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Assessing the impact of policy instruments on food waste reduction in the EU

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Abstract

The issue of food waste and loss is becoming a critical issue all around the globe, resulting in an unsustainable food system. Therefore, food waste reduction is essential to provide food security and combat environmental impacts that deprive agricultural production in the upcoming decades. The UN's Sustainable Development Goals need to be reached by 2030, especially the goals 2 (end hunger) and 12 (ensure sustainable consumption and production patterns) as well as the targets set by the EU. Thus, this research aims to assess the impact of three policy instruments: the incineration tax, the landfill tax and the pay-as-you-throw approach to seek out the most efficient one among these three as well as find loopholes to successfully find a strategy that reaches sustainable development and satisfy the demand of the growing population without depriving the needs of future generations. Identifying the efficiency of the three market-based instruments will contribute to fulfil the EU requirements and targets. A conceptual framework was chosen to explain the relationships between the different factors that have an influence on the policy instruments and thus on the dependent variable "Food waste". The empirical method was a multiple regression model, giving the opportunity to show the significance of several regressors. In the findings, the level of income among the EU member countries was proved to have an insignificant effect on the amount of food waste. Additionally, the findings for the policy instruments showed that the incineration tax and the landfill tax are slightly increasing the quantity of food waste, while the findings for the pay-as-you-throw approach are revealing both and increasing as well as a decreasing effect on the amount of food waste among countries in the EU. The results for the control variables vary depending on the policy and country but the variable "Waste management" has proven to have a significant influence on the reduction of food waste in the EU. There is great need for an improve of data, unified definitions as well as collaboration among stakeholder on national and international level to build up a sustainable food system that is able to cope with the environmental, social and economic challenges.

Keywords: Food waste, Surplus food, Policy instruments, Food value chain, Sustainable Development, Waste management, Waste disposal

Table of contents

List of tables

List of figures

Abbreviations

BMW	Biogradable municipal waste
CPI	Consumer Price Index
ECB	European Central Bank
FAO	Food and Agriculture Organization
FW	Animal and Food Waste; vegetable waste
GHG	Greenhouse Gas Emissions
NGO	Non-government/Non-profit organization
OECD	Organisation for Economic Co-operation and Development
PAYT	Pay-as-you-throw approach
PD	Population density
WM	Waste management

1 Introduction

In the following chapter, an introduction of the topic food waste and its challenges will be given. Additionally the objectives, the research questions and aim as well as the relevance of this thesis will be stated.

The current global food system is unsustainable. Food is unequally distributed around the world, leading to the triple burden of malnutrition: hunger, micro-nutrient deficiencies and obesity as well as non-communicable diseases (Devin & Richards, 2018; FAO et al., 2015). There are imbalances and ethical inequalities in regards to the levels of income within societies (FAO et al., 2015). The current population is rising and will become more urbanized and wealthier. Around 736 million people accounting for ten per cent of the global population are suffering from extreme poverty and 821 million people from hunger (Abu Hatab et al., 2019). Moreover, the food system is responsible for several environmental, economic and social issues like water scarcity and pollution as well as greenhouse gas (GHG) emissions, soil degradations and loss of biodiversity (Thyberg & Tonjes, 2016, p. 111; Garrone et al., 2014; Schanes et al., 2018; Finnveden et al., 2013). Therefore the current food system is characterised by a low resistance to natural and socioeconomic stressor (Abu Hatab et al., 2019).

By 2050, the global population will increase up to nine billion people, eight billion of them in developing countries, where the most poor and insecure people are living. Creating a more sustainable food system would not only feed the growing population more sustainably and fairly but requires to solve the challenges that currently challenge the food system. This will lead to an increased amount of people living in cities, resulting in an urban transformation with two-thirds of the population living in urban areas. Thus, it will not only cause several social challenges but foremost lifestyle changes as well as increased incomes, leading to a rising demand of energy-intensive foods like meat and dairy products. A transformation of the food system is needed. This has lead to a transformation of the agricultural sector implementing intensification and monocultures to satisfy the demand of the growing population. The current agricultural system and food system is characterised by intensification and monocultures to satisfy the demand causing a harmful impact on the environment, the health of humans, plants and animals (Gjerris & Gaiani, 2013, p. 16). The natural resources are getting deprived and are shrinking at an alarming rate, which is causing scarcity, degradation, desertification, and deforestation. As a result of these environmental consequences, climate change will make it more difficult for the food system to produce food in many regions of the world (Abu Hatab et al., 2019). Therefore, the viable environmental, social, economic consequences will make it more difficult to provide food security and creating a food system that is environmentally sustainable and resilient (Garnett, 2013).

Due to the increase of challenges, creating a more sustainable and resilient agricultural systems has gained an increasing attention in regard to policy and agricultural research to find solutions to the environmental changes as well as reach food security among the whole globe and meet the demand of the growing population. Therefore, the UN’s Sustainable Development Goal 2 (end hunger, achieve food security and improve nutrition, and promote sustainable agriculture) will be dependent on the countries’ ability to create a sustainable food system that can both cope with the challenges and satisfy the demand in a sustainable and resilient matter. The issues of food loss and waste in the context of transforming the food system have gained a higher interest in the recent years. Taking a look at the definition of food loss and waste, it can be referred to the edible parts of plants and animals that are produced for consumption but are not consumed by people in the end. According to Parfitt et al. (2010), food loss accounts for the food that is lost in the process along the food chain and does not reach the final consumer. On the other hand, food waste occurs at the retail and consumption stage and refers to "food appropriate for human consumption being discarded or left to spoil at consumer level, regardless of the cause" (HLPE, 2014, p. 11).

Taking a look at a definition of food waste, there is no uniform definition on which scholars agree on. The most widely used definition by the Food and Agriculture Organization (FAO) describes food waste as “the removal of food from the supply chain which is fit for consumption, or which has spoiled or expired, mainly caused by economic behaviour, poor stock management or neglect” (FAO, 2014, p. 4) and happens at the end of the value chain (Teller et al., 2018). The definition distinguishes between avoidable and unavoidable food waste and shows that food waste is occurring at the end of the food system in developed countries. Besides this definition, the FAO and the Organisation for Economic Co-operation and Development (OECD) presented a working definition regarding waste reduction that includes “preventing and/or reducing the generation of waste, improving the quality of waste generated, including reduction of hazard, and encouraging re-use, recycling and recovery” (Kim, 2002, p. 12).

There are no accurate estimates of food losses and waste available. Evidence indicates that around one-third of the food produced globally is lost or wasted along the food chain, from production to consumption (Kummu et al., 2012). This not only leads to an amount of 25 to 50 per cent of food that is wasted along the food chain but also pushing the responsibility on retailers and consumers which are accountable for it (Mackie, 2014, p. 4; Lundqvist et al., 2008; Parfitt et al., 2010). Moreover, the FAO states that ”if FLW was a country, it would be the world's third largest emitter of GHGs" (FAO, 2015, p. 1). That means, that food losses and waste are closely connected to the sustainability of the food system from two different perspectives, first from a food security perspective and second from an environmental perspective. Creating a sustainable food system will thus be an effective tool to provide food security and lower GHG emission, which results in a reduced environmental footprint of the food system (Abu Hatab et al., 2019). In order to achieve the SDGs, food loss and waste need to be reduced by half at the retail and consumer level by 2030, which SDG 12 "Ensure sustainable consumption and production patterns" stands for (UN, 2019). This becomes very significant to address since in developed countries like in Europe or North America, food waste reaches the quantity of 280-300 kg per capita and has a value of around 165,5 billion dollars per year in the USA (Garrone et al., 2014; Gjerris & Gaiani, 2013). Accordingly to Kusch & Evoh (2013) food losses and wastes have a global quantity estimation of 1.3 billion tons per year. In environmental terms, food waste worldwide is accountable for 3.49 Gt CO2-eq (FAO, 2014). It is seen as an "integral part of western consumer societies" (Gjerris & Gaiani, 2013, p. 16), especially by households which make reduction as the best strategy to minimize waste (Parfitt et al., 2010; Kusch & Evoh, 2013). The issue of food losses and waste aroused first in the 1940s when the FAO was founded (Kusch & Evoh, 2013).

Like in other developed regions, most food waste occurs at the retailer and consumer stages of the food chain. Several policies have been implemented by the EU and its member states to reduce food waste. In 1999, the EU started with the EU Landfill Directive as a "turning point" to deal with waste (Bulkeley & Gregson, 2009, p. 932). It had the purpose to cut the methane emissions by half and reduce the quantity of municipal waste going to landfill (Secondi et al., 2015). But even before, in the year 1975, a European directive has introduced the three R's (reduce, recycle, recover) and put them into law (EC, 1975). One of those is called "The Waste Hierarchy" which is seen as an efficient approach showing how surplus food can be redistributed (ibid.). Since then, the EU updates their Framework over the years to add more sustainability and adapt the framework to its targets. Therefore, in 2008 the EU Waste Framework was revised to focus more on waste, recycling and recovery (Secondi et al., 2015). Recently, the EU released the waste hierarchy prioritising reduce, reuse and recycle before landfilling or incineration of waste. Setting targets towards circular economy and the promotion of more sustainable waste treatments (Marques et al., 2018). The goal is to achieve 50 per cent recycling of municipal waste until 2020, which was updated in 2014 up to 70 per cent until 2030, giving the member states more times to realize that target (Secondi et al., 2015). This was set along with the goal to eliminate landfilling virtually, implement waste management plans by 2025 and "meet an aspirational objective to reduce food waste by 30 per cent" (Finnveden et al., 2013; Milliute-Plepiene & Plepys, 2015, p. 182; Secondi et al., 2015). This is very crucial, since 40 per cent of food is wasted in households and other studies found out, that 10-30 per cent of food is wasted by consumers (Monier et al., 2010; Gjerres & Gaiani, 2013; Quested et al., 2013; Buzby & Hyman, 2012). To address this issue, EU countries have implemented a number of policies including initiatives and campaigns realized by Non-governmental organizations (NGO's) or authorities to reduce food waste in the EU for example the Waste and

Resource Action Programme (WRAP) in the UK, ”Love Food, Hate Waste” campaign and the Swedish research program ”Towards a sustainable waste management” (TOSUWAMA) as well as EU-Fusions Food Use for Social Innovation by Optimising Waste Prevention Strategies (Secondi et al., 2015). Next to campaigns in several EU countries like ”Too good to go”, incentives and penalties like the landfill tax are expanding to decrease food waste and promote solutions for energy recovery (Sahlin 2007; Cossu & Masi, 2013). Therefore, countries have focussed not only on soft policy instruments but also on market-based and control policy instruments like the incineration tax, landfill tax and the Pay-as-you-throw (PAYT) approach.

There is a lack of studies that assess the impact of policy instruments on macro level or national level as well as “the business or management side of food waste initiatives” that makes it ”unclear which factors influence the success” (Aschemann-Witzel et al., 2017, p. 34). Taking a look at the published literature, there are some studies concerning policy instruments of food waste but mainly and foremost they are country specific seldom comparing the impact of policy instruments with each other (Finnveden et al., 2013; Cossu & Masi, 2013; Bulkeley & Gregson, 2009). Another characteristic of this literature it that it focuses on food waste at the household level, identifying drivers for changing consumer level (Andersson & Stage, 2018; Johnsone & Labonne, 2004; Thyberg & Tonjes, 2016). This is also significant to reduce food waste but hard to compare among countries like EU members. Only a few studies seek to analyse the impact of policies on food waste on national or international level (Bräutigam et al., 2014; Priefer et al., 2016; Watkins et al., 2012). This is mainly due to the fact that the data is insufficient and countries of the EU are still struggling to find a uniform definitions for food loss or waste. Therefore, more studies are needed that analyse the efficiency of policy instruments to seek out not only the most efficient one but also the most sustainable as well as the most applicable among the member countries of the EU.

Against this background, the aim of this thesis is to assess the impact of market-based instruments implemented by the EU to on food waste reduction. The specific objective of this thesis is twofold: i) to assess the impact of policy instruments on food waste reduction in the EU, and ii) to investigate heterogeneities of the effect of these policy instruments within individual EU countries. The empirical analysis will focus on three policy instruments, namely: the incineration tax, the landfill tax and the PAYT approach. Specifically, the study will address the following two research questions:

- What is the impact of policy instruments like the incineration and landfill tax as well as the PAYT fee on the reduction of food waste in the EU?
- How and why does the impact of the policy instruments differ across the investigated countries?

A distinction has to be made between market-based instruments, command and control instruments and soft instruments as for example campaigns, education and information (EEA, 2016). Due to a limited scope, this thesis will focus on market-based instruments due to a limited scope but it should be noted that the impacts of all policy instruments are interlinked and need to complement each other for a successful achievement of food waste reduction, changing food waste behaviour and rising awareness. Especially, developed countries have to change their behaviour regarding waste, needing to try to apply the waste pyramid more efficiently (EC, 2019). Additionally, the governments are the strongest force and need to take responsibility to enforce power to combat food waste and change consumer behaviour in form of regulations at the consumer and retailer stage of the food chain. Thus, the prerequisites are diverse across the EU member countries. Some countries might have better infrastructures or invest more capital in waste management than others to reach their national goals. The analysis of the research questions will be underlined by data including variables of all three pillars of sustainable development that are essential for the achievement of the SDGs until 2030. With the findings of the thesis, the most effective policy instruments will be sorted out to improve and to further applicate as well as the differences across the policy instruments and countries. The thesis seeks to contribute to a solution regarding food security to combat against the unethical aspect of food waste. Additionally, the thesis will give evidence about different factors that influence the amount of waste in the countries of the EU. Hence, it can give ideas of how to prevent food waste or make waste management more efficient. This will be significant when implementing a policy for disposal that complement the waste hierarchy. It is not only on the governments to implement policy instruments but, it is also the responsibility of the population. They need to change their behaviour since waste performance in developed countries is highly dependent on consumers and their knowledge in order to build up a sustainable food system for future generations. That means that consumers and retailers have to get involved and carry out and adapt the policy instruments implemented by the governments. Hence, the findings will not only give evidence about the most efficient policy but also contribute to find a solution to decrease the environmental, economic and social impacts food waste has. Lastly, it should be kept in mind that food waste is a small part of the total waste collected but the conclusions of the thesis might also be valid for the waste management of other parts of waste since incineration and landfilling are also common waste disposal solutions for other waste. Consequently could the conclusions of this thesis not only contribute to waste management in the food sector but also to the total waste management as well as to the achieving of the SDGs of the UN but more prior the targets set by the EU, while meeting the demand without depriving the demand of future generations (UN, 2019).

2 Overview of EU policies for food waste reduction

This chapter will give an overview of the EU policies to reduce food waste along with a separate introduction of the three different policy instruments, the incineration, landfill tax and the pay-as-you-throw approach.

2.1 Trends in EU policies for food waste reduction

Over the past few decades, the EU and European Commission have changed and updated several times their strategy for food waste reduction, as presented in Figure 1. The management of food waste requires the involvement of different policy areas to sufficiently reduce food waste and its environmental consequences. That means, that policy areas like “sustainable resource management, climate change, energy, biodiversity, habitat protection, agriculture and soil protection” have to go hand in hand to combat food waste since they are interlinked with each other (Monier et al., 2010, p. 26). In order to include all these policy areas, the European Commission has declared different Waste Directives, like the EU Landfill Directive, the Waste Framework Directive or, recently, the Circular Economy Package.

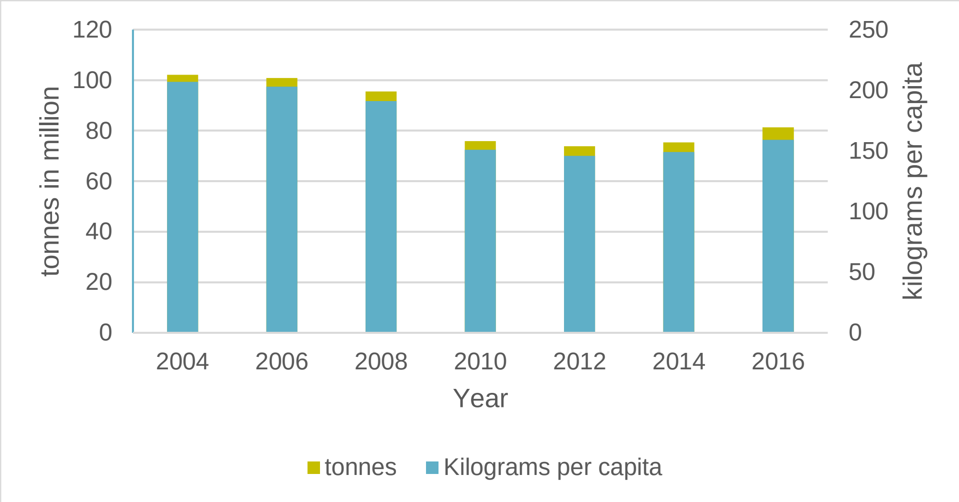

Figure 1. Animal and Food waste; vegetable waste of the EU28 (2004-2016). (Source: EUROSTAT, 2020)

In 1999, the adoption of the Landfill Directive by the EU was a turning point in dealing with waste in member countries (Bulkeley & Gregson, 2009). The purpose of the directive was to cut the methane emissions by half and reduce the quantity of municipal waste going to landfill (Secondi et al., 2015). Thus, the Landfill Directive aimed to minimize the amount of biodegradable municipal waste (BMW) that will be disposed on landfill (Monier et al., 2010). The Landfill Directive not only set targets about the amount of tonnes that are allowed to be landfilled by 2006, 2009 and 2016, but also that biodegradable waste has to be reduced by 65 per cent in 2016 in comparison to levels in 1995. Additionally, 75 per cent of the quantity of BMW produced in 1995 was allowed to go to landfill in 2006, 50 per cent in 2009 and 35 percent in 2016. There are no specific regulations on how countries should dispose the waste, which is the reason why most countries favour incineration (ibid.). In 2014, the European Commission revised the targets of the Landfill Directive and set a new goal until 2025. Thus, the European Commission aims to “phase out land-filling by 2025 for recyclable waste [...] in non-hazardous waste landfills, corre-sponding to a maximum landfilling rate of 25 per cent (EC, 2019).

In April 2006, the European Parliament agreed on the Directive 2006/12/EC with the aim to protect not only humans but also the environment against environmental negative externalities that are caused by the value chain including the disposal of waste (Monier et al., 2010). After the publication of the Directive 2006/12/EC, the Directive got revised on June 17th 2008. The new Waste Framework Directive 2008/98/EC aimed at simplifying and developing unified definitions as well as push waste prevention and its measures more forward. Therefore, the new Directive sought to replace three already existing directives: the Directive 2006/12/EC, the Hazardous Waste Directive as well as the Waste Oils Directive. Additionally, new and revised targets were formulated like new recycling targets that need to be achieved by 2020, pushing waste prevention more forward with the help of national waste plans and "[...] a commitment from the EC to report on prevention and set waste prevention objectives" (ibid., p. 27). A waste hierarchy is also included in the new targets of the Waste Directive 2008/98/EC, having the focus on prevention as the highest goal, then reuse, recycling, recovery and lastly disposal of waste. To gain more clarity, the European Commission aims at achieving unified definitions of recycling, recovery etc. as well as separate waste and by-products for more transparency and defining an "end-of waste criteria" (EC, 2019). To achieve these targets, a clear strategy is needed. Thus, Article 22 gives evidence on how to prevent and recycle waste like "a) the separate collection of bio-waste with a view to the composting and digestion of bio-waste b) the treatment of bio-waste in a way that fulfils a high level of environmental protection and c) the use of environmentally safe materials produced from bio-waste" (Secondi et al., 2015, p. 27).

In recent years, the European Commission published an ambitious Circular Economy Package that revised not only the Landfill Directive but also the Waste Directive Framework, to integrate more sustainability into waste management (EC, 2019; Secondi et al., 2015). To achieve prevention or in general better waste management, a few key elements have been revised and included into the new Circular Economy Package. One target will be to have a recycling rate of municipal waste of 65 per cent by 2030 as well as 75 per cent for packaging waste by 2030. Additionally, landfilling of municipal waste should have a maximum of ten per cent by 2030 and a total "ban of landfilling separately collected waste" (EC, 2019). Additionally, economic incentives that discourage landfilling should be pushed forward and as in the Waste Framework Directive 2008/98/EC, definitions are aimed to be improved and simplified to make a unification of calculation methods of recycling in the EU possible and more transparent. The European Commission promotes concrete measures to push forward re-use as well as "stimulate industrial symbiosis – turning one industry's by-product into another industry's raw material" (ibid.). Lastly, one of the revised key elements for prevention and better waste management is to integrated economic incentives targeting producers to provide the demand with greener products and encourage recovery and recycling schemes as for "packaging, batteries, electric and electronic equipment, vehicles" (ibid.). The targets that are set will try to meet the "increasing challenges through circular economy to promote recycling and sustainable waste treatment with energy recover" (Marques et al., 2018, p. 293).

Along with the Directive, the European Commission set a "thematic strategy on the prevention and recycling of waste" (Monier et al., 2010, p. 27) in 2005, that has the aim to minimize the negative environmental externalities of every step of a product's or resource's lifecycle (Secondi et al., 2015). It focusses on using other more environmentally friendly ways to manage waste, particularly biodegradable waste. The Directive 1999/31/EC says that two-thirds have to be redirected for disposal instead of going to landfill. Additionally, the EU published the green paper to deal with bio-waste in the EU. It aims to find options to manage bio-waste and promote the development of future waste management as well as to review the present situation. In 2010, the EU released a "communication on bio-waste management in the EU" (EC, 2019). This entails along with recommendations for managing bio-waste also the promotion of separate collection of waste. Also, a few key points are included in the EU future plan like the "encouragement of prevention of bio-waste, treatment of bio-waste according to the waste hierarchy, protection of EU soils via a focus on compost and digestive, investment in research, [and] innovation and efforts to reinforce the full implementation of the existing set of EU waste legislation" (ibid.). There are two most common waste treatment operations in the EU: landfilling and incineration (ibid.). But since the past years, there are more and more campaigns and programmes coming up for example the EU's Sixth Environment Action Programme that went from 2002 until 2013, the Waste and Resources Action Programme (WRAP) from the UK as well as the Swedish research program "towards a sustainable waste management" (TOSUWAMA) (Finnveden et al., 2013, p. 844).

The next sub-sections provide a brief overview of each of the three strategies for food waste reduction that are investigated in this thesis.

2.2 Incineration tax

In order to deal with waste, several countries like Austria, Belgium, Denmark and Italy have started to implement an incineration tax in the 1990s as one of the most widely used incentives (Thi et al., 2015; Jofra Sora, 2013; Sahlin et al., 2007). The incineration tax is an economic market-based solution that has the effect to change waste management from landfilling towards incineration and increase the recycling rate as well as the costs for waste management (Chalak et al., 2016; Priefer et al., 2013; FUSIONS, 2016).

The aim of most waste policies and regulations is to increase the recycling of food waste and diversion of food waste "away from landfills" through taxes like landfill tax, incineration tax or the PAYT approach (Chalak et al., 2016, p. 419). That means that the incineration tax is a tool to efficiently reduce general waste and food waste (Thi et al., 2015; Priefer et al., 2016). According to Watkins et al. (2012, p. 5) "there is a broad overall trend that higher incineration charges are generally associated with higher percentages of municipal waste being recycled and composted, indicating that higher incineration charges may help to push waste treatment up the waste hierarchy". That means, that incineration taxes not only reduce waste but also turn waste into energy that can be recovered (Watkins et al., 2012). It is "an established technology" (Cristobal et al., 2016, p. 159) and one of the common operations to handle food waste along with anaerobic digestion, composting and landfilling and is implemented as a unit tax (Karousakis, 2006). Therefore, the tax is seen as a very important strategy to minimize waste and valorisation and is also applicable for food waste and residues (Otles et al., 2015; Hodges et al. 2011; Sasao, 2014).

Increased efficiency comes with a high cost in capital and maintenance since the technical-based operations and instruments to control the residues are expensive (e.g. an incineration boiler) (World Bank Technical Report, 1999; Thi et al., 2015; Finnveden et al., 2007; Murugan et al., 2013). Additionally, the incineration process is bound to some requirements that are necessary to make the process efficient. For example, there has to be a "mandatory separate collection of food waste" established and the rate of the tax needs to be at a sufficient level to have an impact on the reduction of food waste (Priefer et al., 2013, p. 6). Also, the regulations that are currently implemented need to be promoted and new solutions like renewable energies need to be verified and pushed forward in the EU (Priefer et al., 2013). The efficiency of the tax also depends on "institutional as well as technological factors" (Sahlin et al., 2007, p. 843).

When implementing the incineration tax, there is a distinction to be made between the tax carried out by the public authorities and gate fees set by the operators to provide the service of handling the waste. The fee is designed to cover the costs and profit of these operations (Watkins et al., 2012). The amount of tax ranges from €2.40/tonne in France up to €44/tonne in Denmark and is dependent on the fee accepting the waste (ibid.). That means according to Watkins et al. (2012) if waste is factored in, the costs for incinerating per tonne waste can range between €46 (Czech Republic) up to €174 (Germany). The result of implementing an incineration tax comes also with higher incineration gate fees (Profu, 2006; RVF, 2006b; Sahlin et al., 2007). Nevertheless, incineration with energy recovery remains the largest household waste treatment method (50%), followed by recycling (34%) as well as "biological treatment" (10%) (Sahlin et al., 2007, p. 829). Because incineration results in energy recover, the interest by electricity companies to use waste as a fuel for heating is expect to be increasing in the next years, since 10 to 15 per cent of municipalities in Sweden are already heating with energy recovered from waste (Eriksson, 2015; Finnveden et al., 2007).

The reasons to handle more waste through incineration than landfill are diverse. For example, it is less energy intensive than landfilling and generates less GHG emissions except when incinerating plastics in a short run (Finnveden et al., 2007). Even though there will be more waste managed by incineration, recycling will remain favourable "from an environmental perspective" compared to biofuels in the long run (Sahlin et al., 2007; Finnveden et al., 2007, p. 3). Thus, waste incineration is better than landfill disposal and plays a role in modern and progressive waste management systems but should not substitute recycling (Finnveden et al., 2007). But besides plastic there are other waste flows like wood waste, garden and food waste or disposal of unsorted waste as well as "residues from recycling of materials and biological treatments" where incineration is the most sustainable waste strategy (ibid., p. 7). According to Otles et al. (2015, p. 14), "incineration is a viable option for food wastes with relatively low water content (<50% by mass) and an option for hazardous wastes". The process utilizes oxygen to incinerate the waste while it remains staying under emissions standards (Jofra Sora, 2013). The process has some advantages like reduction of waste, non-hazardous treatment of waste, energy recover as well as the mitigation of environmental impacts (ibid.).

Comparing disposal with the EU waste pyramid (reuse, recycle and energy recover), incineration and landfilling is seen as the less environmentally friendly options (Finnveden et al., 2007; Murugan et al., 2013). The goal should always be to reuse, recycle and recover before incineration or landfill (Finnveden et al., 2007). Also, incineration is newly categorized as a recovery option in the new waste hierarchy as long as the energy recovered is greater than the "designated threshold" (Grosso et al., 2010, p. 1239). The incineration tax can possibly encourage illegal dumping when too high fees or taxes of not only incineration but also landfill and PAYT systems are applied. Additionally, the incineration tax has a more increasing effect on the recycle rate instead of preventing waste at first place (Finnveden et al., 2007; Sahlin et al., 2007; Watkins et al., 2012). Additionally, incineration is seen as "an inefficient way to produce energy" and will be not the final solution to the food waste treatment or climate change in the future as well as an answer to the energy problem because as mentioned before, "incineration is a very expensive source of energy" (Jofra Sora, 2013, p. 21). Since, incineration is one of the most common waste treatment methods, the tax still has a great influence of waste treatment in European countries and plays an important role in the achievement of the targets of the EU Waste Directive as well as changing food waste behaviour.

2.3 Landfill tax

Along with the introduced incineration tax, the landfill tax forms another market-based and economic incentive for waste producers to minimize the quantity of waste that is transmitted to landfill in order to meet the EU Waste directive targets like "[…] to boost the energetic utilization of waste" (Skeldon et al., 2018; Chalak et al., 2016; Sommer & Ragossnig, 2011, p. 74). The tax is an environmental negative incentive paid by companies, local authorities or other waste producers for getting their waste disposed and is determined on a national level by members of the European Union (Chalak et al., 2016; Karousakis, 2006; FUSIONS, 2016; Sasao, 2014). Thus, "landfill operators are subject to the tax and costs are passed on to end user in form of higher charges" (Chalak et al., 2016, p. 419). Next to incineration, anaerobe digestion and composting, landfilling is one of the options of waste management (Cristobal et al., 2016; Thi et al., 2015). The point of the introduction of a landfill tax "[…] is to increase the unit price paid for landfill disposal, thus providing municipalities with economic incentives to reduce the amount of waste they deliver to landfills and to stimulate recycling programs" (Karousakis, 2006, p. 34; Mazzanti et al., 2012; Secondi et al., 2015). The landfill tax has contributed to the promotion of the waste hierarchy and the reduction of waste in general (Mazzanti et al., 2009).

A high landfill tax shows efforts for more sustainable waste management systems like recycling as well as greater environmental outcome and encouragement to change food waste behaviour (Karousakis, 2006; Withana et al., 2014). Higher costs of landfilling will push treating waste towards recycling and composting (Priefer et al., 2016). Even that the landfill tax is a priced-based instrument, it seems to have little impact on the quantity of waste going to landfills, which was one of the targets embedded in the EU Landfill Directive to set rates in order to fulfil the environmental targets (Karousakis, 2006; FUSIONS, 2016). But since the 1990s, landfilling of biodegradable waste is associated with concerns regarding environmental impacts because the gas methane is released during the process of decomposition (Smith et al. 2001; Skeldon et al., 2018; Bulkeley & Gregson, 2009). Landfilling and its environmental impact as well as the separation of bio-waste and recycling are an important target and issue among Europe (Bräutigam et al., 2014). One positive effect is that the landfill tax drives waste management companies forward until the competition is satisfied (ibid.). In the year 2010, 50 per cent of bio-waste was set to landfill in the EU-27 and in some countries even up to 100 per cent (EEA, 2013; Bräutigam et al., 2014). Also, since the introduction of the Landfill tax in 1996, landfilling as waste management continued at the same levels and did not seems to influence the rate of recycling. But with the introduction of the "waste hierarchy" by the EU, governments are supposed to divert waste from landfill to "reduce, reuse, and recycle" (Bulkeley & Gregson, 2009, p. 934). There is a transition towards more sustainable practices as recycling since landfilling burry high environmental costs (Chalak et al., 2016; Cristobal et al., 2016). The waste hierarchy needs to be "prioritise prevention and redistribution of surplus food" before other waste management options like landfilling (Vittuari et al., 2016, p. 66). Changing the handling of food waste would result in less environmental impacts and consumption of resources when focussing on less landfilling and more on energy recover (Martin & Danielsson, 2016). According to the FUSIONS report (2016) the landfill tax as well as the incineration tax has a greater influence on recycling than the prevention of food waste. There is evidence that too high taxes can lead to illegal waste disposal (Karousakis, 2006; Finnveden et al., 2007; Sahlin et al., 2007; Watkins et al., 2012; FUSIONS, 2016).

Going over the charge of the tax, it is very different among Europe. For example, the tax ranges from €3 (per tonne) in Bulgaria up to €107.49 (per tonne) in the Netherlands (Watkins et al., 2012). Taking the gate fee into account, the total charge for landfill goes up to €155.50 in Sweden with the lowest charge of €17.50 in Latvia (ibid.). A clear upwards trend over the past years for the landfill tax is visible but it seems challenging to get rid of "landfilling" by only implementing higher taxes (ibid.). Comparing landfill tax with incineration tax, the charge of the landfill tax is higher in nearly every country (ibid.). The higher the landfill tax the more expensive is domestic landfilling, which also is connected to a higher expensive in landfilling residues from incineration (Olofsson et al., 2005). The main purpose of landfill and incineration taxes might be to move waste management towards recovery and recycling but they also contribute to decrease food waste (Priefer et al., 2016).

To be an effective policy instrument some requirements needs to be included according to Otles et al. (2015). The first one is a landfill ban on food waste, followed by a landfill tax that push forwards alternatives like recycling and supports diversion. Better sustainable alternatives like composting and anaerobe digestion needs further development as well as a sufficient infrastructure including a waste treatment network (Kosseva, 2013). Meeting the requirements will make landfilling an efficient treatment for food waste reduction and can also be applied for by-products of food waste (FUSIONS, 2016). But, encouraging to switch to recycling and composting will have a positive influence towards an increase in employment in the waste management sector (Withana et al., 2014). This would lead to the assumption that landfill taxes will not only contribute to decrease waste and promote more sustainable solution like recycling etc., but also contributing to the achievement of some of the SDGs as well as the targets set by the EU Waste Directive.

2.4 Pay-as-you-throw approach

In the year 2011, the European Commission has set the aim to cut avoidable food waste by half of its quantity until 2020 (Priefer et al., 2013). Additionally, a target of the European Waste Framework Directive is for member states to implement mandatory regulations to reduce and prevent food waste (ibid.). One of the possible regulations is a PAYT approach or unit pricing program, an economic incentive, to combat food waste and its consequences (Karousakis, 2006). It is designed to measure the amount or weight of food waste on mainly household level to regulate the quantity as well as works as negative price-based instrument in form of punishment (Chalak et al., 2016; Vittuari et al., 2016). The approach of the fee is to have a reducing effect on the quantity of food waste (ibid.). Thereby, the PAYT approach is set into force by the commune or municipalities as well as by private companies that are specialized into waste management (Chalak et al., 2016; Withana et al., 2014).

The approach is a very common and widely varying incentive in Europe, but only seldom implemented on a national level (Withana et al., 2014; Watkins et al., 2012). Nevertheless for a successfully implementation, a positive public opinion is needed and a “not too high fee[s]” because a high fee “[…] will lead to illegal dumping or waste burning” (Priefer et al., 2013, p. 122; Hebrok & Boks, 2017). According to the FUSIONS report the PAYT approach seems to be the most promising tool in terms of effectiveness to reduce and prevent food waste under the condition that the fees are able to pay by households but at the same time enough to change waste behaviour and encourage to engage with “separate collection systems” (Watkins et al., 2012, p. 99; Vittuari et al., 2016). The PAYT approach can also lead not only to prevent food waste but also to encourage using food that would be wasted otherwise in other ways like donation etc. (Vittuari et al., 2016). It is important, that a policy is comprehensive and applicable for all stakeholders in the food system, from primary production until waste management, to be successful (FAO, 2013).

There are four different common fees that are implemented. The first one is a fixed annual fee per household like in Catalonia (Spain) or Stuttgart (Germany) and ranges from €40 to €2,415. The second is a fee for purchasing refuse bags, which is implemented in Catalonia (Spain) and Stuttgart (Germany) too and costs €0.65 for a 17 litre bag up to €5.50 for a 70 litre bag. The third fee is per emptying of a bin and is for example implemented in Ribeauvillé (France) (€0.50) or north Helsinki (Finland) (€4.20) for 120 to 140 litre. Lastly, there is a weight-based fee that costs €0.17 per kg in Slovakia and up to €0.36 per kg in Sweden (Watkins et al., 2012). The four fees are also noun as volume-based, sack-based, frequency-based and weight-based schemes, whereas weight-based schemes are the most effective, the volume-based and frequency/sack-based schemes and lastly the volume-based scheme in terms of preventing waste (ibid.).

For a successful implementation not only a positive attitude is necessary but also a good infrastructure, which is most expensive for weight-based schemes but also have greater results (ibid.). For example in Sweden, municipalities gathered 20 per cent less waste of households per citizen than municipalities without a PAYT scheme (Priefer et al., 2016). It is necessary that regions are cooperating to bring PAYT schemes forward in form for example of campaigns about waste management like PAYT schemes to educate the public and reduce waste in the long run (Watkins et al., 2012). This would lead to positive environmental effects like growing recycling rates and "overall waste prevention" (Holmes et al., 2014, p. 56; Dahlén & Lagerkvist, 2010; Dunne et al., 2008; FUSIONS, 2016). But also in economic terms for example "collection and treatment costs are adjusted to the weight treated" and socially because households are charged after the quantity of waste (Aramyan et al., 2016, p. 27). PAYT schemes seem to increase recycling more than having an effect on the reduction of waste (FUSIONS, 2016; Giovanis, 2015). According to a paper by Giovanis (2015) PAYT schemes have a favourable effect on air quality and along with the findings of Priefer et al., (2016), PAYT schemes seems to have an average recycling rate of 33.75 per cent in comparison to municipalities without a PAYT scheme (25.68 per cent).

To summarise, PAYT schemes seem to have a positive effect on the environment, which leads to a decreasing demand for new disposal facilities (Bilitewski, 2008; Reichenbach, 2008). But in order to be able to successfully implement the PAYT approach the aim should be to create a standard criteria at municipal level to use this tool effectively and "modify the economic behaviour" (FUSIONS, 2016, p. 30). The approach needs to be seen individually from "[…] similar policies to avoid the 'double counting' of improvements in waste management performance" (Watkins et al., 2012, p. 100). Lastly, the PAYT approach is a tool to achieve the target of the EU Waste Directive and therefore an instrument that will contribute to the achievement of the SDGs 2030, especially target 12.3.

Table 1. *Overview of the Policy's characteristics*

Policies		Pros and Cons	Countries included in this study
Incineration tax	Tax and gate fee	Pros: Commonly used with food waste and good for the possibilities with biofuel. More environmental friendly Cons: Expensive	Sweden, Austria, Ireland, Norway, Spain
Landfill tax	Tax and gate fee	Pros: Most commonly used and easy to apply Cons: Less Environmental friendly	Greece, Hungary, Netherlands, Norway, Portugal, Slovakia, Estonia

Policies		Pros and Cons	Countries included in this study
Pay-as-you-throw approach	- fixed annual fee per household - fee for purchasing re fuse bags - per emptying of a bin - weight-based fee	Mainly household level Pros: More environmentally friendly Cons: Not as much used as the other two policies	France, Ireland, Italy, Poland, UK, Slovakia

3 Literature review and Conceptual Framework

In this chapter, the literature review will be presented of studies regarding food waste and policy instruments to reduce food waste, following by the conceptual framework to assess and analyse the research questions.

3.1 Literature review

There is a growing literature body discussing waste in general, and food waste in particular. In this work, the focus is on literature addressing the impact of policy instruments on the reduction of food waste around the world and especially in EU. To get a better overview, the literature review will be separated into studies about food waste in general, EU studies on food waste in general and in regard to reduction of food waste as well as the three different policy instruments, the landfill tax, the incineration and the pay-as-you-throw approach.

3.1.1 General studies on food waste

Starting with the studies about food waste, the literature addresses mainly the household level to analyse food waste behaviour. There are in-depth studies about food waste in developed countries (Griffin et al., 2009; Mena et al., 2011; Sonnino & McWilliam, 2011; Buzby and Hyman, 2012; Beretta et al., 2013; Garrone et al., 2014). Some of the papers about food waste try to identify behavioural causes of food waste with the help of surveys and interviews (Graham-Rowe et al., 2015; Jorissen et al., 2015; Neff et al., 2015; Parizeau et al., 2015). Also, Otles et al. (2015) include the management of food waste, valorisation as well as brings up the topic of sustainability in the food industry. This will be a challenging task to achieve in the future. Another very relevant aspect is the measurement of food waste to evaluate the impact food waste causes. For this, the paper by Parfitt et al. (2010) addresses the potential for food supply chains to change by 2050. Since, food waste mainly occurs at the end of the value chain in developed countries, Chalak et al. (2018), quantified the amount of food waste of the hospitality as well as the food retail sector from developed economies. The study was approached from a national perspective and included policy instruments like a legislative framework, awareness campaigns and fiscal incentives which are essential to implement for food waste reduction.

3.1.2 EU studies on food waste and studies on food waste reduction

Since the European Commission introduced the Waste Directive, several countries started to address the issue of food waste and integrated policy instruments in their national targets. There are several studies that discuss the quantity of food waste in the EU and make a distinction across the member states (Bräutigam et al., 2014; Priefer et al., 2016; Watkins et al., 2012; Cristóbal et al., 2016). It is hard to compare the findings of the studies since there is no unified definition on food waste on which scholars agree upon; and the measurement methods differ between the studies (Garrone et al., 2014; Bräutigam et al., 2014; Thyberg & Tonjes, 2016). There are empirical studies on EU member states like the UK (Cox & Downing, 2007; Williams et al., 2011; Ventour, 2008), the Netherlands (Soethoudt & Timmermans, 2013; Thönissen, 2010), Denmark (Stenmarck et al., 2011), Sweden (Jensen et al., 2011), Finland (Katajajuuri et al., 2011) as well as Norway (Hanssen & Møller, 2013; Møller et al., 2012). Additionally, there are national surveys on food waste in Austria (Obersteiner & Schneider, 2006; Schneider & Lebersorger, 2009), Germany (Göbel et al., 2012; Kranert et al., 2012), Switzerland (Beretta et al., 2013) as well as France (Viel & Prigent, 2011), Italy (BCFN, 2012; Garrone et al., 2012), Portugal (Baptista, 2012), Spain/Catalonia (ARC, 2012) and Greece (Abeliotis et al., 2014). But studies on countries from Southern and Eastern Europe are very rare (Bräutigam et al., 2014).

Additionally, there were studies found that discussed policy instruments like taxes, subsidies etc. to reduce food waste in the EU. The paper by Finnveden et al. (2013) discusses the implementation of tax incentives in Sweden. Also, the paper by Marques et al. (2013) gives evidence about the impact of policy instruments in Portugal and Cossu & Masi (2013) in Italy. Literature from developing and developed countries regarding food waste reduction can also be found by Kusch & Evoh (2013) as well as in the paper by Kim (2002) with a good example of the establishment of taxes in Korea for reducing waste. The impact of policy instruments, like direct payments or subsidies in Sweden, can be found in the paper by Andersson & Stage (2018). It is also included in the paper by Finnveden et al. (2013) utilising the data from the Swedish Waste Management Association, Kolada and Statistics Sweden (SCB). Andersson & Stage (2018) are also discussing the impact of tariffs that is taking into account by the paper of Marques et al. (2018) for Portugal. Furthermore, the paper by Kusch & Evoh (2013) analyses both developing and developed countries regarding the effectiveness of tariffs. Another policy instrument that has been discussed in the literature are new technologies that can have possibly a significant influence on the decreasing of food waste. That means, that new technologies can create a more sustainable solution in the future, which is discussed by the paper by Bulkeley & Gregson (2009) for the UK and Andersson & Stage (2018) for Sweden. In comparison to the previously mentioned papers, Bulkeley & Gregson (2009) are also including infrastructure and quotas as policy instruments and as well as Kim

(2002) discuss the impact of direct regulations. Additionally Lee et al. (2007, p. 43) are assessing the effectiveness of policies for “separate food waste collection and volume-based charge system” in Korea.

3.1.3 Studies of the incineration tax, landfill tax and the PAYT approach

Going over to the policy instruments that were chosen to analyse in this thesis, different scholars are discussing the effectiveness of the landfill tax, incineration tax and the pay-as-you-throw approach on food waste behaviour. Skeldon et al. (2018) chose agent-based modelling to predict the outcome of policy in regard to food waste for the UK. The paper by Chalak et al. (2016) is analysing in a cross-country analysis the effectiveness of the three different policy instruments, trying to identify the economic determinants that influence household food waste. There were three papers found that included the landfill tax into their research (Eriksson et al., 2015; Finnveden et al., 2007; Ljunggren Söderman et al., 2016). Thus the paper by Eriksson et al. (2015) did a case study to assess the carbon footprint of the different levels of the waste hierarchy to manage waste. The other two papers focussed on the effectiveness of policy instruments and strategies to reduce waste in Sweden. Additionally, the paper by Kiss & Drescher (2014) did a similar study for Hungary and Mazzanti et al. (2009, 2011, 2012) performed a regression analysis using panel data looking at the landfill tax and other influences and their impact on food waste in regions of Italy. A paper by Sasao (2014) also performed a study using panel data to look at a waste management solution from Japan. A more comprehensive and comparable study was undertaken by Sommer & Ragossnig (2011), that compared and analysed the EU 27 in terms of their waste management practices with energy recover, including the landfill tax. Regarding the studies on the effectiveness of the incineration tax, different literature were found. Thereby, the paper by Chalak et al. (2016) and Eriksson et al. (2015) included not only the landfill tax into their assessment but also the incineration tax as well as the PAYT approach in the paper of Chalak et al. (2016). Some studies looked at the incineration tax from the EU level to identify new solutions for waste management in order to food secure the growing population (Watkins et al., 2012; FUSIONS, 2016; Ljunggren Söderman et al., 2016; Priefer et al., 2013). Also, Sahlin et al. (2007) took a national perspective and analysed the effect of the incineration tax on the waste streams in Sweden. In contrast, Olofsson et al. (2005) that focussed on energy recovery from waste in Sweden, where incineration is playing a role in it, especially when member states are trying to implement the circular economy package of the EU. Because of that target, several member countries are integrating other waste management strategies, following the waste hierarchy, that are more environmentally friendly like the PAYT approach. Therefore, several scholars are analysing the performance of new waste management solutions and propose policy frameworks for the EU and OECD member states (Vittuari et al., 2016; Karousakis, 2006; Watkins et al., 2012; FUSIONS, 2016; Priefer et al., 2013). There is still a huge knowledge gap about the outcome and effect of taxes and fees like the landfill tax, incineration tax and the PAYT approach (Schanes et al., 2018).

3.2 Conceptual framework

Based on the results of the literature review, a conceptual model was developed to examine the impact of policy instruments on food waste in the EU. Specifically, the framework was designed to conceptualise the relationship of these policies on food waste reduction, while accounting also for other factors/variables that may influence this connection. Taking a look at the prior literature, most studies are analysing the impact of policy instruments mainly on a household level or doing an in-depth study on one stage of the food chain as well as drivers and consequences of food waste. This thesis is taking a different path of assessing the impact of policy instruments on the reduction of food waste by creating a comprehensive framework that seeks to simplify the relationship of different socio-economic variables towards food waste.

To start with the control variables, different socio-economic variables were chosen as visible in Figure 2. Based on the literature (Secondi et al., 2015; Dithmer & Abdulai, 2017), the consumer producer index (CPI) shows a great influence on the quantity of food waste and needs to be included into the model. This also counts for the Gross domestic product (GDP) per capita, which is an economic indicator standing for the wealth of a country and has therefore an influence on food waste (Mak et al., 2020; Dithmer & Abdulai, 2017; Sommer & Ragossnig, 2011; Miliute-Plepiene & Plepys, 2015). It is calculated as the amount of the gross value of the whole population of an economy including product taxes minus subsidies (Faostat, 2019). The third control variable shown in Figure 2 is urban density and represents the number of people living per square kilometre in a country. This is a significant variable since some studies show results that indicate high likelihood of food waste in urban areas than in rural areas (Secondi et al., 2015). The last included control variable of the framework is waste management accounting for the amount of capital a country invest to reduce waste or food waste. It can be expected that countries that invest more capital in waste management should have less waste. According to the model, the control variables are supposed to have a positive or negative impact on the efficiency of policy instruments and thus on the variable of interest, food waste.

The policy instruments, incineration tax, landfill tax and the PAYT approach, are visualised in the middle of the framework. All three policies have a direct influence on the amount of food waste in a country. It is expected that all three policies will reduce food waste since the taxes and fees are implemented to combat waste from the EU (Schanes et al., 2018). That means that the policies are tools by the EU, which are influenced by the control variables as well as other environmental, social and economic indicators, excluded by this framework, that will increase or decrease the impact on the reduction of food waste in a member state in the EU. The last variable in the conceptual framework is the dependent variable or the variable of interest, food waste. In the framework, the control variables have a direct effect on the policies, impacting on the quantity on food waste. The conceptual model explains and visualise very well the connection and relationships that will be explained later on by the regression model and what results will be expected. It gives an over-view on the variables included in the model and how the path of influence flows. In summary, the control variables affect the independent variables (policies), which affect the variable of interest.

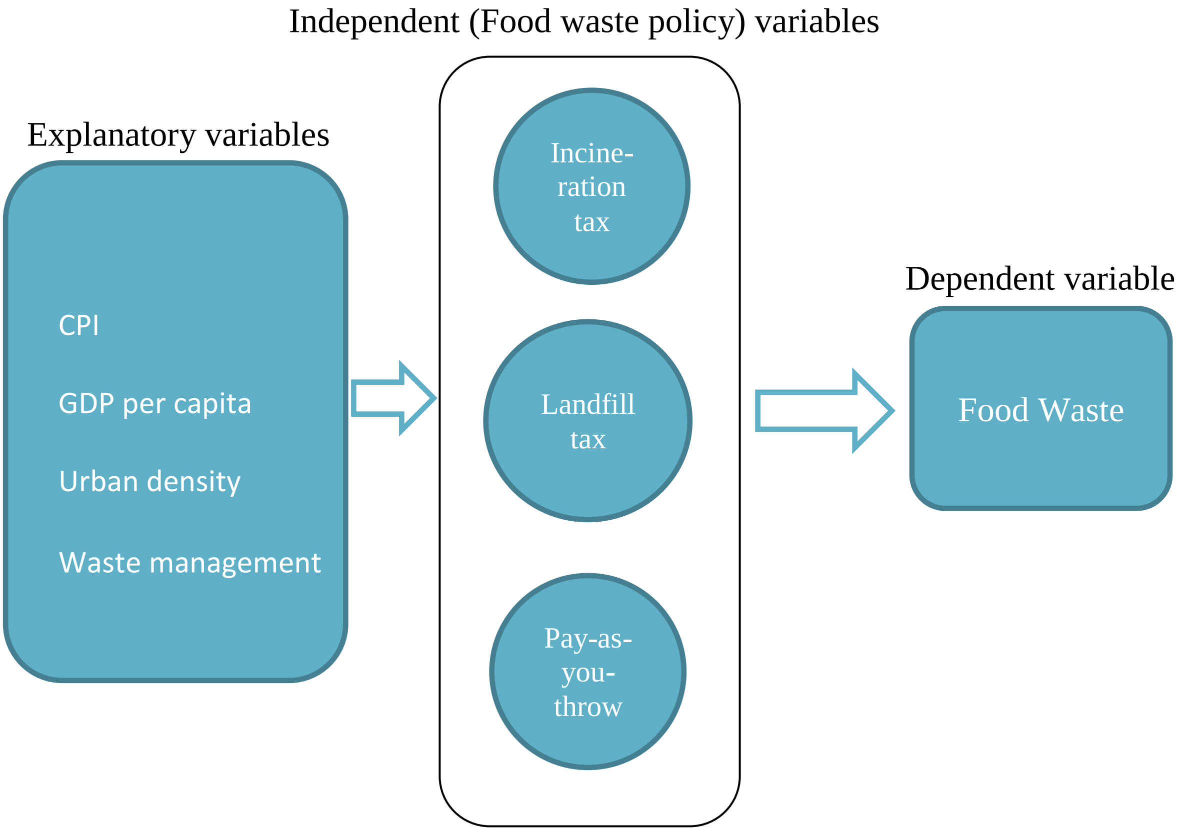

Figure 2. Conceptual Framework for analysing the impact of independent variables on food waste

4 Empirical Model and Data

In this chapter, the empirical model and the chosen data will be presented as well as an overview of a description of the variables included in the model.

4.1 Model Specification

In order to answer the two research questions of this thesis, the following multiple regression model was used. In Equation (1), the standard multiple regression equation is presented, integrating indicator variables (x) that should have an explanatory power on Y as well as the error term (ε).

(1) $$Y = b_0 + bx_1 + bx_2 + bx_3 + bx_4 + bx_5 + \varepsilon$$

With the result of the literature review, different variables were found that would be relevant to include into the regression analysis. The focus was to utilise variables that are widely used and have shown an effect on the amount of food waste in the EU, but also for better comparability on a global perspective. In several studies, socio-economic variables were included in the model and have shown to have an impact on food waste behaviour (Milieue-Plepiene & Plepys, 2015). The variable "Population density (PD)" was included, which contributes to analysing the research questions. The variable "PD" is a very common variable for assessing the impact of policies or food waste behaviour (Mazzanti et al., 2011 Cerciello et al., 2019). Additionally, the economic variables "CPI" (Secondi et al., 2015; Dithmer & Abdulai, 2017) and "GDP per capita" (Ederveen et al., 2006; Mak et al., 2020; Miliute-Plepiene & Plepys, 2015) were chosen to have a significant influence on the quantity of food waste. According to the World Bank (2019), the CPI accounts for the change of cost that a consumer needs to acquire for a "[…] basket of goods and services that may be fixed or changed at specified intervals, such as yearly". The GDP per capita is the GDP of a country divided by the midyear population. Both variables represent numbers for the level of income and wealth in a country, whereas the CPI represents an index and is thus measured in percentage and the GDP per capita is in US Dollar. Along with the independent variables "PD", "CPI" and "GDP per capita", the variable "Waste management (WM)" could be found several times in literature (Secondi et al., 2015; Mazzanti et al., 2012). It accounts for the amount of capital a country is spending on waste management. The variables is measured in US Dollar. In order to assess the impact of policies on the amount of food waste in the EU, the three chosen policies “incineration tax”, “landfill tax” and the PAYT approach were included as dummy variables. If the policies were implemented in the years, (a “yes”), the policy instrument is equal to 1 whereas a “no” equalled 0. This will show insight regarding the influence of the policy instrument on food waste, positive or negative. Because the research questions are not only a matter of social and economic interest but also on environmental interest, a variety of variables were included, covering all three pillars of sustainable development. The “CPI” and “GDP per capita” are serving the economic pillar, while the “PD” the social and the “WM” the environmental pillar. Having introduced the independent variables, they will have an influence on the dependent variable “Animal and Food waste; vegetable waste” that accounts for food waste (FW) in the EU and is measured in tonnes.

Thus, the dependent variable Y in Equation (2) is covering the Animal and Food waste, vegetable waste (FW) in the EU in the period of time (t). The independent variables x_1 is “CPI”, x_2 is “GDP per capita”, x_3 is “PD”, x_4 is “WM” and x_5 expresses the dummy variables “incineration tax”, “landfill tax “ and “PAYT” in the period (t). The variables “GDP per capita”, “WM” and “Animal and Food waste; vegetable waste (FW)” are represented logarithmic for better results. The model ranges in the period (t) from 2004 until 2016, every other year. The end of Equation (2) forms the error term (ε), be accountable for errors and residuals that could not be included into the model.

$$\hat{y}_t = b_{0t} + b_1 * CPI + b_2 * Log(GDP\ per\ capita) + b_3 * PD + b_4 * Log(WM) + b_5 * Dummy\ variable\ (Policy) + \varepsilon \quad (2)$$

The Equation (2) aims at finding significant results that will allow to draw conclusions of the impact of policy instruments on the reduction of food waste in the EU as well as how and why the impact of the policy instruments differs across the investigated countries.

4.2 Data

During the research for variables that have an influence of food waste behaviour, different database were explored. Table 1 gives an overview of the different variables, their definitions as well as units and data sources. The main database was EUROSTAT, were the data for the dependent variable “FW” as well as the independent variable “WM” are based on. The variable “FW” stands for the amount of food waste in the member countries of the EU and is measured in tonnes. The database offers access to data on topics related to food and agriculture as well as trade about the European countries. It is free to access and its website combines data from surveys and reports (EU, 2019). Additionally, the exchange rate from Euro to US Dollar from the ECB was used to calculate the amount of capital countries are spending on “WM”. This was necessary to unify the currencies to make the variables comparable and transparent for the model. The data from the variables “CPI” and “PD” were found on the database of the World Bank. The other independent variable “GDP per capita” is based on the data found from the database of FAOSTAT. It is the database of the FAO and “provides free access to food and agriculture data for over 245 countries and territories and covers all FAO regional groupings from 1961 to the most recent year available” (FAOSTAT, 2020). While looking for sufficient variables, that can be included in the model, it was not easy to find data on the mentioned variables above and the time period was limited to the years 2004-2016, providing data for only every two years. Also, other databases like OECD database, trading economics as well as national databases were analysed to find more sufficient variables. There were more variables that are connected to the issue of food waste, but did not fit into the model.

Table 2. *Variables Description, Measurement and Data sources*

Variable	Label	Operational definition	Measurement unit	Data
Incineration tax	IT	Incineration tax is a fee to reduce waste in the EU	Dummy variable	
Landfill tax	LT	Landfill tax is a fee to reduce waste in the EU	Dummy variable	
Pay-as-you-throw	PAYT	Pay-as-you-throw is a unit-price system for waste management	Dummy variable	
Consumer price index	CPI	changes in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals	percentage (2010 = 100)	The world bank
GDP per capita	GDP	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes	US Dollar	FAOSTAT
Population density	PD	Population density is midyear population divided by land area in square kilometres.	people per sq. km of land area	The world bank
Waste Management	WM	Amount of capital spend by countries on waste management	US Dollar	EUROSTAT; European Central Bank (ECB)
Animal and Food waste; vegetable waste	FW	Generation of Animal and Food waste and vegetable waste	tonnes	EUROSTAT

4.3 Limitations

Going over to the quality of the data that was chosen for this research, several limitations need to be stated. First of all, there is no unified methodology across the countries, leaving it free for the member countries "to decide on the methods [they use] for data collection" (Bräutigam et al., 2014, p. 685). Accordingly to the FUSIONS report, there are limitations in regard to the reliability of EUROSTAT and national data as well as that there are several methodologies of the food waste data that get reported to EUROSTAT across the member states. This is not only causing a lack of reliability but more importantly a lack of clarity, which might be significant in regard of the results (FUSIONS, 2014, p. 97). It might cause incongruences that will have a limiting effect on the power of the results and the conclusion (Chalak et al., 2016). Thus the "food waste generation in EU-27 differ significantly, depending on the data sources chosen and the assumptions made (Bräutigam et al., 2014, p. 693). Nevertheless, there will be an improvement expected of the EUROSTAT data in the upcoming FUSIONS project that focusses on the data to form a comprehensive European framework for more transparency (ibid.). To not only achieve more reliable data and international standards, but also to clarify the term "food waste" across the member states, a unified definition should be developed to build the basis for further research (Bräutigam et al., 2014; Dahlén et al., 2009). Since this thesis is taking a macro perspective on the quantity of food waste and the impact policy instruments will have on it, it might will overlook some micro determinants "that include, but not limited to, socio-economic household characteristics, and would include cultural predispositions, behavioural and attitudinal patterns and environmental awareness" (Chalak et al., 2016, p. 422). A larger panel data would also contribute to a higher quality in regard to the results, but was not possible due to the data from EUROSTAT. But since there is no unified definition and the term food waste is still causing several debates, the "existing researches are difficult to compare" (Gjerris & Gaiani, 2013, p. 20). This limitations are demanding a greater effort to improve the methods and collection of data across the EU members to unify the term "food waste" and make the outcomes of research studies more transparent and reliable (Jörissen et al., 2015).

5 Results and Discussion

The empirical results and a discussion about the validity and impact of the results will be presented in this chapter.

5.1 Empirical results

The empirical results of the regression analysis are divided into three chapters, the three policies (Incineration tax, Landfill tax, PAYT), for a better discussion and overview. Thus, it seems reasonable to look at the correlation of the variables first to better analyse and interpret the results. In the analysis the Pearson's Correlations Coefficient was chosen to analyse the relationship between the variables included into the model.

In Table 11 in the Appendix, the results of the relationships between the variables are shown. Thus, the variable "GDP per capita" and "CPI" have proven to have an extremely insignificant positive correlation in all three models. This means that there is no relationship between the amounts of "GDP per capita" and the "CPI" in the member states. The "PD" and the "CPI" can also be characterised by an insignificant positive relationship regarding the analysis of the incineration tax, landfill tax and the PAYT approach. Taking a look at the variables "WM" and "CPI", an extremely insignificant negative correlation is found for the incineration tax but a positive relationship for the landfill tax and PAYT approach. Going over to the variables "GDP per capita" and "PD", the variables have an insignificant negative correlation in the model of the incineration tax and an extremely insignificant positive correlation in the model of the PAYT approach. There is an insignificant positive correlation between the "GDP per capita" and the "PD" in the results of the landfill tax. The relationship between the variables "GDP per capita" and "WM" show the results of an insignificant negative correlation for the model of the incineration tax, but a moderate positive correlation for the model of the landfill tax. Regarding the results for the model of the PAYT approach, the results show an insignificant positive correlation. However, the results of the correlation of the variables "PD" and "WM" are expected to be correlated, since the "PD" seems to have an influence on the amount of capital countries spend on waste management. Looking at the results, an insignificant negative correlation is shown for the model for the incineration tax.

Still, in the other two models of the landfill tax and the PAYT approach a highly significant positive correlation is the result. This means that the higher the "PD" is in the member states, the more "WM" occurs.

5.1.1 Results of the Incineration tax model

Passing over to the first model after showing the correlation results, the quantity of food waste in the countries included in the model of the incineration tax are visible in Figure 3. It can be seen, that Sweden, Austria, Ireland and Norway are producing similar amounts of food waste annually. In contrast to them is Spain, which have a higher quantity of food waste that can be due to different influencing factors (i.e. the amount of production and infrastructure). All member states have a decreasing or consisting trend in terms of quantity of food waste in the period of 2004 until 2016. Taking a closer look at Austria, a peak is visible in the year 2008 with a significant upwards trend in the following two years. This can be because of the Waste Directive Framework that was published in 2008 or also because of the financial crisis at that time (APSE, 2013).

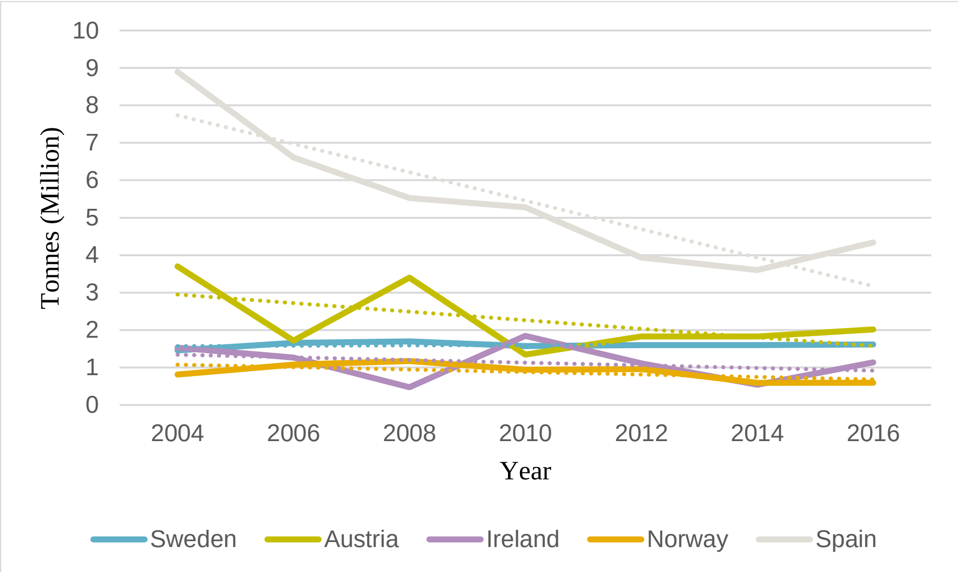

Figure 3. Animal and Food waste; vegetable waste of the countries that implemented the incineration tax during the period 2004-2016. (Source: EUROSTAT, 2020)

For a better comparison of the results and interpretation, the countries that have implemented the incineration tax in the period between 2004 until 2016 were categorised according to their level of income in Table 2. As seen in Table 2, Austria and Norway have a high level of income that means the median equivalised net income was higher or equal to €23,000 in 2016. Having a high level of income can indicate for better waste management performance due to better prerequisites regarding infrastructure, education etc. (Zen et al., 2014). Moreover, Sweden and Ireland are categorised as middle to high level of income countries, which stands for that the countries had a median equivalised net income of €16,500 up to €23,000 in 2016. Spain is representing a middle income country that had a median equivalised net income of €10,000 to €16,500 in 2016. Showing that Spain has a lower level of income than the countries could also be a possible explanation for their waste performance because it cannot invest as capital as the other countries into waste management. According to Zen et al. (2014), higher income and higher educational backgrounds resulted in a more general positive attitude towards the environment.

Table 3. *Countries' level of income and year of implementation of the incineration tax*

Country	Level of income	Year of implementation
Sweden	Middle/High	2006-2010 (Watkins et al., 2012)
Austria	High	2006 (Ettlinger & Bapasola, 2016)
Ireland	Middle/High	2010 (Clarke, 2010)
Norway	High	1999-2010 (Papineschi et al., 2019)
Spain	Middle	2009 (Puig Ventosa, 2011)

After the categorisation of the countries that are included in the model of the incineration tax, Table 12, which can be found in the Appendix, presents the descriptive statistics of the variables divided by the countries. Thus, the differences between the countries are visible. It can be noted that Sweden and Norway have a very low population density compared to the other countries.

The first results are presenting the impact of the incineration tax as a policy instrument on the quantity of food waste in Sweden, Austria, Ireland, Norway and Spain. All countries are categorised into level of income that will be taken into consideration when interpreting the results. Starting with the regressions results shown in Table 3, the R^2 is of all countries is very high, meaning that nearly all variance of the dependent variable that can be explained by the independent variables, respectably 76.5 per cent in the regression analysis of Sweden up to 99 per cent in the regression analysis of Austria. Also, the adjusted R^2 is high in Austria, Ireland, Norway and Spain but negative for Sweden. This means that there is an insignificance of explanatory variables which would be changed by higher sample size or avoiding correlation of independent variables. In terms of independent variables, the incineration tax was integrated into the model as a dummy variable and was expected to have a negative effect on the quantity of food waste. In Table 3, it is shown that the results of Ireland (-1.168) and Norway (-1.195) are meeting the expectations and the incineration tax has a decreasing effect on food waste. This results are also reflected in the paper by Chalak et al. (2018), where they found that frameworks, awareness campaigns and incentives will reduce food waste. Nevertheless, for Sweden (0.013), Austria (0.188) and Spain (0.093) it shows the opposite. The results show that the implementation of the incineration tax is increasing the amount of food waste for all three countries, even if only slightly. For Italy, incineration has no influence on food waste as found out by Mazzanti et al. (2012).

The "CPI" is expected to have an increasing effect on the amount of food waste since a higher consumer price index can indicate for more wealth in a country which has been shown to have negative effect on food waste (Mak et al., 2020; Cox & Downing, 2007; WasteMinz, 2014). In the results of the "CPI" of Sweden (-0.012), Austria (-0.136), Ireland (-0.146) and Spain (-0.030), the coefficients show a negative impact on the amount of food waste which is contrary to expected results. Nonetheless, it shows that the "CPI" has a negative effect on food waste, which is positive for sustainable development. The results of the analysis of Norway (0.302) show the opposite, in that analysis the "CPI" has an increasing effect on food waste, which fits the expectation.

For the other economic variable "GDP per capita", the expectation was to have also an increasing effect because a wealthier population is more likely to waste food (Cox and Downing, 2007; WasteMinz, 2014). According to Miliute-Plepiene & Plepys (2013) the "GDP per capita" has a significant influence on the quantity of food waste. In the results, the "GDP per capita" has an increasing effect on the quantity of food waste for Sweden (0.001), Austria (26.261) and Spain (1.400). The value is small for Sweden and Spain but very high for Austria. That means that in Austria, the "GDP per capita" has a significant influence on the quantity of food waste. A decreasing effect is presented for Ireland (-5.877) and Norway (-0.186).

Looking at the "PD", it is expected to have a negative effect on incineration which means that urban areas are characterised by less food waste that is incinerated (Gnolonfin et al., 2016). Thus, "PD" is expected to have a decreasing effect in countries with a high population density. This stands in contrast to the results by Dahlén et al (2009) where more population density correlated with higher amounts of household waste per capita. This result is also shared by Dithmer & Abdulai (2017, p. 227), which found out that "[…] a high rural population share, high population growth and inflation negatively affect food security". The results indicate that it has an increasing effect for Sweden (0.069), Austria (0.283), Ireland (0.385) and Spain (0.071). For Sweden and Ireland the results seem reasonable since their "PD" is lower than that of Austria and Spain. Additionally, the results for Norway (-5.348) indicate a negative coefficient, which is unusual since the population density is low. According to Banerjee & Sarkhel (2010), "PD" has a significant influence in waste management and economic development of a country. In the results of the paper by Usui & Takeuchi (2014), population density does not have significant effect in the equations.

Additionally, the results of the regression analysis regarding the incineration tax are characterised by both negative and positive coefficient towards the independent variable "WM". Therefore, the country analysis of Sweden (0.576), Ireland (0.152) and Norway (3.522) present positive coefficients. That means that "WM" is encouraging the quantity of food waste instead of diminishing it. For Austria (-18.422) and Spain (-2.037) the coefficient is negative, leading to a decrease of food waste. This would be the expected result and also the reason for countries to manage waste as well as apply economic incentives in general. Taking the standard deviation into account, the values are very low.

Table 4. *Regression results of the countries that implemented the incineration tax*

	Sweden	Austria	Ireland	Norway	Spain
Incineration tax	0.013**	0.188	-1.168	-1.195	0.093*
CPI	-0.012**	-0.136	-0.146	0.302	-0.030**
LOG GDP per capita	0.001***	26.261	-5.877	-0.186	1.400
PD	0.069*	0.283	0.385	-5.348	0.071*
LOG WM	0.576	-18.422	0.152	3.522	-2.037
SD	0.025**	0.014**	0.129	0.046**	0.014**
R^2	0.765	0.999	0.944	0.974	0.998
Adjusted R^2	-0.412	0.992	0.664	0.847	0.990

In Table 4, the empirical results of the countries that have implemented the incineration tax are presented. Thus, taking a deeper look at the p-values of the different variables result in different conclusions. For the regression results of Sweden, the p-value of all independent variables are insignificant. That means, that a higher p-value than 0.10 is not statistically significant and results in accepting the null hypothesis and rejecting the alternative hypothesis. For the other countries like Austria, the intercept (0.037) and the control variables “CPI” (0.037), “GDP per capita” (0.043), “PD” (0.037) and “WM” (0.050) are significant on a 90 per cent level of confidence. That means that the results are statistically relevant and indicates to reject the null hypothesis. The p-values of the control variables and the intercept of the analysis from Ireland and Norway are statistically insignificant with higher p-values than 0.10. The country analysis from Spain shows different results. The control variable “CPI” has a p-value of 0.075 and is thus significant on a 90 per cent level of confidence. Taking all results from the regression analysis into account, there is no proof that level of income has an influence on the empirical results. Therefore, the level of income is not connected to the waste management performance of the countries included that implemented the incineration tax. Nevertheless, it can be said that the conditions of the member states as well as their economic situation like income “which increases environmental awareness” varies (Giovanis, 2015, p. 201).

Table 5. *Empirical results of the models of the countries that implemented the incineration tax*

Country		Intercept	Incineration tax	CPI	LOG GDP per capita	PD	LOG WM
Sweden	Regressors	0.646	0.013**	-0.012**	0.001***	0.069*	0.025**
	p-value	0.963	0.774	0.723	0.994	0.659	0.708
Austria	Regressors	-135.875	0.188	-0.136	26.261	0.283	-18.422
	p-value	0.037**	0.205	0.037**	0.043**	0.037**	0.050**
Ireland	Regressors	58.311	-1.168	-0.146	-5.877	0.385	0.152
	p-value	0.293	0.356	0.229	0.329	0.294	0.631
Norway	Regressors	19.122	-1.195	0.302	-0.186	-5.348	3.522

Country		Intercept	Incinera-tion tax	CPI	LOG GDP per capita	PD	LOG WM
	p-value	0.280	0.273	0.273	0.470	0.263	0.223
Spain	Regressors	8.516	0.093*	-0.030**	1.400	0.071*	-2.037
	p-value	0.207	0.336	0.075*	0.286	0.157	0.182

* denotes significance at the 90% level of confidence
**denotes significance at the 95% level of confidence
***denotes significance at the 99% level of confidence

5.1.2 Landfill tax

With the Waste Directive of the EU, several countries implemented policies into their waste management to achieve the targets of the EU. Thus, the landfill tax serves as economic incentive to combat food waste in several member countries like Greece, Norway, Estonia, and Hungary, Portugal as well as the Netherlands, Slovakia and several others. Nevertheless, the aim is the waste hierarchy instead of landfilling to avoid the environmental consequences and provide a more sustainable solution for future waste management. In Figure 4, the amount of food waste in the mentioned countries is present in the period from 2004 until 2016. It can be noted, that the quantity of food waste ranges between 37.066 up to 2.785.642 tonnes in the countries: Greece, Norway, Hungary, Portugal, Slovakia and Estonia. Even that there is a higher volatility between the years and countries, the most significant number comes from the Netherlands. In comparison to the other countries that have introduced the landfill tax the Netherlands have a quantity of around eleven Million tonnes of food waste annually. That number seems very high and it might be possible that there are differences in the definition and measurement of food waste across the countries. The data is gathered by the EUROSTAT database. It is important to have a critical view on the results because of the contrast in quantity of food waste.

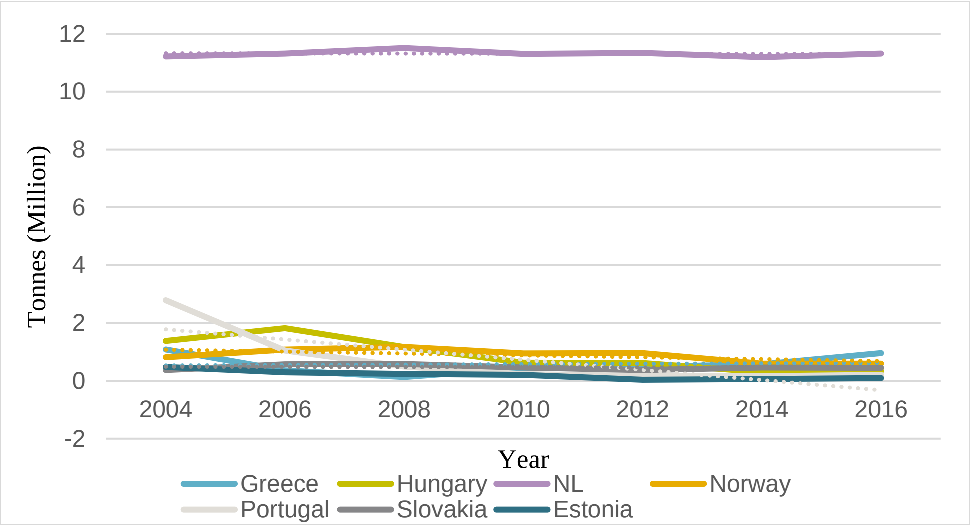

Figure 4. Animal and Food waste; vegetable waste of the countries that implemented the landfill tax during the period 2004-2016. (Source: EUROSTAT, 2020)

The landfill tax was categorised regarding the level of income, shown in Table 5. The year of implementation was given to be able to integrate the landfill tax as a dummy variable into the regression analysis. Hence, Greece, Slovakia and Estonia are categorised as low income countries, meaning that the median equivalised net income was less than €10,000 in 2016. Additionally, Hungary and Portugal are middle income countries according to the categorisation of EUROSTAT. This means the median equivalised net income was between €10,000 and €16,500 in 2016. The Netherlands were the only country that was categorised middle/high (€16,500-23,000) and Norway the only country categorised as a high income country (>€23,000) in 2016. Having these countries included in the model, a variety of level of income countries is given, making it possible to draw conclusions between level of income and waste management performance as well as categorise the findings.

Table 6. *Countries' level of income and year of implementation of the landfill tax*

Country	Level of income	Year of implementation
Greece	Low	2014 (CEWEP, 2017)
Hungary	Middle	2013 (ibid.)
Netherlands	Middle/High	1995-2012 (ibid.)
Norway	High	1999-2015 (Papineschi et al., 2019)
Portugal	Middle	2007 (CEWEP, 2017)
Slovakia	Low	2014 (ibid.)
Estonia	Low	2005 (ibid.)

In Table 13 in the Appendix, the descriptive statistics of the countries that implemented the landfill tax in the period 2004-2016 are presented. The differences between the control variables that have an impact on the implementation of the landfill tax as well as on the food waste in total are visible. Having the level of income in mind it seems obvious that countries with a low level of income like Greece, Slovakia and Estonia are investing less capital in waste management. This is the case for Slovakia and Estonia but not for Greece. Therefore, the results have to be analysed carefully to not draw wrong conclusions.

The implementation of the landfill tax was one of the earliest solutions to combat food waste thus more countries could have been included in the model to see how much of an impact the landfill tax will have on food waste. In Table 6, the regression results are shown. All R^2 of the analysis from the countries are very high and close to one, which would indicate that almost all of the variance of the dependent variable that can be explained by the independent variables. The values vary from 86.8 per cent in the case of Estonia up to 99.9 per cent in the case of Slovakia and the Netherlands as presented in Table 6. Also, the adjusted R^2 is high as well, except for Estonia which has a value of 0.207, which means that 20.7 per cent of total variance of the dependent variable can be explained by the model. The value is still sufficient for taking the results into account. Introducing a policy instrument like the landfill tax is connected to some constraints like if the population's income level is enough to be able to afford the high tax to manage the waste (Kiss et al., 2014).

Looking at the regression results of the impact of the landfill tax, the tax has a decreasing effect on food waste in the models of Hungary (-0.155), Norway (-0.561) and Portugal (-0.082) but an increasing effect on food waste in the models of Greece (0.394), the Netherlands (0.010), Slovakia (0.076) and Estonia (1.844). The value for the model of the Netherlands is really small (0.010), so it can almost be seen that the landfill tax is having no significant influence on the quantity of food waste. This was also the result by Mazzanti et al. (2012) for Italy. Thus, incineration and landfilling have no significant influence on the amount of food waste in Italy, which represent a middle income country.

The "CPI" is having a negative coefficient, decreasing the quantity of food waste in the models of Greece (-0.007), Hungary (-0.003), Portugal (-0.030) and Estonia (-0.058). Nonetheless, the influence is minimal and has only a slight impact on the quantity of food waste. The "CPI" has a positive coefficient for the models of the Netherlands (0.002), Norway (0.046) and Slovakia (0.009). This means that the "CPI" has an increasing effect, leading to higher amounts of waste. A high change in the costs for consumer to buy goods in service will result in volatility and can lead to panic buying that can result in an increase of wasted food.

Additionally to this economic variable, the "GDP per capita" takes an essential role of assessing the impact of policy instruments and their effect on the quantity of food waste (Miliute-Plepiene & Plepys, 2013; Miliute and Staniski, 2010). The results show that the "GDP per capita" has a negative coefficient for the models of Greece (-2.837), the Netherlands (-0.232) and Estonia (-0.719). The values are not very high but still have a decreasing effect that make them significant when multiplied with the amount of food waste. This results can also found in the paper by Dithmer & Abdulai (2017), where the "GDP per capita" is showing to have a positive effect on the reduction of food waste. The models for Hungary (0.252), Portugal (0.291), Norway (0.291) and Slovakia (2.172) have positive coefficients. In the paper by Ederveen et al. (2006) and De Weerdt et al. (2020) the results regarding the "GDP per capita" reflect a negative effect on waste management. That means, that the "GDP per capita" will increase the amount of food waste instead of minimising it. It is interesting to see that the results include different levels of income countries where the variable "GDP per capita" has an increasing effect. It seems that countries with low level of income will have less food waste than countries with higher levels of income because a wealthier population might care less about the food that is wasted. This could be because they can afford more food and are not as concerned about wasted food as a population that cannot afford an excess of food and has to be more conscious (Cox and Downing, 2007; WasteMinz, 2014).

Going over to the social variable "PD", the results in Table 6 are very different across the member states. According to the literature, the "PD" had a negative impact on food waste in Italy (Mazzanti et al., 2011) and Japan (Usui & Takeuchi, 2014) but a positive effect in France (Gnolonfin, 2016) and the US (Giovanis, 2015). Johnstone and Labonne (2004) came to the same results in their study about the

OECD countries. They assessed the amount of household solid waste and discovered that “PD” has a positive effect on it. Another paper by Mazzanti et al. (2008) and Mazzanti and Zoboli (2008) had the opposite findings. According to these papers and Hage and Söderholm (2008), the variable “PD” has an increasing effect on municipal waste in Italy and the EU25. Looking at the results in Table 9, the regression analysis of the Netherlands (-0.001), Norway (-0.274), Slovakia (-0.359) and Estonia (-0.716) are presenting negative coefficients. That means, that “PD” has a positive effect on the reduction of food waste. This stands in contrast to the findings by Dahlén et al. (2009), which found out that a higher population density is causing more food waste per capita. The analysis of Hungary (0.105), Portugal (0.014) and Greece (0.280) is showing positive coefficients, leading to an increase in quantity of food waste. These results go in line with the results of Dithmer & Abdulai (2017). A high population density as well as rural population have a negative effect on food security, leading to more inequality across the world.

The last control variable is “WM”, which indicates the amount of capital the countries invest in waste management annually. In the results, “WM” seems to have a negative coefficient in Greece (-1.244), Hungary (-0.214), Norway (-1.312), Portugal (-1.712), Slovakia (-2.236) and Estonia (-6.888). Only the analysis of the Netherlands has a positive coefficient, leading to an increase in food waste. This result seems to be very positive since almost all countries that have implemented the landfill tax have shown that the management of waste is effective and reduces food waste.

Table 7. *Regression results of the countries that implemented the landfill tax*

	Greece	Hungary	NL	Norway	Portugal	Slovakia	Estonia
Landfill tax	0.394	-0.155	0.010***	-0.561	-0.082*	0.076*	1.844
CPI	-0.007***	-0.003***	0.002***	0.046**	-0.030**	0.009***	-0.058*
LOG GDP per capita	-2.837	0.252	-0.232	0.291	0.561	2.172	-0.719
PD	0.280	0.105	-0.001***	-0.274	0.014**	-0.359	-0.716
LOG WM	-1.244	-0.214	0.432	-1.312	-1.712	-2.236	-6.888
SD	0.075	0.172	0.000	0.067	0.077	0.003	0.357
R^2	0.990	0.945	0.999	0.947	0.996	1.000	0.868
Adjusted R^2	0.939	0.671	0.997	0.682	0.973	0.998	0.207

The empirical results of the countries that have implemented the landfill tax are demonstrated in Table 7. Also, the regression results are different among the countries that is visible when looking at the p-value. Starting with the model of Greece, the p-values are higher than 0.10 which indicates that the results are statistically insignificant, resulting to accept the null hypothesis. This is also valid for the models of Hungary, Norway, Portugal and Estonia due to the high p-values. Accordingly to the study by Abeliotis et al. (2014, p. 239), the landfill tax as well as food waste prevention campaigns are "expected to produce positive environmental and economic results at both the household level and the overall waste management in Greece. In the results of the model from the Netherlands, the intercept (0.011) is highly significant denoting for 95 per cent level of confidence. The value of the dummy variable "landfill tax" is 0.023, which indicates a 95 per cent level of confidence. That means that the values are highly significant and the null hypothesis will be rejected in the model of the Netherlands. Additionally, the CPI and the GDP per capita have a significant p-value of 0.071 and 0.051 as well as the control variable "PD" with a p-value of 0.066, marking a 90 per cent level of confidence. The last control variable "WM" has not only a decreasing effect on the quantity of food waste but also a highly significant p-value (0.045). Comparing the results of the Netherlands with the results of Slovakia, the intercept is statistically highly significant (0.029) as well as the p-values of the control variables "GDP per capita" (0.017), "PD" (0.027) and "WM" (0.018). The dummy variable "landfill tax" has a negative effect on the reduction of food waste but its p-value is statistically significant (0.059) leading to retain the null hypothesis. The value marks a 90 per cent level of confidence with the value of control variable "CPI" (0,073).

As in the results of the incineration tax, the level of income of the countries seems to have low impact on the results, leading to the assumption that the income level and waste performance is only slightly correlated compliant with the collected data. Also, economic factors like the income increase environmental awareness on one hand but can vary across member states (Giovanis, 2015, p. 201).

Table 8. *Empirical results of the models of the countries that implemented the landfill tax*

Country	Predictors	Intercept	Landfill tax	CPI	GDP per capita	PD	LOG WM
Greece	Regressors	23.223	0.394	-0.007***	-2.837	0.280	-1.244
	p-value	0.229	0.339	0.581	0.321	0.338	0.242
Hungary	Regressors	-6.187	-0.155	-0.003***	0.252	0.105	-0.214
	p-value	0.935	0.839	0.978	0.965	0.921	0.902
NL	Regressors	5.840	0.010	0.002***	-0.232	-0.001***	0.432
	p-value	0.011**	0.023**	0.071*	0.056*	0.066*	0.045**
Norway	Regressors	13.553	-0.561	0.046**	0.291	-0.274	-1.312
	p-value	0.422	0.409	0.476	0.289	0.628	0.574
Portugal	Regressors	16.087	-0.082	-0.030**	0.561	0.014**	-1.712
	p-value	0.413	0.739	0.207	0.764	0.854	0.237
Slovakia	Regressors	42.157	0.076	0.009***	2.172	-0.359	-2.236
	p-value	0.029**	0.059*	0.073*	0.017**	0.027**	0.018**
Estonia	Regressors	91.150	1.844	-0.058*	-0.719	-0.716	-6.888
	p-value	0.731	0.773	0.553	0.727	0.695	0.778

* denotes significance at the 90% level of confidence
**denotes significance at the 95% level of confidence
***denotes significance at the 99% level of confidence

5.1.3 Pay-as-you-throw approach

Following the presentation and discussion of the prior two economic incentives, the incineration tax and the landfill tax, the waste management approach PAYT is presented in this chapter. In Figure 5, the amount of food waste that has been collected during the years 2004-2016 in the countries that introduced the PAYT approach is visible. It should be noted that in comparison to the countries included in the models of the other policy instruments, the countries in Figure 5 show different quantities of food waste. It is seen that the highest quantity of food waste was collected by the UK until 2008. After the financial crisis the curve has a drop that has a slightly increasing trend in the past years. For Ireland, Poland and Italy the trend is going downwards, leading to a trend of less food waste in the past years. Only France has a slightly increasing trend line that is almost stagnant since 2012. From all the countries presented in Figure 5, France has the highest amount of food waste since 2010 with a total of around 11,512,213 tonnes in 2016.

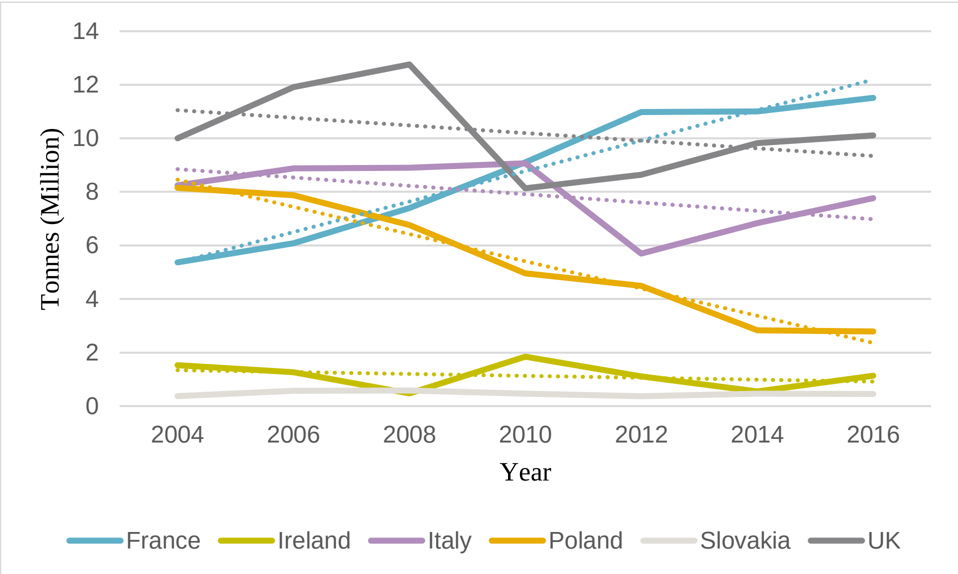

Figure 5. Animal and Food waste; vegetable waste of the countries that implemented the Pay-as-you-throw approach during the period 2004-2016. (Source: EUROSTAT, 2020)

Separating the countries into income levels, Table 8 is giving an overview of the categorisation. According to the categorisation of EUROSTAT, Slovakia is classified as a low income country with a median equivalised net income of less than €10,000 in 2016. The country implemented the PAYT in 2013. Furthermore, Italy and Poland are categorised as middle income countries (€10,000-16,500) as well as they introduced the approach in 2011 (Zagórska, 2015). In the paper by Gentil (2013) and Dunne et al. (2008), the countries France and Ireland implemented the PAYT approach from 2009 to 2014 in France and 2005 in Ireland. Both of these countries are categorised as middle to high level income countries (€16,500-23,000) as well as the United Kingdom that implemented the PAYT approach in 2014 (BBC, 2019).

Table 9. *Countries' level of income and year of implementation of the Pay-as-you-throw approach*

Country	Level of income	Year of implementation
France	Middle/High	2009-2014 (Gentil, 2013)
Ireland	Middle/High	2005 (Dunne et al., 2008)
Italy	Middle	2011
Poland	Middle	2011 (Zagórska, 2015)
Slovakia	Low	2013
United Kingdom	Middle/High	2014 (BBC, 2019)

The descriptive statistics of the countries that have implemented the PAYT approach are presented in Table 14, which can be found in the Appendix, giving an overview of the variables included in the model as well as the differences between the countries. It can be mentioned, that France and UK have the lowest mean "CPI" as middle to high income countries. Additionally, Italy, Poland and UK are characterised by a low mean "GDP per capita" as they are middle and middle to high income countries. The UK and Italy have the highest mean population density and the UK and France the highest amount of capital that is invested in waste management among these countries. The UK also has the highest amount of food waste collected, whereas Slovakia and Ireland have the lowest in comparison.

The regression results of the model including the policy instrument, PAYT approach, are shown in Table 9. The table provides the overview of the first results for further discussion. It can be seen that the R^2 are very high. Especially of the analysis of France, Slovakia and the UK, the R^2 are around 0.9999, indicating that 99,99 per cent of the variance in the dependent variable can be explained by the independent variables. The values of all R^2 are very similar and high of all countries as well as the adjusted R^2. This entails that for example for Italy 69.7 per cent of the total variance of the dependent variable "food waste" can be reasoned by the model. For the other country models, the adjusted R^2 is ranging between 0.987 up to 0.9999.

Taking a look at the coefficients of the variables, the results vary significantly between the countries. The intercept as the constant is showing a negative coefficient for Poland (-114.022) and UK (-29.187), while the value of the intercept from Poland, when all X are equal to 0, is high in comparison. For the models of France (7.598), Ireland (11.078), Italy (4.748) and Slovakia (42.157) the coefficient remains positive.

The dummy variable "PAYT" is presented to have both an increasing and decreasing impact on the quantity of food waste in Table 9. The PAYT approach have in the models of Italy (-0.190), Poland (-0.871) and the UK (-0.099) a negative coefficient. This accounts for a decreasing effect on food waste. According to Chalak et al. (2018) have frameworks (17.6%), awareness campaigns (21.3%) and incentives (14.3%) like the PAYT approach have an impact on the reduction of food waste. On the opposite are the results of the models France (0.157), Ireland (0.816) and Slovakia (0.076) where the PAYT approach has an increasing effect on food waste. The values are not very high even if it has a negative effect on the reduction of food waste in the EU and thus the achievement of the SDGs as well as targets set by the EU to cut food waste until 2030.

Since the variables “WM” and “CPI” have an extremely weak correlation it will be of interest to look at the coefficients that resulted out of the regression analysis. Thus, the “CPI” has a positive coefficient in the analysis of France (0.038), Poland (0.082) and Slovakia (0.009), which all have very low values. Hence, the “CPI” has an increasing effect but not a significant effect on the amount of food waste in these countries. For the models of Ireland (-0.131), Italy (-0.005) and the UK (-0.043) the coefficient is negative, which means that the “CPI” has positive impact on the reduction of food waste in these countries. All the countries where the “CPI” has a negative effect on food waste are middle and middle to high level income countries.

The next economic variable is the “GDP per capita” and shows both negative and positive coefficients across the countries included in the model. Because of this, the countries have to be considered separately. In the results, the “GDP per capita” only has a negative coefficient in the model of Ireland (-0.421), which is a middle to high country. The other models of France (2.494), Italy (0.004), Poland (0.122), Slovakia (2.172) as well as the UK (2.983) show that the “GDP per capita” has an increasing effect on food waste. According to Mak et al. (2020), in countries with a higher “GDP per capita” like Switzerland, the last stages of the food chain are accounts for the highest amount of food waste.

How dense the population is in a country is closely correlated to the amount of wasted food. The results of the analysis of France (0.023), Ireland (0.110), Italy (0.032), Poland (1.023) and the UK (0.053) show that the “PD” have a positive coefficient. This is resulting in an increase of the amount of food waste in these countries. This findings can also be found in the paper by Dahlén et al. (2009), where a higher population density resulted in an increase of food waste per capita. Especially for Italy, the food waste increases with population density (Cerciello et al., 2019). Only the model of Slovakia (-0.359) has a negative coefficient and therefore a decreasing effect on food waste.

The last control variable in the model is “WM” and is strongly correlated with the “PD”. In the regression results in Table 9, the “WM” have a negative effect on the reduction of food waste for the analysis of Ireland (0.671), which is also a middle to high income country. Even that the value is not significantly high, it seems that Ireland as a middle to high income country could invest more in waste management to decrease the effect on waste management. This is the case for the models of France (-3.343), Italy (-0.376), Poland (-1.799), Slovakia (-2.236) and the UK (-0.488). There the “WM” has a negative effect on the amount of food waste. It is significant that nearly all countries that implemented the PAYT approach show that “WM” contributes to combat waste.

Table 10. *Regression results of the countries that implemented the Pay-as-you-throw approach*

	France	Ireland	Italy	Poland	Slovakia	UK
PAYT	0.157	0.816	-0.190	-0.871	0.076*	-0.099*
CPI	0.038**	-0.131	-0.005***	0.082*	0.009***	-0.043**
LOG GDP per capita	2.494	-0.421	0.004***	0.122	2.172	2.983
PD	0.023**	0.110	0.032**	1.023	-0.359	0.053*
LOG WM	-3.343	0.671	-0.376	-1.799	-2.236	-0.488
SD	0.006	0.025	0.041	0.021	0.003	0.000
R^2	1.000	0.998	0.949	0.998	1.000	1.000
Adjusted R^2	0.998	0.987	0.697	0.988	0.998	1.000

The empirical results of France present a significant p-value for the intercept (0.099) as well as the dummy variable “PAYT” (0.096) and the control variable “CPI” (0.086) as shown in Table 10. All three variables are significant on a 90 per cent level of confidence. The dummy variable “PAYT” (0.065) and the control variable “WM” (0.073) are significant on a 90 per cent level of confidence for analysis of Ireland. Also, the control variables “CPI” (0.039) and “PD” (0.045) are highly significant on a 95 per cent level of confidence. A p-value under 0.10 indicates for a rejection of the null hypothesis, which makes the results statistically significant. In comparison to France, the analysis of Ireland shows an insignificance of the intercept. Going over to the country model Italy, all the variables are characterised by insignificant p-values, having a value above 0.10, resulting in accepting the null hypothesis. The analysis of Poland exposes a significant p-value of the intercept (0.082) and the control variable “PD” (0.078) on a 90 per cent level of confidence, while the other p-values remain statistically insignificant. Looking at the empirical results of the country Slovakia, the intercept (0.029) is highly significant as well as the “GDP per capita” (0.017), “PD” (0.027) and “WM” (0.018) on a 95 per cent level of confidence. The other variables “PAYT” (0.059) and “CPI” (0.073) are statistically significant on a 90 per cent level of confidence. All variables of the model Slovakia are significant, leading to rejecting the null hypothesis. In addition, the results of the variables of the UK that are presented in Table 14, showing highly significant p-values. Thus, the intercept has a p-value of (0.002) along with the dummy variable “PAYT” (0.006) and the control variables “CPI” (0.002), “GDP per capita” (0.002), “PD” (0.003) as well as “WM” (0.007). Having a p-value below 0.01 denoting significance at the 99 per cent level of confidence. Nonetheless, as in the results of the policy instruments “incineration tax” and “landfill tax”, the level of income of the countries is not closely connected to their waste performance. It is more dependent on amount of capital invest in waste management and if the topic is on the countries’ agenda and included in their targets.

Table 11. *Empirical results of the models of the countries that implemented the Pay-as-you-throw approach*

Country		Intercept	PAYT	CPI	LOG GDP per capita	PD	LOG WM
France	Regressors	7.598	0.157	0.038**	2.494	0.023**	-3.343
	p-value	0.099*	0.096*	0.086*	0.129	0.225	0.117
Ireland	Regressors	11.078	0.816	-0.131	-0.421	0.110	0.671
	p-value	0.147	0.065*	0.039**	0.339	0.045**	0.073*
Italy	Regressors	4.748	-0.190	-0.005***	0.004***	0.032**	-0.376
	p-value	0.461	0.228	0.740	0.939	0.296	0.577
Poland	Regressors	-114.022	-0.871	0.082*	0.122	1.023	-1.799
	p-value	0.082*	0.138	0.157	0.276	0.078*	0.172
Slovakia	Regressors	42.157	0.076	0.009***	2.172	-0.359	-2.236
	p-value	0.029**	0.059*	0.073*	0.017**	0.027**	0.018**
UK	Regressors	-29.187	-0.099*	-0.043**	2.983	0.053*	-0.488
	p-value	0.002***	0.006***	0.002***	0.002***	0.003***	0.007***

* denotes significance at the 90% level of confidence
**denotes significance at the 95% level of confidence
***denotes significance at the 99% level of confidence

6 Summary and concluding remarks

With the growing population and increasing demand for food, negative externalities are emerging. The current food system is unsustainable and the environmental, social and economic impacts must be taken under consideration. It is necessary to find a more efficient and sustainable way to produce food so that the world's food system can deliver better nutritional outcomes at a smaller environmental cost (Garnett, 2013). In this thesis, the impact of EU's policy instruments on the reduction of food waste was examined. The findings of this thesis aim to contribute to the research on food waste reduction in the EU, giving the example of three policies to compare with each other. Additionally, it seeks to discover the most efficient policy instrument that will complement the waste hierarchy. Thus, the findings are assisting to achieve the SDG's of the UN like SDG 2 (end hunger, achieve food security and improve nutrition, and promote sustainable agriculture) as well as SDG 12 (ensure sustainable consumption and production patterns). The empirical method of the thesis was a multiple regression analysis to analyse the different explanatory variables in order to gain knowledge about their impact for future operations and policy frameworks. This method or similar econometric methods were also chosen by several scholars to assess the impact of policies on either household or regional, national and international level (Sasao, 2014; Dithmer & Abdulai, 2017, Mazzanti et al., 2009; Mazzanti et al., 2011; Mazzanti & Zoboli, 2008).

When quantifying the amounts of food waste in the EU, nearly all countries included in the models had a decreasing trend in the period 2004-2016. Only France showed an increasing trend over the past years. Also, the Netherlands were showing a high amount of food waste, which might be due to the fact that the Netherlands are a major producer of agricultural products. There is a lack of common and harmonised methodology for collecting food waste data on EU level and global level that made it difficult to compare results of existing studies and statistics at national level (FUSIONS, 2014, p. 4; Bräutigam et al., 2014; Thyberg & Tonjes, 2016). This is valid especially between the EU member countries in the North and the South of Europe.

Going over to the main findings, the empirical analysis shows a significant positive correlation in the analysis of the landfill tax as well as the PAYT approach between the variables ”WM” and ”CPI”. Furthermore, the ”GDP per capita” and the ”PD” were positive correlated in the model of the landfill tax and the variables ”PD” and ”WM” showed a significant positive correlation in the model of the landfill tax and the PAYT approach. All other variables’ relationships were insignificant.

Looking at the empirical findings, the landfill tax seems mainly to have a decreasing effect on food waste for the countries included in the model, while the incineration tax and PAYT approach are both increasing as well as decreasing the quantity of food waste. The “CPI” is showing to have a negative effect on the amount of food waste in the model of the landfill tax and incineration tax, which refute the expected result. Only the models of the PAYT approach sharing both positive and negative coefficients in the results, resulting in a decreasing effect of the “CPI” on food waste. The “GDP per capita” is expected to increase food waste, which is confirmed by the models of the landfill tax, incineration tax and PAYT approach, leading to the conclusion that a higher GDP per capita is resulting into more food waste. Only the results of Slovakia refutes the findings, leading to a decrease in food waste. In a study by Padilla & Trujillo (2018), the results showed that the level of income and education is not connected to the waste performance, which lead to a reliability of the results of Slovakia. As the “PD” is expected to reduce food waste, the findings of the landfill tax and PAYT approach show the opposite. The models of the countries that implemented the incineration tax mainly show negative coefficients. Lastly, the variable “WM” was expected to have a negative coefficient, leading to a decrease of food waste. The results of the models of the landfill tax and the PAYT present that nearly all countries included, command of a sufficient waste management. Only the results of the models of the countries that implemented the incineration tax show an increase in food waste regarding their management of waste.

Additionally to the findings, the level of income seems to have no significant influence on the waste management performance or the quantity of food wasted. Accordingly to Pearson et al. (2013, p. 127), food waste appears on “all levels of income”. It can be said, that the results of the analysis differ across the countries and policy instruments. It seems that there is not one main efficient policy instrument, thus it is important to implement a variety of instruments like policies but also soft instruments as awareness campaigns to spread out knowledge and change consumer behaviour (Finnveden et al., 2013). It has to be proven that awareness campaigns were the most popular instrument in the EU over the past years that focussed to highlight the cost of food waste to consumers (Cerciello et al., 2019). A policy instrument that is effective does not necessarily have to be cost-effective (Andersson & Stage, 2018). Economic incentives seems often not longer up to date and ”[...] are often an impediment to new more environmentally sustainable technology (Cossu & Masi, 2013, p. 2546). A revision of policies might be necessary to improve waste management across the member states (Cossu & Masi, 2013). As seen in the EU, there is a decreasing trend of landfilling, leading to the conclusion that more environmentally friendly ways of disposal are managing waste as well as that the framework of the EU is entered into force (Mazzanti et al., 2011). Including the potential of technological development in the future, recycling could be equally efficient as incineration (Finnveden et al., 2007). According to Rispo et al. (2015), low-income communities for example with a high population density "[...] need more effort and resources to drive behavioural change towards food waste reduction". In order to combat food waste and achieve the targets of the EU as well as the UN Sustainable Development Goals, there is a need that all stakeholders of the food system are collaborating (Mourad, 2016; Beretta et al., 2013, p. 772). Also, the member countries of the EU as well as on an international view need to agree on one unified definition in regard to food loss and waste in order to make the results more transparent and the data more reliable. Some parts of food waste are challenging to avoid like peels etc. as well as it has to be kept in mind that redistribution of edible food is connected to costs like transportation and distribution (Schott et al., 2013; Buzby et al., 2014). There is also lack of literature that has assessed "the business or management side of food waste initiatives" that makes it "unclear which factors influence the success" (Aschemann-Witzel et al., 2017, p. 34). Accordingly to Bulkeley & Askins (2009, p. 258), there are three key targets to achieve – "technical innovations, attempts to change behaviour, and efforts to enrol new waste streams" for better and more effective waste disposal. The government needs further enforcement to create a more ”socially responsible and sustainable pathway" for the supply chain (Devin & Richards, 2018, p. 208). Thus it would be beneficial to include several stakeholders like municipalities, local authorities etc. to debate sustainability of food and focussing on the ”culture of valuing resources" (Garnett, 2013; Giovanis, 2015, p. 202). This would be also necessary to moralise about the ethical aspect of food waste as well as adress drivers (Gjerris & Gaiani, 2013; Hebrok & Broks, 2017). For further research, scholars need to assess further the impact of different policy instruments on a macro level to create a sustainable and resilient food system that is able to cope with the environmental challenges and at the same time provide enough food to feed the growing urban and global population.

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Appendix 1

Table 12. *Correlation matrix*

Policy instrument		CPI	GDP per capita	PD	WM
Incineration tax	CPI	1	0.023	0.105	-0.047
	GDP per capita	0.023	1	-0.182	-0.328
	PD	0.105	-0.182	1	-0.021
	WM	-0.047	-0.328	-0.021	1
Landfill tax	CPI	1	0.132	0.081	0.125
	GDP per capita	0.132	1	0.294	0.562
	PD	0.081	0.294	1	0.663
	WM	0.125	0.562	0.663	1
PAYT	CPI	1	0.164	0.024	0.008
	GDP per capita	0.164	1	0.038	0.023
	PD	0.024	0.038	1	0.782
	WM	0.008	0.023	0.782	1

Table 13. Descriptive statistics Incineration tax

Country		CPI	LOG GDP per capita	PD	LOG WM	Incineration tax (dummy variable)	LOG FW
Sweden	Mean	99.68	10.57	22.99	8.87	0.50	6.20
	SD	4.55	0.34	0.83	0.05	0.50	0.02
	Min	92.29	9.75	21.92	8.80	0.00	6.16
	Max	104.61	10.77	24.36	8.96	1.00	6.23
Austria	Mean	100.99	10.66	101.81	8.30	0.50	6.33
	SD	7.85	0.05	2.14	0.06	0.50	0.15
	Min	89.30	10.56	98.96	8.19	0.00	6.13
	Max	111.68	10.71	105.87	8.38	1.00	6.57
Ireland	Mean	101.06	10.73	65.13	7.11	0.50	6.01
	SD	5.11	0.05	3.19	0.24	0.50	0.21
	Min	90.93	10.67	59.08	6.77	0.00	5.68
	Max	105.66	10.81	69.03	7.40	1.00	6.27
Norway	Mean	99.38	10.77	13.42	8.85	0.50	5.93
	SD	7.86	0.33	0.62	0.10	0.50	0.11
	Min	88.00	9.99	12.57	8.69	0.00	5.77
	Max	112.44	11.01	14.34	8.97	1.00	6.07

Country		CPI	LOG GDP per capita	PD	LOG WM	Incinera-tion tax (dummy variable)	LOG FW
Spain	Mean	99.39	10.46	91.39	9.83	0.50	6.72
	SD	7.35	0.05	2.63	0.09	0.50	0.13
	Min	86.06	10.39	85.98	9.65	0.00	6.56
	Max	107.05	10.55	93.51	9.91	1.00	6.95

Table 14. *Descriptive statistics Landfill tax*

Country		CPI	LOG GDP per capita	PD	LOG WM	Landfill tax (dummy variable)	LOG FW
Greece	Mean	96.02	10.36	85.21	9.16	0.50	5.68
	SD	7.60	0.07	0.86	0.15	0.50	0.28
	Min	82.40	10.24	83.60	8.88	0.00	5.12
	Max	104.88	10.49	86.28	9.39	1.00	6.04
Hungary	Mean	96.97	10.11	110.66	8.39	0.50	5.87
	SD	14.34	0.06	1.62	0.11	0.50	0.28
	Min	74.27	10.01	108.41	8.22	0.00	5.48
	Max	111.82	10.20	112.78	8.53	1.00	6.26
NL	Mean	100.76	10.69	492.74	9.64	0.50	7.05
	SD	6.62	0.05	8.07	0.03	0.50	0.00
	Min	91.14	10.61	482.28	9.58	0.00	7.05
	Max	109.53	10.76	505.50	9.68	1.00	7.06
Norway	Mean	98.77	10.31	114.51	8.70	0.50	5.61
	SD	9.22	0.05	0.94	0.11	0.50	0.43
	Min	85.03	10.25	112.72	8.46	0.00	5.21
	Max	109.08	10.39	115.44	8.80	1.00	6.44
Portugal	Mean	99.66	10.16	112.21	8.58	0.50	5.66
	SD	8.79	0.13	0.47	0.11	0.50	0.07
	Min	84.51	9.90	111.69	8.38	0.00	5.57
	Max	109.09	10.27	112.95	8.68	1.00	5.76
Slovakia	Mean	99.38	10.77	13.42	8.85	0.50	5.93
	SD	7.86	0.33	0.62	0.10	0.50	0.11
	Min	88.00	9.99	12.57	8.69	0.00	5.77
	Max	112.44	11.01	14.34	8.97	1.00	6.07
Estonia	Mean	98.37	9.89	31.23	7.60	0.50	5.17
	SD	13.26	0.68	0.67	0.10	0.50	0.37
	Min	76.00	8.26	30.24	7.39	0.00	4.57
	Max	112.03	10.30	32.14	7.76	1.00	5.68

Table 15. *Descriptive statistics Pay-as-you-throw approach*

Country		CPI	LOG GDP per capita	PD	LOG WM	PAYT (dummy variable)	LOG FW
France	Mean	99.90	10.59	118.60	10.07	0.50	6.93
	SD	5.26	0.04	2.50	0.08	0.50	0.12
	Min	91.16	10.53	114.52	9.93	0.00	6.73
	Max	105.77	10.66	122.11	10.18	1.00	7.06
Ireland	Mean	101.06	10.73	65.13	7.11	0.50	6.01
	SD	5.11	0.05	3.19	0.24	0.50	0.21
	Min	90.93	10.67	59.08	6.77	0.00	5.68
	Max	105.66	10.81	69.03	7.40	1.00	6.27
Italy	Mean	100.08	10.25	201.50	9.95	0.50	6.89
	SD	6.74	0.46	3.68	0.11	0.50	0.07
	Min	89.20	9.49	196.12	9.78	0.00	6.76
	Max	107.46	10.60	206.67	10.11	1.00	6.96
Poland	Mean	100.65	9.91	124.33	8.67	0.50	6.70
	SD	6.28	0.35	0.21	0.13	0.50	0.18
	Min	89.72	9.09	124.01	8.43	0.00	6.45
	Max	107.69	10.15	124.64	8.84	1.00	6.91
UK	Mean	100.21	10.63	259.41	10.23	0.50	7.00
	SD	9.26	0.03	7.75	0.06	0.50	0.06
	Min	86.31	10.59	247.96	10.11	0.00	6.91
	Max	112.08	10.67	271.13	10.30	1.00	7.11
Slovakia	Mean	99.66	10.16	112.21	8.58	0.50	5.66
	SD	8.79	0.13	0.47	0.11	0.50	0.07
	Min	84.51	9.90	111.69	8.38	0.00	5.57
	Max	109.09	10.27	112.95	8.68	1.00	5.76

Popular Scientific Summary
Master thesis in food science – EX0875
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Assessing the impact of policy instruments on food waste reduction in the EU

In a human's life, there are several needs that has to be satisfied. One of the most urgent needs is nutrition. In order to fulfil these need, food security has to be provided all around the world. But, the current food system is unsustainable, being characterised by unequal distribution of food across the world. This not only lead to the triple burden of malnutrition (hunger, micro-nutrient deficiencies and obesity) but also to several economic, evironmental and social consequences. Achieving a population of 9 billion by 2050 will increase urbanization, demand for food and wealth. The current agricultural system is shaped by monocultures that has deprived the natural resources at an alarming rate. Environmental consequences like soil pollution, degradation, loss of biodiversity are only a few examples of these consequences. Moreover, the ongoing climate change and the unsustainable agricultural production will make it even harder to produce food in the future and provide food security. This is even more controverse since there is enough food produced on the world to feed the whole population. It is about the distribution and the food that is lost in the process as well as wasted at the consumer and retailer stage. It is known that around 1/3 of the food that is produced is wasted or lost, resulting in an emergence way to find a solution for it. Food loss is characterised to happen more often in developing countries, due to lack of infrastructure like cooling facilities etc., while food waste is characterised to happen more often in developed countries. This is because of the oversupply, high appearance standards of the food and the lifestyle change that occured in the past years. The population tend to demand more convenient food that is easy to grasp as well as the demand for more land and water demanding foods are increasing, like milk and dairy.

There are several actions needed to find a solution for not only the current unsustainable food system but also the food loss and waste problem that is interlinked with it. The UN published several goals to fight food insecurity and food waste and loss around the world, like the SDG 2 (end hunger) and 12 (ensure sustainable consumption and production patterns) as well as the EU implemented directives and published a Circular Economy Package to set targets for combatting waste. One way to fulfil the goals and targets is to implement economic incentives for example taxes or fees to let the population pay for the waste they produce or provide subsidies in developing countries to avoid food loss. Therefore, this thesis took a look at three different economic incentives, the incineration tax, the landfill tax and the pay-as-you-throw approach and their impact on the reduction of food waste. The focus was on the member states of the EU, where food waste is appearing more often that food loss. To analyse the research questions, a multiple regression analysis was utilized that includes several variables and calculate the amount that the variables influences food waste in a negative or positive way. In the model, independent variables covering all three pillars of sustainable development were included. In the analysis not all member states of the EU could have been assessed due to the quantity of data on food waste. It was only a dataset available from the period 2004-2016, which lead to an exclusion of several countries. Nevertheless, there were still five member states for the incineration tax, seven for the landfill tax and six for the pay-as-you-throw approach available. It was shown, that each economic incentive and member states' results varied significantly and the level of income of the member states had not an influence on the amount of food waste or waste performance. Also, the quantities of food waste in the member states varied, which is due to the lack of unified definition of food waste acroos the member countries as well as the poor quantity of data. But in general the results show that the landfill tax has a decreasing effect on food waste and the incineration tax and PAYT approach show both, an increasing and decreasing effect on food waste. Overall, it can be said that the variable ”WM” had for almost all member states a decreasing effect on food waste, which results in the conclusion that waste management is viable.

All in all, the economic incentives that were included in the model are the most common ones to use for waste disposal but there is no prefect incentive or instrument to reduce food waste. Thus, a variety of instruments like taxes, subsidies, campaigns, knowledge and education has to be applied to reduce food waste and achieve the SDG's 2 and 12 as well as the targets set by the EU. A collaboration of all stakeholders operating in the food chain is needed as well as unified definition of food waste and loss to make data more reliable and transparent and be able to include more member states for better comparison.

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