called “soft law”, are labeling, environmental management systems and voluntary agreements. While there are no requirements to follow these, firms may be encouraged to reduce emissions since consumers care for a firm's corporate social responsibility. In the same way can consumers be affected through this voluntary approach as with a deposit refund scheme where consumers are incentivized to change their behavior, i.e., nudging. Market-based instruments include subsidies/feed-in tariffs, taxes, charges, fees, tradable permits and quotas and liability rules. These instruments are more often individually implemented by member states and not by the European Commission themselves. Using these tools, states hope to create (dis)incentives to adjust to a more environmentally friendly production as this change would be less costly than the taxes for not changing production techniques.

2.3 Environmental Kuznets Curve

Published in 1955, the Environmental Kuznets Curve (EKC) was proposed by Simon Kuznets with the goal to depict the relationship between income per capita and income inequality. It consists of an inverted U-shaped curve that has with time been adjusted to fit environmental studies. The change was most notably implemented by Grossman and Kreuger in 1991 and is now more famously using the axis environmental degradation and income growth (GDP per capita). The curve is divided into three phases (pre-industrial economies, industrial economies and post-industrial economies) that illustrate the different stages of economic development. (Hipólito & Marques, 2022). Kaika and Zervas (2013) argues that in the pre-industrial era economic activity is limited, resulting in an overuse of resources without considering the negative externalities from environmental degradation that follows. This period of development later leads to economic growth and associated higher income without having to invest quite as much in resource intensive production to sustain it. When reaching the second phase, the industrial economy, much of resources has been depleted but related waste has accumulated. Succeeding this is phase three, where countries possess a higher GDP per capita and now can instead focus on innovation that recognizes negative externalities. We find the Kuznets Curve to be relevant for our study in the way that it connects environmental degradation with GDP per capita, which is one of the explanatory variables that we will control for in this study.

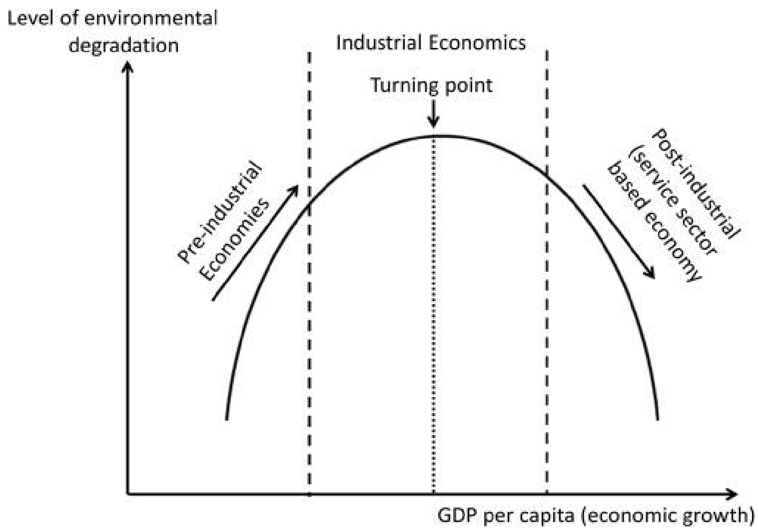

Figure 2: The Kuznets Curve
Source: (Stern, 2004)

4. Data

The dataset for the study was created by gathering information from several various datasets and compiling them into one relevant for our research question. It is organized in a panel data setting with a time period stretched between 2008-2020 and European Union member countries used as cross sectional entities. A list over the included countries can be found in Appendix A. Data after 2020 have unfortunately not yet been published for waste generation and treatment, giving us a smaller dataset. The option to use a wider time frame and include data before 2008 was possible, but disregarded for the regressions since the outcomes post-implementation of the Waste Framework Directive is what is aimed to measure. When analyzing and creating descriptive data, values from 2006 have been used to examine how the recycling rate, energy recovery and disposal has changed since the implementation. For the data originating from Eurostat, the member states decided themselves the collection method of data, ranging from surveys, statistical estimations or administrative sources.

When gathering relevant literature the policy instrument "pay as you throw" (PAYT) was mentioned as effective by the European Environment Agency (2023). Although, by the European Environment Agency (2023). Although, when collecting data it showed that the majority of countries have had the system implemented even before the directive. If we were to measure this it would be as a binary variable with the majority of values being 1 (as a 1 indicates the policy implementation). Therefore the variable was excluded as the data of it was not significant to the research question of how the directive has affected the policy. Other variables of interest, such as environmental awareness, were also not included due to issues with data availability for the desired years and countries.

Table 1 below summarizes the variables being used for the regressions and where they originate from. Using different sources for the independent variables has contributed to having missing values. Missing data can affect the dataset as it implies some measurement error. The number of observations for each variable is presented in Table 2 together with other descriptive statistics such as mean, standard deviation, minimum and maximum values. Further, we have chosen to download data in comparable units between the countries such as per capita values, rates, and other standardized units. By using these unit measurements we aim to make the data more comparable across countries and the different levels of the hierarchy. Unfortunately could no data over recycling be obtained in a kilogram per capita unit, which would simplify the process of comparing the different levels.

Table 1: Variable description

Variable name (unit)	**Type of variable**	**Source**
Recycling rate of municipal waste (percentage of total municipal waste generation)	Dependent variable	Eurostat (2024b)
Treatment of waste by energy recovery (kilogram per capita)	Dependent variable	Eurostat (2023a)
Disposal Incineration (kilogram per capita)	Dependent variable	Eurostat (2023a)
Government effectiveness (scale from -2.5 to 2.5)	Independent variable	World Bank Database (2023)
Logged real GDP (per capita)	Independent variable	Eurostat (2024c)
Gross domestic expenditure on research and development (% of GDP)	Independent variable	Eurostat (2024d)
Environmental policy stringency (scale from 0 to 6)	Independent variable	OECD (2022)
Population density (persons per square kilometers)	Independent variable	Eurostat (2024e)
Arable land (holding)	Independent variable	Eurostat (2023b)

Tax on municipal waste incineration (binary)	Independent variable	European Environmental Agency (2023)
Tax on municipal waste landfilling (binary)	Independent variable	European Environmental Agency (2023)
Deposit refund scheme (binary)	Independent variable	Independent Commodity Intelligence Services (2022)

4.1 Variable description

The dependent variables have been chosen based on the fact that they are directly linked to the waste hierarchy and our research question. For step three on the waste hierarchy, recycling, we have chosen the dependent variable *recycling rate*. Relating to step four on the waste hierarchy, recovery, we have chosen dependent variable *energy recovery through incineration*. At last, related to step five on the waste hierarchy disposal, we have chosen the dependent variable *disposal through incineration*. Eurostat (2024a) defines the collected data as municipal solid waste produced by households, offices and public institutions. Data for recycling rate of municipal waste stretches between 2000-2022 and is generated by dividing the tonnage recycled from municipal waste by total municipal waste arising. Energy recovery measures the amount of non-recyclable waste that has been incinerated and in the process transformed to energy such as electricity or heat. (Environmental Protection Agency, 2024). This treatment will only be topical if it has a high level of energy efficiency, as stated in the directive (2008/98/EC). Disposal of waste through incineration accounts for the waste that could not be successfully prevented, recycled or recovered. Both energy recovery and disposal is measured in the unit kilogram per capita, captured by dividing the total waste by the population. Disposal of waste through incineration accounts for the waste that could not be successfully prevented, recycled or recovered. Both energy recovery and disposal is measured in the unit kilogram per capita, captured by dividing the total waste by the population.

Included as an explanatory variable is real GDP per capita, logged. The variable is logged to get more evenly distributed values, since the variable unlogged was highly skewed. By logging the variable, a better fit for the fixed effect regression model is created. Real GDP per capita is the ratio of real GDP to the average population. It is relevant as it measures a country's economic activity, which in turn works as a proxy for living standards. Often a significant correlation can be found between a country's real GDP and other non monetary indicators. In the case of waste it is predicted that a higher real GDP per capita indicates higher consumption, leading to more waste. However, it is important to highlight that real GDP can also be misleading as it does not account for environmental degradation, income disparity or quality of life. Further was gross domestic expenditure on research and development included that recalls the percentage member states spend of their GDP on research and development.

The data for government effectiveness was collected from the World Bank. The dataset contains six different government indicators that contribute to countries' development in building human capital, improving economic growth and strengthening social unity. We decided to only use government effectiveness since this variable indirectly captures the effect of the other government indicators. It captures the quality of policy formulation, government's credibility to commit to these policies, quality of the civil and public services and the degree of its independence from political pressures. By including all indicators the prediction was a concern that they would highly correlate, causing the problem of multicollinearity. (Pronti & Zoboli, 2024). The variable consists of composite measures generated in units of a standard normal distribution (mean zero) with a standard deviation of 1, giving values stretching between minus 2.5 to 2.5 where a higher value indicates better governance. (World Bank, 2022).

OECD (2022) created an index for environmental policy stringency for the purpose of internationally comparing the effect of having consistent environmental policies. Stringency in this case is defined by OECD as 'the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behavior'. It captures the effect of 13 different policies where the index can take a value between 0 (not stringent) to 6 (very stringent). Albeit, many of the policies included in the index focus on policies concerning carbon emissions and other air pollutants, not waste management itself. Despite this, the variable has been included since the included policies can inadvertently affect waste management.

Tax on municipal waste incineration is an environmental tax that users have to pay beyond the normal incineration rate for being permitted to dispose of waste in an approved incineration facility. The tax concerns the treatment of waste on the municipal scale, thereby excluding waste from large construction jobs, agriculture and similar waste streams. Disposal landfilling is a type of waste treatment used at the end of a product's life cycle. It is important to note that this data excludes exports and imports of waste, only counting waste treated within the borders of a country. A tax on municipal landfilling of waste is a similar tax where those wanting to dispose of their waste have to pay a tax for it, where you usually are charged by weight. While the tax might differ both within a country's municipalities and other member states this tax rate has not been studied individually. Instead, a binary variable was created to study the effect that takes the value 1 if they have the tax and the value 0 if they don't. This means that if a country implemented a tax in 2014 all previous years would be assigned a 0 and the later years assigned a 1. The numbers were obtained through a report from the European Environmental Agency (2023) where each concerned country was listed with the year they implemented either (or both) of the taxes. Similarly, a binary variable was created to measure the amount of countries that have a deposit refund scheme implemented, with 0 being that a country does not have an implemented deposit refund system and 1 being that they do, acting as a dummy where countries are assigned a 1 the year they implement the policy and forward.

To investigate what can affect the level of incineration disposal arable land and population density is included. Arable land is a sub-category over Eurostats dataset on main farmland used by NUTS 2 regions (2023b). It describes the structure of agricultural holdings and farms, livestock and labor force. The unit agricultural holding can be seen as one single unit functioning as a single management. The amount of arable land a country has is greatly affected by the size of a country, causing great variance within the variable and generating risk for outliers that may negatively affect the regression results. A similar problem appears with population density, which is why we chose to use a logarithmic value for that variable as well. By using a logarithmic version we get more evenly distributed values that are easier to interpret within the regressions.

4.2 Descriptive statistics

Described by Table 2 is the number of observations, mean, standard deviation, variance and the minimum and maximum value for the variables included in the study.

Table 2: Descriptive statistics of variables

Variable	Obs	Mean	Std. dev.	Min	Max

Recycling rate of municipal waste	188	33.20	16.53	0.9	70.30
Treatment of waste by energy recycling	185	243.90	319.86	0	1906
Disposal incineration	185	35.24	68.72	0	455
Government effectiveness	189	1.07	0.58	-0.36	2.24
Logged real GDP	189	9.43	0.64	8.53	11.37
Gross domestic expenditure on research & development	189	1.58	0.90	0.38	3.71
Environmental policy stringency	126	3.11	0.54	1.81	4.89
Logged population density	135	4.66	0.91	2.88	7.38
Logged arable land	162	11.34	1.63	7.22	14.97
Tax on municipal waste incineration	189	0.32	0.47	0	1
Tax on municipal waste landfilling	189	0.32	0.47	0	1
Deposit refund scheme	189	0.30	0.46	0	1

4.3 Compliance with the Waste Framework Directive

The dependent variables exhibit large variation between the minimum and maximum values. The recycling rates in the table range from 0.9 percent in Romania 2008 to 70.30 percent in Germany 2020. This showcases the large heterogeneity between all the countries over the years. Albeit, even if we were to compare the recycling rates between Romania and Germany the same year a large difference is seen, being 11.9 percent in Romania 2020. This showcases the large heterogeneity between all the countries over the years. Albeit, even if we were to compare the recycling rates between Romania and Germany the same year a large difference is seen, being 11.9 percent in Romania 2020. Additionally, there is large variation in the data for energy recovery and disposal through incineration. The mean for policy stringency is 3.11 meaning it is more balanced toward the maximum (4.89) than the minimum (1.81). A similar distribution is seen in government effectiveness and percentage of GDP spent on research and development with the mean being closer to the maximum than the minimum. To implement and enforce the Circular Model it is more achievable if a country has a high value in these variables. As the literature and data suggest, positive correlation can be found between these variables, implying that when scoring high on one of these values the other variables will also be higher. A table over the correlation between all variables can be found in Appendix B.

Consequently it can then be incoherent to include these variables in the same regression. For instance,, the correlation between government effectiveness and a GDP per capita is 0.82. The correlation could then be too strong so the effect of a government effectiveness scheme will be captured by GDP, making it insignificant in comparison. However, this may not always be true and it can still be interesting to capture the effect of variables in the same regression controlling for each other.

4.4 Heterogeneity across data

Depicted in Figure 3 is energy recovery through incineration, showcasing the heterogeneity in our dataset. The box and whiskers graph highlights how the amount of waste being recovered has changed within countries and how it is not evenly distributed within and between countries. Although, the graph is somewhat misleading since Finland is an outlier, making the other countries appear more homogenous since it is harder to see the variance in their values. By excluding Finland from the data we get more evenly distributed graphs but with more apparent variation and heterogeneity - making the graph easier to interpret. A graph without Finland can be found in Figure 9, Appendix C. Further, Figure 4 presents the heterogeneity between countries at disposal through incineration. To further expand on is the data not evenly distributed, displaying more heterogeneity within countries such as Austria, Belgium and the Netherlands. Depicted in Figure 5 is a graph that showcases the heterogeneity in recycling rates, showing the large discrepancy between nations recycling rates. While there is some skewness within the data for each country it is still relatively evenly distributed without many outliers.

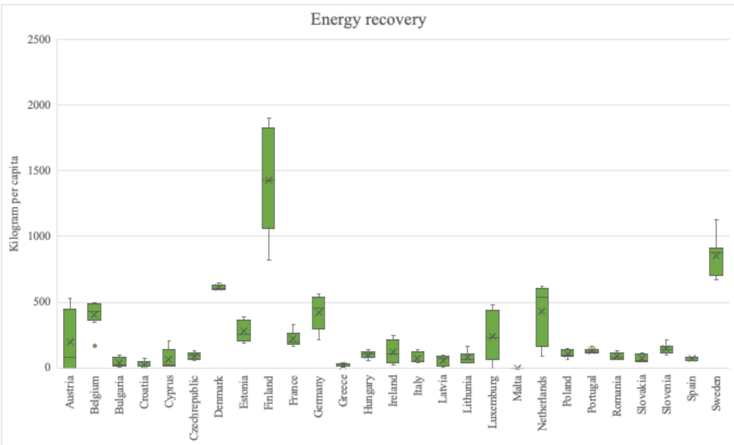

Figure 3: Energy recovery through incineration between 2006-2020

Source: Eurostat (2023a)

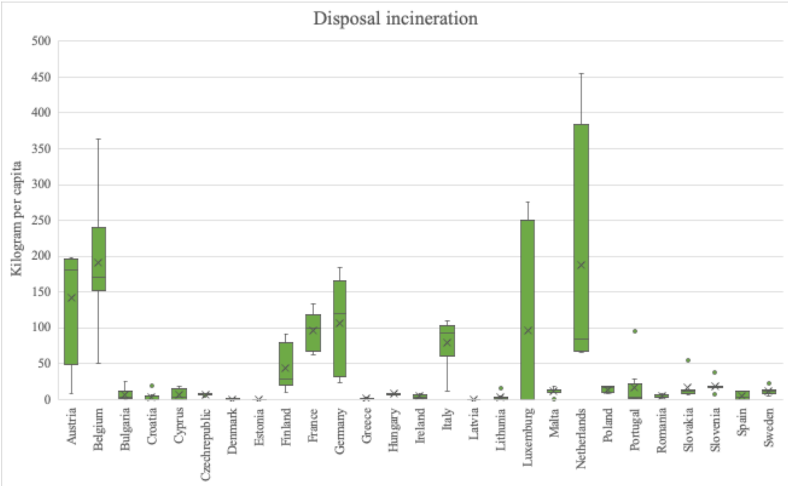

Figure 4: Disposal through incineration without energy recovery between 2006-2020

Source: Eurostat (2023a)

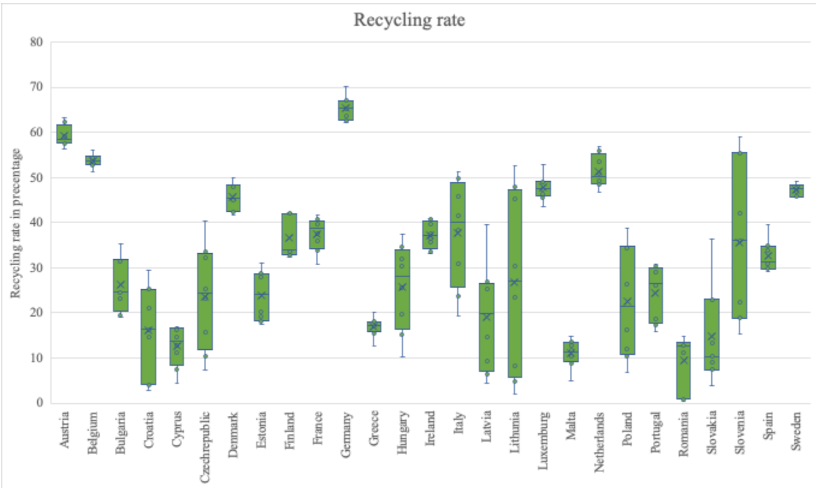

Figure 5: Recycling rate for municipal solid waste between 2006-2020
Source: Eurostat (2024b)

5. Econometric method

This chapter outlines the study's methodology and clarifies the three fixed effect regression models used to answer the research question. In addition, an in-depth explanation of the construction of the regression models and the reasoning behind the chosen methodological approach is provided.

5.1 Methodology

In order to estimate the relationship between the chosen dependent variables and the explanatory variables, fixed effects models were used. The independent variables were carefully chosen from the literature, in order to capture their effect on the outcome variables in an attempt to explain why they differ. Three different regressions will be conducted relating to the three chosen steps in the waste hierarchy model. Furthermore will the independent variables be added gradually to analyze if the results might change and to see when, or if, they lose significance. The order they are added is deliberate. For all regressions, policy variables will be added first since the Waste Framework Directives ambition is to affect waste generation through policy implementation. Following this will other variables of importance to the outcome variables be added. The grouping of variables added is based on how similar they are, making it easier to interpret their effect on each other and the outcome variable.

Our fixed effects models allow us to control for the effects of time- and unit invariant omitted variables. The fixed effect model estimates the causal effects from panel data, while adjusting for un-observed time and country specific confounders at the same time. It allows for an analysis that controls for differences across countries that are constant over time, and for differences that vary over time but are constant across countries. By using this method we can control for all variables while removing the variation between them. After removing this variation, it is only the variation within a country that consists. For instance, since we are aware that countries have historical differences that can affect their performance within the waste hierarchy we have through this fixed effect model controlled for these. This ensures that countries are instead compared to their own past performance. (Huntington-Klein, 2021).

As our thesis concerns three of the different levels in the waste hierarchy, we are interested in investigating if the different levels also affect each other. The level of disposal could, as an example, also be dependent on the levels of recycling and recovery (when recycling rate increases, the trend of disposal could possibly decrease). In our hypothesized relationship, we believe that disposal could possibly be affected by both recovery and recycling and recovery to only be affected by the level of recycling. As recycling is higher up on the waste hierarchy, we do not believe that the rate of recycling could be affected by the levels of recovery and disposal. These potential relationships are showcased in the regressions below.

5.2 Regressions

Listed below are the formulas for the different regressions that will be performed. .

Table 3: Specifications of the preformed regressions

$$recyclingrate\_municipal_{it} = \beta_0 + \beta_1 \cdot deposit\_refund_{it} + \beta_2 \cdot tax\_incineration_{it} + \beta_3 \cdot policy\_stringency_{it} + \beta_4 \cdot gov\_effectivenesss_{it} + \beta_5 \cdot ln\_gdp_{it} + \beta_6 \cdot gdp\_RD_{it} + \beta_7 \cdot disposal\_incineration_{it} + \beta_8 \cdot FE_{country, year} + u_{it} \quad (1)$$

$$energy\_recovery_{it} = \beta_0 + \beta_1 \cdot policystringency_{it} + \beta_2 \cdot gov\_effectivenesss_{it} + \beta_3 \cdot ln\_gdp_{it} + \beta_4 \cdot gdp\_RD_{it} + \beta_5 \cdot FE_{country, year} + u_{it} \quad (2)$$

$$disposal\_incineration_{it} = \beta_0 + \beta_1 \cdot tax\_incineration_{it} + \beta_2 \cdot tax\_landfill_{it} + \beta_3 \cdot policy\_stringency_{it} + \beta_4 \cdot gov\_effectiveness_{it} + \beta_5 \cdot ln\_gdp_{it} + \beta_6 \cdot gdp\_RD_{it} + \beta_7 \cdot ln\_populationdensity_{it} + \beta_8 \cdot ln\_arableland_{it} + \beta_9 \cdot FE_{country, year} + u_{it} \quad (3)$$

The coefficient β can be interpreted as the effect the independent variable has on the dependent, i.e., how much will y change when changed with one unit. When using logarithmic values in regressions the outcomes are to be interpreted in a percentage form. For instance, if ln_gdp increases by one percent it will increase/decrease y β_n units. Further, for the first (1) model the dependent variable is in the unit percentage points so in this case the change affecting the variables x and y will both be in a percentage form. We have also included an error term to capture the effects of all other unknown variables that can affect the regression.

The regressions were performed with the xtreg commando created for regressions with time-series dimensions. These types of regressions then also account for potential correlation and dependence between observation within the same group over time. (Torres-Reyna, 2007).

5.3 Methodological concerns

When creating the dataset and researching what explanatory variables are potentially affecting the dependent variables, concerns about correlation and confounding variables arise. The chosen explanatory variables are, as earlier mentioned, based on what related literature have observed about the subject. However, when checking for multicollinearity it can be observed that several variables are correlated. For example, GDP per capita and government effectiveness with a correlation of 75 percent and government effectiveness and R&D with a correlation of 78 percent (see Appendix B). The occurrence of multicollinearity in a regression model risks turning the explanatory variable estimates imprecise and vague, resulting in less reliable statistical inferences (Hayes, 2024). Similarly, we are aware of the risk of existing confounding variables that may affect the relationship between the independent and dependent variables. Consequently this helps us draw the conclusion that omitted variable bias exists within our model since there are other variables we don't account for that may have a larger impact, contributing to the results not being entirely accurate in reflecting the relationship between these variables. (Pourhoseingholi et al., 2012). When choosing what regression model to use it was also discussed if a non linear model would be a better fit. This since it was debated if some of our variables had diminishing returns, such as recycling rates, and a linear model would then not be representative over how countries have adapted the Waste Framework Directive. Ultimately it was decided not to perform this type of regression as we found a linear model still interesting to evaluate and more fitting to some of the explanatory variables. When choosing what regression model to use it was also discussed if a non linear model would be a better fit. This since it was debated if some of our variables had diminishing returns, such as recycling rates, and a linear model would then not be representative over how countries have adapted the Waste Framework Directive. Ultimately it was decided not to perform this type of regression as we found a linear model still interesting to evaluate and more fitting to some of the explanatory variables.

6. Results

This section will present both the descriptive and the regression results in order to answer our research questions. The descriptive results are presented first and then followed by the regression results.

6.1 Descriptive results

In order to answer research question one, "*How has the implementation of the EU Waste Framework Directive from 2008 developed in the EU countries between the years of 2008-2020?",* descriptive data has been composed to describe the development of each level before and after the implementation of the directive Since we are interested in measuring the effect of the directive, we have chosen to compass the data from 2020 to data from 2006 as it illustrates how waste management has changed during the entirety of the Waste Framework Directive so far.

Illustrated in Figure 6 below is the recycling rate for each country in 2006 and 2020. The year of 2006 represents how each country's recycling rates were before the implementation of the Waste Framework Directive and the year 2020 shows how the recycling rates are several years after the directive was enforced. The figure also presents the recycling goals for 2025, 2030 and 2035. In general, the trend is positive with the overall recycling rates through countries increasing. Missing values exist for Croatia in 2006. Several countries have greatly succeeded in increasing their recycling rates, such as Lithuania, Slovakia and Slovenia that increased their recycling rate by 40 percentage points. However, despite the trend being positive only four countries have reached the 2025 goal of having a recycling rate of at least 55 percent. These countries are Austria, Germany, Netherlands and Slovenia. Several countries that started up on a low level of recycling rates have only made small progresses and are therefore far away from reaching the goals, such as Romania and Cyprus. At the same time Sweden and Belgium decreased their recycling rates from 2006 to 2020, showcasing a different, negative trend.

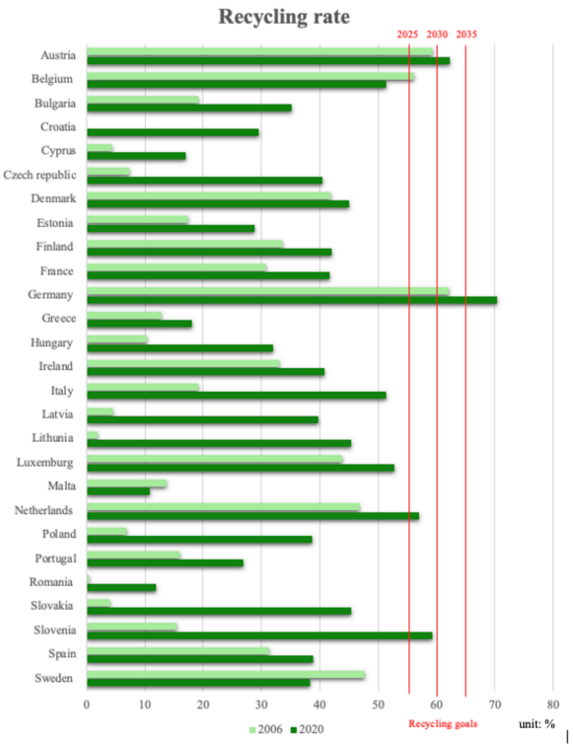

Figure 6: Recycling rates for municipal solid waste between 2006-2020
Source: Eurostat (2024b)

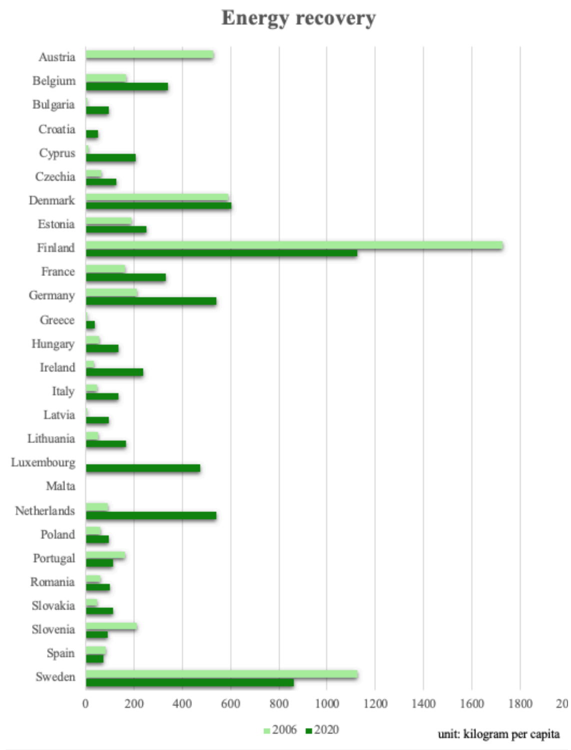

Figure 7: Energy recovery measured in kilogram per capita between 2006-2020
Source: Eurostat (2023a)

In Figure 7 energy recovery levels for each country in 2006 and 2020 is showcased. Overall, many European countries have low numbers of energy recovery both in 2006 and 2020, with some countries standing for the vast majority of the total energy recovery operations in the EU. In particular, Finland and Sweden recover double the amount than the majority of remaining countries in the EU. However, both Finland and Sweden have decreased their energy recovery since 2006. Looking at the rest of the countries, most of them have increased their energy recovery since then. The numbers are therefore getting closer to each other, and decreasing the variance between countries. Missing values exist in Malta 2006 and 2020, Bulgaria, Croatia and Austria in 2006. In Figure 8, the values for disposal through incineration is presented. The overall trend is decreasing, with numbers that vary a lot between countries. For instance, some countries started with very high levels of incineration and some with very low levels. Netherlands stands for the greatest decrease of disposal through incineration. In 2020, the numbers of disposal through incineration are low throughout Europe with lower variety than before in 2006.

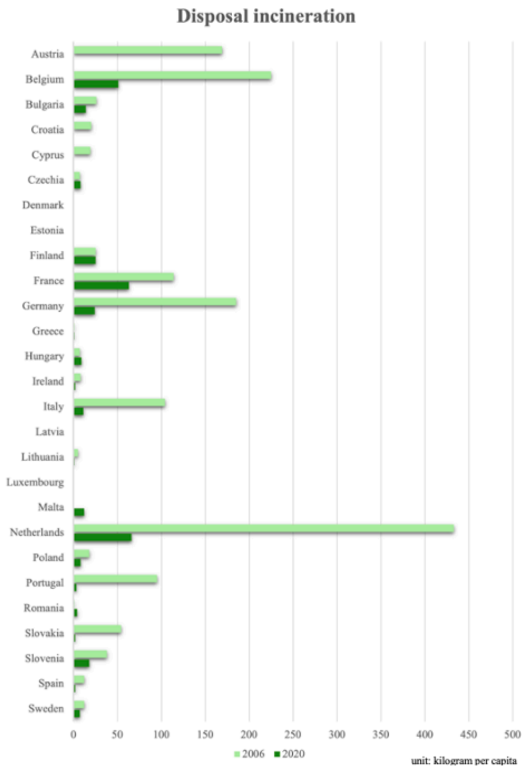

Figure 8: Disposal through incineration measured in kilograms per capita 2006-2020.
Source: Eurostat (2023a) & (2024c)

6.2 Regression results

This section presents the results from the three regressions ”*What may be statistically significant reasons as to why the compliance to the directive may differ across the EU countries?”*. To analyze the effect of the Waste Framework Directive, we are interested in first isolating the effect of policy variables on the outcome variables before including the other explanatory variables, as explained earlier in the method section. Through using this method it became easier to identify if and when different policies became more or less significant when combined with others. In addition, we analyze how the different levels of the hierarchy will potentially affect each other by using the dependent variables as independent when modeling regressions further down the waste hierarchy. Each regression has their own corresponding table, showing the process of adding the different, related variables. They will be presented in the order of the hierarchy, starting with recycling rate and then moving on to energy recovery and disposal through incineration. The regressions are run with a 95%-confidence interval, making our chosen level of significance 0.05.

6.2.1 Recycling rate

Table 4 shows the coefficient outputs of running the regression with the outcome variable recycling rate.

Table 4: Regressions on recycling rate of municipal solid waste

Dependent Variable: recyclingrate_ municipal	(1)	(2)	(3)
deposit_refund	12.47*** (2.79)	6.82 (4.15)	8.79** (4.18)
tax_incineration	0.09 (3.92)	0.55 (4.20)	0.57 (4.13)
policy_stringency		-0.55 (2.41)	0.43 (2.41)
gov_effectiveness		8.12 (5.46)	7.33 (5.40)
ln_gdp			20.35** (8.75)
gdp_RD			1.46 (2.77)
Constant	22.6*** (1.77)	21.70** (10.56)	-188.92** (91.12)
Fixed year effects	*YES*	*YES*	*YES*
Fixed country effects	*YES*	*YES*	*YES*
Observations	188	125	125
R-squared	0.19	0.43	0.53

$*p < 0.1$　　*$** p < 0.05$*　　*$***p < 0.01$*

As shown in Table 4, our result suggests a positive significant relationship between establishing a deposit refund system and recycling rates, proposing that the establishment of a deposit refund system increases the recycling rate by 8.79 percentage points. The finding suggests that policy instruments can be of importance for increasing recycling within the EU. All else equal, the variable showed significance from the beginning in the first **model** (1). However, the effect disappeared in the second model (2) when controlling for policy stringency and government effectiveness - the effect probably eaten up by the other variables. In model three (3) the positive significant correlation between the variables returned when controlling for other variables that have proved explanatory for the outcome variable, implying that a deposit refund system is of importance for recycling rates. Moreover, GDP per capita also showed a significant value in the last round. When increasing GDP per capita in a country with one percent the effect on recycling rates would be 0.2035 percentage points - proposing that countries with higher GDP have an easier time increasing recycling rates. From the results we can see that the establishment of a deposit refund system had a greater effect on recycling rates than GDP per capita. The regression obtained a R-squared of 0.5353, meaning that 53 percent of the variation in recycling rates in the EU can be explained by the model.

6.2.2 Energy recovery

Table 5 shows the coefficient outputs of running the regression with the outcome variable energy recovery.

Table 5: Regressions on energy recovery

Dependent Variable: energy_recovery	(1)	(2)	(3)	(4)
policy_stringency	-103.41** (49.25)	-85.57* (49.56)	-77.26 (50.07)	-59.76 (45.33)
gov_effectiveness		218.32* (117.02)	209.40* (117.16)	257.78** (106.62)
ln_gdp			203.11 (183.68)	382.25** (169.31)
gdp_RD				272.72*** (53.39)
recyclingrate_municipal				-2.38 (1.97)
Constant	599.03*** (49.25)	278.27 (222.15)	-1768.18 (1880.12)	-4095.964** (1745.84)
Fixed year effects	*YES*	*YES*	*YES*	*YES*
Fixed country effects	*YES*	*YES*	*YES*	*YES*
Observations	122	122	122	121
R-squared	0.16	0.40	0.43	0.59

$*p < 0.1$ $**p < 0.05$ $***p < 0.01$

When looking at Table 5 policy stringency showed a negative significant relationship with energy recovery in the first (1) and second model (2). This implies that higher levels of environmental policy stringency results in lower rates of energy recovery - going against earlier literature. However, when adding additional explanatory variables the significance of the relationship disappeared. Therefore, when controlling for other variables, no relationship could be found. Variables that showed significance in the final model were the other three explanatory variables. One percent increase in real GDP per capita will increase energy recovery with 3.82 kilograms per capita, meaning that 3.82 more kilos of waste will efficiently be recovered through incineration. In the final model (4) government effectiveness showed that when increasing government effectiveness with one unit, energy recovery will increase with 257.7 kilograms per capita. The final model also showed significance for R&D as energy recovery increases 272.72 kilogram per capita when investing one percent more of their GDP in R&D. Overall this suggests that, all else equal, high GDP, investment in R&D and an effective governance is of importance for higher amounts of energy recovery. In addition, the regression did not showcase any relationship between recycling rates and energy recovery - meaning that we can not conclude that the two levels in the waste hierarchy are affecting each other in any direction. The regression achieved a R-squared of 0.59 meaning that around 60 percent of the variation in the variable can be explained by the model.

6.2.3 Disposal through incineration

Table 6 shows the coefficient outputs of running the regression with the outcome variable disposal through incineration.

Table 6: Regressions on disposal incineration

Dependentvariable: disposal_incineration	(1)	(2)	(3)	(4)	(5)
tax_incineration	53.79 (33.36)	53.84 (33.58)	48.88 (32.64)	26.01 (27.00)	25.12 (27.75)
tax_landfill	12.77 (18.13)	12.63 (18.89)	17.51 (18.48)	-21.83 (15.18)	-20.99 (15.69)
policy_stringency		-2.64 (18.04)	-2.03 (17.69)	-0.97 (13.53)	-0.45 (13.94)
gov_effectiveness		1.23 (42.97)	-7.66 (41.80)	78.73*** (30.84)	83.06** (33.85)
ln_gdp			49.32 (64.17)	123.70** (57.98)	121.30* (61.85)
gdp_RD			-52.58** (20.66)	-12.46 (18.06)	-9.21 (20.38)
ln_ populationdensity				-75.71 (267.06)	-22.46 (307.40)
ln_arableland				-26.54 (22.20)	-27.24 (22.88)
recyclingrate_municipal					0.26 (0.74)
energy_recovery					-0.01 (0.03)
Constant	59.18 (50.50)	61.06 (83.14)	-341.69 (663.72)	-597.34 (1286.50)	-836.29 (1448.92)
Fixed year effects	*YES*	*YES*	*YES*	*YES*	*YES*
Fixed country effects	*YES*	*YES*	*YES*	*YES*	*YES*
Observations	122	185	135	69	69
R-squared	0.14	0.12	0.03	0.01	0.08

$*p < 0.1$ *$**p < 0.05$* *$***p < 0.01$*

As revealed in Table 5, no policy instrument showed a significant relationship with disposal through incineration in any of the rounds..When controlling for all variables, government effectiveness and GDP per capita showed a positive significant effect on disposal through incineration - implying that countries with higher GDP and more effective governments also tend to dispose more through incineration. Increasing GDP per capita with one percent would result in an increase in disposal through incineration with 1.21 kilograms per capita. The corresponding number for government effectiveness is an increase of 83 kilograms of capita in disposal through incineration, by each unit increase in the variable. However, the two variables have a high correlation of 0.77 (see Appendix B), implying a risk that the effect of the two variables are hard to interpret independently of each other. In addition, the regression did not showcase any relationship between disposal through incineration, energy recovery and recycling rates. We can therefore not conclude that the levels of the hierarchy are affecting each other in any direction. The regression obtained a R-squared of 0.08, meaning that around two percent of the variation in the variable can be explained by the model. The number is low, implying a bad fit of the model and that our chosen explanatory variables in fact does not explain why disposal through incineration differs around countries in the EU. This finding stands in contradiction to what was found in the literature.

7. Discussion

With connection to our first research question of how the implementation of the waste hierarchy has developed, we have found that recycling rates overall have increased in the EU - contributing to leaving the old linear model of produce-use-dispose behind which is the goal of The Circular Economy model. Figure 6 shows that the majority of recycling rates have increased between the years 2006-2020. The changes can be associated with both stronger policy instruments that producers have to follow, as indicated by the regression concerning recycling where the deposit refund scheme and GDP are significant variables. That recycling rates have increased is a sign of the polluter pays principle having an effect. The policy instrument has influenced the Waste Hierarchy in the levels of prevention and preparing for re-use, contributing to changes made in packaging and production so products are more recyclable. With more sustainable materials being used in production recycling rates are likely to increase. However, to raise recycling rate it is also necessary with strong institutions and policy stringency that simplify the process, implement long-lasting policies and can manage all the waste. Why the data differentiates so much between countries could be attributed to differentiating history, giving countries different political landscapes to enforce policies in. Likewise, different policy instruments can be more or less effective in different countries for the same reason. Included in our study was only two specific ones and a variable for policy stringency. The results of the regressions and the significance of the variables could've been different if other policy instruments were chosen to measure since Member States adhere to the polluter pays policy using different sub-instrument they themselves choose. It is therefore also possible that the variable policy stringency was not significant in the final model concerning recycling rates because the variable did not account for policies sufficiently connected to waste management.

In addition, we have found through our descriptive result that energy recovery has increased in most European countries during the years of 2006-2020. The result for increased energy recovery can be interpreted both as positive and negative. While the results are "good" in the way that efficient waste incineration has increased, the descriptive data does not tell us if it is because of increased waste generation or not. When analyzing Figure 6, we can see that energy recovery has decreased for some countries between 2006-2020. One of these countries is Finland, which can be classified as being wealthy within the EU. While this development sounds counterproductive, it can presumably be attributed to more recyclable materials being used in production, decreasing the demand for waste being incinerated - Finland has increased their recycling rates by around nine percentage points between 2006-2020. At the same time Sweden decreased both their energy recovery and recycling rate between the same time period, questioning if the reasoning holds in all cases.

In connection to our second research question of which factors are statistically significant reasons as to why the performances within each level of the hierarchy differ, our regression tells us that higher performances in energy recovery are connected to government effectiveness, investment in R&D as well as GDP per capita. Investment in R&D shows a higher effect than government effectiveness, with a difference of around twenty kilograms per capita for each unit increase in the variables - highlighting the importance of investing GDP in research and development for the countries seeking to improve their energy recovery. Even though government effectiveness did not show the same magnitude as investment in R&D, its effect is still worth interpreting. Since government effectiveness has been used to measure institutional quality and trust in institutions (Pronti and Zoboli, 2024), there is a possibility to highlight the importance of having a strong government and having trust in the same institutions when aiming to increase energy recovery. Worth mentioning when interpreting the result is that government effectiveness and GDP per capita has a high correlation of 0.78 (see Appendix B)- creating a risk that the two variables are hard to interpret independently of each other.

Disposal through incineration has, at the same time, decreased as seen in Figure **XX**. A decreased amount of disposal through incineration is always positive since it is the least desirable method - both according to the circular economy model and to the Waste Framework Directive. The regression findings for disposal was that it increased when government effectiveness and GDP increased. When comparing this to the descriptive results it was also seen that countries such as the Netherlands, France and Belgium did the most of this type of disposal, which is logical when considering that they have higher GDP per capita and therefore generate more waste. This is aligned with the findings of Clapp (2002), which highlighted the relationship between GDP and waste generation. The regression on disposal through incineration stands out due to its low R-squared number of eight percent and the large amount of insignificant variables, resulting in a weak result. This suggests that the model has failed in capturing the real causes as to why disposal through incineration differs around the EU countries. As described in the paragraph above, this failure may be due to a smaller sample size, the missing of explanatory variables and that the explanatory variables chosen could be misdirected. Since the explanatory variables were chosen from earlier research, the finding raises questions on what might be *affecting the heterogeneity* in the variable and what kind of method is needed to find the answers. We acknowledge the need for further research on the matter, and in particular encourage the use of other and perhaps new to the subject variables that have not yet been researched before.

In all regression models we also found, in many cases several, insignificant results. Many of the explanatory variables that have been found important and of significance in the literature, did not deliver the same results in our models. Why this occurred can be due to several reasons. Firstly, it can be due to the absence of unknown important variables, or the absence of variables that we found important but failed to add due to the lack of data (Mullet, 2018). In turn, this may have resulted in the range of independent variables being too small or misdirected which can have caused a failure to capture the full picture of why the waste hierarchy implementation differs among countries (Mullet, 2018). Further on, the insignificance of two of our binary variables (tax on incineration and tax on landfill) may be due to the constancy of these variables over time - resulting in the fixed effects model eating up the effects of these variables. The results from these taxes could have been easier to interpret if we instead chose to tabulate this variable after more country specific tax rates. However, this information was not easily attainable when searching for values over all countries and years. Another factor affecting our results can be the small sample size. A smaller sample size will narrow the distribution of values, decreasing the precision of the estimates. Compared to a larger sample size where a small deviation can prove to be statistically significant, a small sample does not capture this effect. (Cornish, 2006). Consequently, it is also worth mentioning that when finding variables with missing values it also affected the sample in a way that affected the significance of the results. Although, because of this we can also conclude that the significant values captured are truly significant.

Moreover, our findings display that some countries that score high on the indicators that, according to the findings of our regressions, are connected with higher recycling rates (such as high GDP and having a deposit refund system) have decreased their performances. Sweden, as an example, has decreased the recycling rate **(Figure 5)** since the beginning of the implementation. Another country that scored higher in recycling rates in 2006 than in 2020 is Belgium. The fact that some countries that are scoring high on the factors corresponding to an improvement in recycling rates are worsening their performances and therefore are slowing down the transition to a circular economy, may lead to a questioning if the relationship holds in all cases. At the same time, some countries that performed high on recycling rates already in 2006 have had a hard time increasing their recycling rates with high numbers. One example is Austria that has increased their recycling rates with around three percentage points, in comparison with Latvia that increased their rates with 35 percentage points (starting up on a recycling rate of 4.5 percent). What might be causing this is the diminishing returns, as we mentioned in methodological concerns. The effect of efficient waste management operations will decrease as they evolve. Albeit, Austria is one of the few countries that has reached the recycling goals for 2025 and 2030. Comparing the increase in percentage points to other countries their increase has been relatively small, giving some strength to the argument that waste management operations become relatively "less" efficient once they reach a certain level of efficiency.

Evidence of the Environmental Kuznets Curve can be found through all of the regressions. In the final model of all regressions GDP per capita was included and showed significance. This indicates that countries with higher GDP per capita both have more efficient waste management's operating for recycling and energy recovery and that they often also dispose of more waste. Countries with higher GDP have often evolved to a level where they now can acknowledge the negative externalities from their production and create methods to manage or prevent waste. Consequently, a higher GDP often results in more investments in R&D which then also improves waste management standards- explaining why the variable measuring R&D was significant when modeling for energy recovery. This echoes the findings presented by Yasmeen et al. (2023), that investing in waste management technologies such as recycling facilities and waste-to-energy systems will make countries more environmentally sustainable, operationally efficient and economically feasible. Although, when using the environmental Kuznets Curve to explain the standings of EU countries, it is important to recognize that most countries are over the “hump” and are now working on improving their operations. When comparing the operations in the countries that are performing badly in the different levels of the hierarchy it is likely due to historical differences that have contributed to variance in GDP levels that still shows its effect today.

7.1 Further research

The research conducted in this paper gives a good overall view of the different aspects connected to waste management within the EU. Further could our results be strengthened by similar research with larger sample sizes and less correlated variables. This could contribute to more significant variables that would align with the findings of the reviewed literature. Moreover, we failed to find any significant relationship in our study that tells us about the connection between the three different levels of the hierarchy. However, the knowledge of how the different levels of the hierarchy affects each other could be of importance for future policy implementations, and we therefore encourage others to investigate the matter further.

There is room for further research concerning what country specific factors exist that affect how countries pertain to the Waste Hierarchy. One way to deepen this analysis would then also be to collect more data on different policy instruments and compare their effect in different countries or by using more precise tax rates for the taxes on waste that could’ve been analyzed further. Likewise would the thesis benefit from including the behavioral factors that affect pro-environmental behavior through a cross country study. In our preparatory research we found studies studying similar questions but not one in a large scale format. This data could be found by either surveys or carrying through experiments. Each method could be useful depending on how you specify the research question. Ultimately, future research on what cross-country policies have been the most effective ones would contribute to a deeper analysis on how waste generation and treatment will evolve.

8. Conclusion

This thesis examines the EU waste framework directive from 2008, with a focus on three levels of the associated waste hierarchy; recycling, recovery and disposal. It aims to investigate the development of these three indicators across countries and what factors exist that affect parts of it. The method to answer the research questions has been to compile and analyze descriptive data, as well as to perform three fixed effect regression models. In order to further analyze the results of the thesis, the Environmental Kuznets Curve, The Circular Economy and the Polluter Pays Principle have been used.

In connection to our first research question as to how the three levels on the waste hierarchy have developed, the results of this study shows that recycling rates and energy recovery have increased in most cases while disposal through incineration has seen a general decrease. However in all levels heterogeneity exists both between and within countries. As an example, despite a general increase in recycling rates most countries had not yet by 2020 increased the recycling rate to the desired level of 55 percent for 2025 for 2025. This showcases that more work needs to be done in order to reach the recycling and packaging goals set by 2025, 2030 and 2035.

Further on, in our study we were able to find statistically significant results that there is a positive correlation between increasing recycling rates and establishing a deposit refund system - implying that policy instruments can be of importance for further development in this sector. We could also see that countries with GDP per capita performed better in this sector. For the countries that saw an increase in energy recovery, government effectiveness, investment on research and development and GDP per capita are important factors based on our result. For the last step on the waste hierarchy, waste disposal, we were not able to find any statistically significant or reliable results except for GDP per capita and government effectiveness that explains the countries' different performances in disposal through incineration. The inconsistency of this result does not match our findings in the literature.

While more measures are being taken to create a more sustainable world, better waste management is still needed. By conducting this study we have concluded that countries have different conditions that affect their performance in this subject. In the future the implementation of environmental policies must continue, but with that comes the challenge to create stringency and keep the development sustainable. While the Waste Framework Directive has had its desired effect in increasing recycling rates, countries are still not meeting the goals set up by the directive. Our hope is that this study can prove useful in future research concerning the subject.

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Appendices

Appendix A

List of member nations in the European Union

Austria	France	Malta
Belgium	Germany	Netherlands
Bulgaria	Greece	Poland
Croatia	Hungary	Portugal
Cyprus	Ireland	Romania
Czech Republic	Italy	Slovakia
Denmark	Latvia	Slovenia
Estonia	Lithuania	Spain
Finland	Luxemburg	Sweden

Appendix B

Table 7: Correlation between variables for recycling rate

	Recycling rate municipal waste	Deposit refund scheme	Tax disposal through incineration	Policy stringency	Government effectiveness	Real GDP	GDP on R&D
Recycling rate municipal waste	1						
Deposit refund scheme	0.48	1					
Tax disposal through incineration	0.33	0.09	1				
Policy stringency	0.34	0.44	0.30	1			
Government effectiveness	0.56	0.65	0.27	0.35	1		
Real GDP	0.67	0.54	0.44	0.42	0.78	1	
GDP on R&D	0.68	0.63	0.30	0.51	0.79	0.69	1

Table 8: Correlation between variables for energy recovery

	Energy recovery	Environmental policy stringency	Real GDP	GDP on R&D	Government effectiveness	Recycling rate
Energy recovery	1					
Environmental policy stringency	0.42	1				
Real GDP	0.55	0.43	1			
GDP on R&D	0.78	0.53	0.68	1		
Government effectiveness	0.74	0.35	0.78	0.79	1	
Recycling rate	0.36	0.35	0.67	0.66	0.56	1

Table 9: Correlation between variables for disposal through incineration

	Disposal incineration	Tax on incineration	Tax on landfill	Policy stringency	Government effectiveness	Real GDP	GDP on R&D	Population density	Arable land	Recycling rate	Energy recovery
Disposal incineration	1										
Tax on incineration	0.22	1									
Tax on landfill	-0.63	0.02	1								
Policy stringency	0.27	0.32	-0.10	1							
Government effectiveness	0.30	0.23	-0.29	0.34	1						
Real GDP	0.33	0.40	-0.26	0.46	0.80	1					
GDP on R&D	0.29	0.27	-0.23	0.53	0.77	0.68	1				
Population density	0.42	0.14	-0.40	-0.13	-0.15	-0.05	-0.16	1			
Arable land	-0.1	0.13	-0.04	0.04	-0.47	-0.33	-0.35	0.03	1		
Recycling rate	0.44	0.23	-0.42	0.31	0.53	0.63	0.65	0.32	-0.15	1	
Energy recovery	0.25	0.11	-0.10	0.48	0.78	0.61	0.77	-0.36	0.32	0.40	1

Appendix C

Figure 9: Energy recovery per kilogram per capita (excluding Finland) between 2006-2020
Source: Eurostat (2023a)