How an Incineration Tax Changes Waste Management Practices among Firms

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Abstract

Sustainable management of industrial plastic waste is crucial in the transition to a circular economy. Today, most industrial plastic waste is incinerated, whereas it could be recycled. As a consequence, governments increasingly make use of incineration taxes to improve current waste management practices. This paper presents an econometric panel analysis that studies the effects of an incineration tax on industrial plastic waste in Flanders (Belgium). Not only is this study the first econometric analysis on industrial plastic waste management in which firm heterogeneity is explicitly taken into account by including firm-specific characteristics, but this study also provides policymakers with insights into the effectiveness of an incineration tax to change current waste management practices. Empirical estimates imply that heterogeneous firms generate industrial plastic waste in different ways and that heterogeneous firms reduce their waste generation in different ways after the incineration tax rate increases. The estimates also show that the unique decrease of the incineration tax in 2007, did not change waste management practices. These estimates show that firms do not disinvest or indicate that loss aversion theory, i.e. a preference for avoiding losses over acquiring equivalent gains, might apply to firms that are faced with environmental taxation in a waste management context.

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1 Introduction

Globally, waste management has become an increasingly important topic. The United Nations explicitly refer to the crucial enhancement of waste management in their Sustainable Development Goals [UN, 2016]. The World Bank states that improving waste management will contribute significantly to reaching the Paris agreement goals [Kaza et al., 2018]. The European Union (EU) recently adopted a new circular economy (CE) action plan that strongly focuses on waste management [EC, 2020].

Indeed, the EU's strategies to become more circular have mainly been built upon their waste management strategy, set out in the waste framework directive [EP, 2008]. The latest circular economy action plan [EC, 2020] - constituting one of the main building blocks of the European Green Deal [EC, 2019] - states that the European Commission (EC) will make additional efforts to support its Member States in their waste management. These efforts will enable the EU to become more circular in the near future.

In the EU's pursuit of circularity, plastics are placed high on the agenda. As a result, a European strategy for plastics in a circular economy has been developed [EC, 2018]. The strategy's aim is to enhance recycling rates of plastics by 2030. Therefore, in the upcoming years, the EC together with Member States, will audit existing and develop new waste management policies that incentivize recycling and avoid the incineration of plastics [EC, 2018]. Since more than 90 percent of the waste that is generated in the EU has an industrial origin [EC, SA], and most studies focus on household waste, the focal point of this study will be on industrial plastic waste.

This study consists of an econometric panel analysis of the effects of an incineration tax[2]. The tax studied in this paper is, i.a. levied to minimize industrial plastic waste in Flanders (Belgium). Although the study focuses on Flanders, results transcend Flemish and even EU borders. Many states levy incineration taxes [Sasao, 2014] to mitigate the planetary threat plastic waste poses [OECD, 2018]. Therefore, in this matter, the study provides policymakers with important insights into the effectiveness of a policy tool aiming at alleviating the increasing threat of plastic waste. To the best of our knowledge, this is the first study to include firm heterogeneity - in the form of firm-specific variables, such as turnover

[2]Type of environmental tax. An environmental tax, is a tax that causes an incentive not to pollute or harm the environment.

- in the econometric panel analysis of a CE policy [De Weerdt et al., 2020, Sasao, 2014].

The remainder of the study is structured as follows: Section 2 introduces the relevant literature on waste management, how firm heterogeneity could impact the effectiveness of waste management policies, and the industrial waste management framework in Flanders. In Section 3, a choice model is developed in which a firm optimizes its waste generation after an incineration tax is levied. This theoretical model provides guidance for interpreting the estimations. Section 4 introduces the materials and method. In Section 5, estimations are presented and discussed. Section 6 concludes on the study's findings.

2 Waste Management

2.1 Environmental Taxes in a Waste Management Context

Many have studied environmental taxes in the context of household waste management. However, mostly due to the scarcity of publicly available data on industrial waste generation, collection, and treatment, studies on environmental taxes in a context of industrial waste management are rather scarce. Below, the most important literature on household waste management is introduced, followed by the presentation of studies on environmental taxes in an industrial waste management context. Note that certain insights from the household waste management literature might hold in a context of industrial waste management.

A good overview of existing literature on environmental taxes in a household waste management context can be found in the study by Dijkgraaf and Gradus [2004] and Sewak et al. [2021]. The main conclusion in this strand of literature is that weight-based-pricing is more effective than a flat rate in reducing waste (see for example the study of Bartelings and Sterner [1999]). However, De Jaeger and Eyckmans [2015] warn that the effectiveness in reducing waste of weight-based-pricing vs. unit-based-pricing might be overestimated due to an introductory effect, i.e. households show a stronger reaction in the first months after the introduction of weight-based-pricing schemes. Moreover, Mazzanti and Zoboli [2008] and Mintz et al. [2019] find that socio-economic drivers and cultural considerations, respectively, have a significant influence on the effectiveness of household waste management policies. In conclusion, weight-based-pricing schemes are found to be effective in reducing household waste. However, the effectiveness is not always sustained throughout time and drivers of the effectiveness can be of a socio-economic or cultural origin. Note that in a context of industrial waste management there is reason to believe firms' culture and economic performance could also bring about a different reaction to environmental taxes. Even more so, bearing in mind that according to standard microeconomics different marginal costs among firms would logically cause different reactions to one single tax rate.

Environmental taxes in the context of industrial waste management have not been widely studied. Based on the existing literature, it remains unclear whether environmental taxes are an effective policy tool in this context. Andersen and Dengsøe [2002], Martin and Scott [2003] and Vallés-Giménez et al. [2010] find that differentiated environmental taxes on the treatment of industrial waste fail to change the type of treatment or the firms' waste generation. The studies were performed in Denmark, the UK, and Spain, respectively. The low environmental tax rate in Denmark is suggested as a possible cause for the ineffectiveness. In Spain, only a few federal regions levy environmental taxes. As a consequence, most waste is found to be exported to other regions with a zero environmental tax rate on the treatment of industrial waste. By way of contrast, Sigman [1996], Sasao [2014], and De Weerdt et al. [2020] find that environmental taxation does influence industrial waste management practices. The studies were performed in the USA, Japan, and Flanders, respectively. The studies' estimates suggest that firms are, to a slight extend, price sensitive towards the environmental taxes assessed. In the USA and Flanders, the assessed environmental taxes are found to be low. Consequently, these taxes only represent a small fraction of the entire waste management cost. It is believed that higher environmental tax rates - constituting a larger fraction of the entire waste management cost - would have a more pronounced effect on the type of treatment or on firms' waste generation [De Weerdt et al., 2020].

None of the above-mentioned studies take firm-specific characteristics into account and thus they consider firms to be homogeneous[3]. However, Mazzanti and Zoboli [2008] and Mintz et al. [2019] find it is wrong to consider households to be homogeneous when studying waste management. Likewise, heterogeneous firms might react differently to an incineration tax on industrial plastic waste [Krass et al., 2013]. Therefore, in this study, apart from including firm-

[3]Panel studies that allow individual errors in different time periods to be correlated, or fixed effects models, or random effects models do not consider all firms to be homogeneous. However, including firm-specific data in a panel analysis will augment the consistency of the estimates.

independent variables, such as the state of the economy, firm-specific variables are also included. Note that the study focuses on Flanders and that cultural differences - found to be drivers of effectiveness by Mintz et al. [2019] - cannot be included as variables.

2.2 Firm Heterogeneity in a Waste Management Context

The firm-specific variables included in our analysis are largely based upon the firm's organizational strategy. According to the literature presented below, firms can be categorized on a continuum, characterized by full efficiency and full flexibility as opposite extremes. The firm's choice to be either efficient or flexible is driven by the strategy to supply standard or made-to-order, i.e. customized, products or services [Randolph and Dess, 1984, Chrisman et al., 1998]. Note that efficiency is defined as standard mass production and should not be confused with economic or technical efficiency, flexibility is defined as customized production. In the past, it was generally accepted firms could not pursue both efficiency and flexibility simultaneously [Doty et al., 1993, Fiegenbaum and Karnani, 1991]. More recently, researchers have not focused on the dichotomy between efficiency and flexibility so much, but have recognized the trade-off between characteristics of both extremes in the pursuit of success [Andriopoulos and Lewis, 2009, Eisenhardt et al., 2010, Eckel and Neary, 2010, Kortmann et al., 2014]. This study builds upon the more recent consensus in the literature. Organizational characteristics are included as variables, enabling us to measure the possibly heterogeneous effects of an incineration tax on industrial plastic waste generation.

Studies measuring firm performance in relation to their organizational strategy help us to identify key characteristics of different strategies. Ebben and Johnson [2005] conduct such a study and base their work on Thompson and Bates [1957], Joan [1965], Thompson [1967], Filley and Aldag [1980], Lowson [2001], Zipkin [2001]. Ebben and Johnson [2005] state that efficient firms use specialized and heavy fixed assets. Flexible firms typically use fewer assets but employ more labour. Efficient organizations have a formal and more rigid organizational design that contrasts with the organic organizational design that characterizes flexible firms. Therefore, total assets and number of employees, both relative to turnover, are included as proxies for efficiency and flexibility. The number of directors relative to turnover is used as a proxy to measure the formality and the rigidity of the organizational design.

Firms typically run an optimized production. Given the heterogeneity of firms, the marginal reduction cost of waste is also expected to be heterogeneous. Consequently, heterogeneous firms might react differently to a changing tax rate. Efficient firms experience high (marginal) reduction costs for plastic waste. The (marginal) reduction cost is high because the entire production line is organised to minimize production costs. A small change in the incineration tax rate does not shift marginal costs sufficiently to re-organize the production line. Typically re-organizing a production line comes with a sunk cost, e.g. shutting down production for a certain time in order to make appropriate changes. Therefore, efficient firms might prefer to run a quasi-optimized production instead or re-optimizing. However, if the incineration tax rate should increase sharply, it could shift (marginal) costs sufficiently for efficient firms to re-optimize their production. In summary, efficient firms are only expected to show reactions to a significantly changed tax rate. Flexible firms on the other hand, are expected to instantly reduce their waste generation when the incineration tax rate increases. Since their production is unit-specific and requires recurrent production planning, it is expected that flexible firms re-optimize their waste generation immediately. However, labourers are typically less economical with regard to material use compared to machines. One reason is that reducing material use would require more - expensive - labour time. Relatively labour-intensive production processes are therefore expected to level out the waste minimizing dynamic driven by flexible firms. In summary, firms optimize their waste generation but efficient and flexible firms experience different (marginal) reduction costs, causing different reactions to a changing incineration tax rate.

Profit or loss is also included in the analysis. No difference between profitable and non-profitable firms is expected. The decision concerning waste generation is a marginal decision and is therefore not linked to profits. Note that including a performance variable, such as profit or loss, could possibly create an endogeneity. In Appendix, Table 5, this hypothesis is rejected.

2.3 Industrial Waste Management in Flanders

In 1981, the Flemish Government, responsible for waste management in Flanders, set up the 'Public Flemish Waste Agency' (OVAM). This agency has been regulating industrial waste streams ever since[4]. The OVAM mainly regulates by means

[4]Decreet van het Vlaamse Gewest van 2 juli 1981 betreffende het beheer van afvalstoffen.

of environmental taxes, e.g. an incineration tax[5], to incentivize sustainable waste treatment. Since this study focuses on the incineration tax on industrial plastic waste, the paper continues by introducing details on the relevant incineration tax and the common practices of industrial plastic waste collection and treatment in Flanders.

Flemish firms that generate industrial plastic waste typically contract with a waste collecting firm. The waste collecting firm delivers the industrial plastic waste to a waste treatment firm (see Figure 1). It is the waste treatment firm that decides on the type of treatment. Since waste collecting and treatment firms compete on a price level, the cheapest type of treatment will be chosen. Given the landfill ban for most materials in Flanders, incineration and recycling are the two most popular types of treatment. In the case of industrial plastic waste, most waste is incinerated due to a capacity shortage for recycling plastics in north-western Europe [Brooks et al., 2018, Qu et al., 2019]. Therefore, waste generating firms, assumed to fully bear the incineration tax [De Weerdt et al., 2020], can, in the short run, only avoid paying the incineration tax by reducing their waste generation. Consequently, the incineration tax on industrial plastic waste does not influence the type of waste treatment, but rather influences industrial plastic waste generation in the short run. Note that in Flanders, if the incineration tax is due, it is the waste treatment firm that has the obligation to pay the tax to the Flemish tax authority[6] (see Figure 1, path a). However, in the event that the waste treatment firm is located outside Flanders, the obligation to pay the tax rests on the waste collecting firm[7] (see Figure 1, path b). This rule avoids exports of waste for reasons of environmental tax evasion, as analyzed by Vallés-Giménez et al. [2010].

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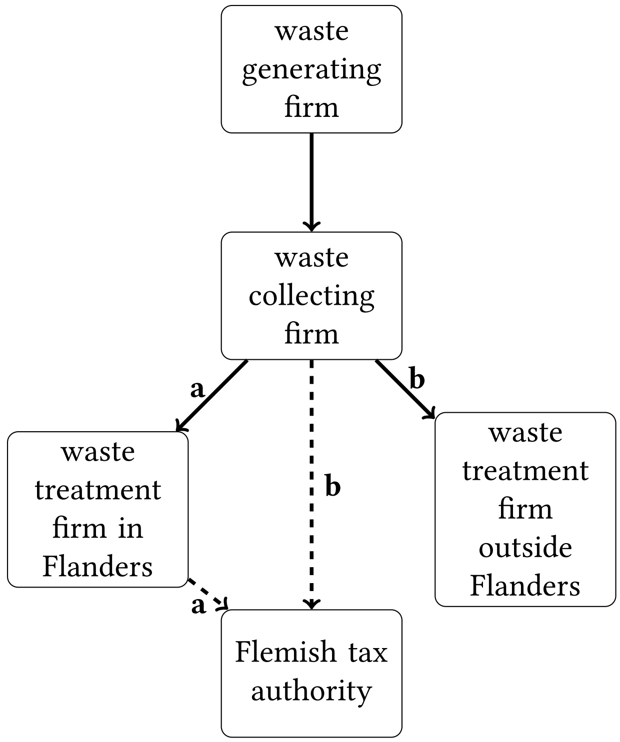
[5] Incineration taxes were first levied in 1990; Decreet van de Vlaamse Raad van 20 december 1989 houdende bepalingen tot uitvoering van de begroting van de Vlaamse Gemeenschap.

[6] Nevertheless, waste generating firms are well informed about the incineration taxes linked to the treatment of their waste. That is because the invoice of the waste collecting or treatment firm will typically provide detailed information on the taxes due. Providing this information protects the waste collecting or treatment firm from paying the taxes if the waste generating firm would, e.g. be a defaulter. Described in article 51 Decreet van de Vlaamse Overheid van 23 december 2011 betreffende het duurzaam beheer van materiaalkringlopen en afvalstoffen .

[7] Possibly corrected for foreign environmental taxes, art. 46 §1 19° Decreet van de Vlaamse Overheid van 23 december 2011 betreffende het duurzaam beheer van materiaalkringlopen en afvalstoffen . This article works similar to treaties for the avoidance of double taxation.



(a) Path a is followed when industrial waste is treated inside Flanders. In case the opposite holds, path b is followed.

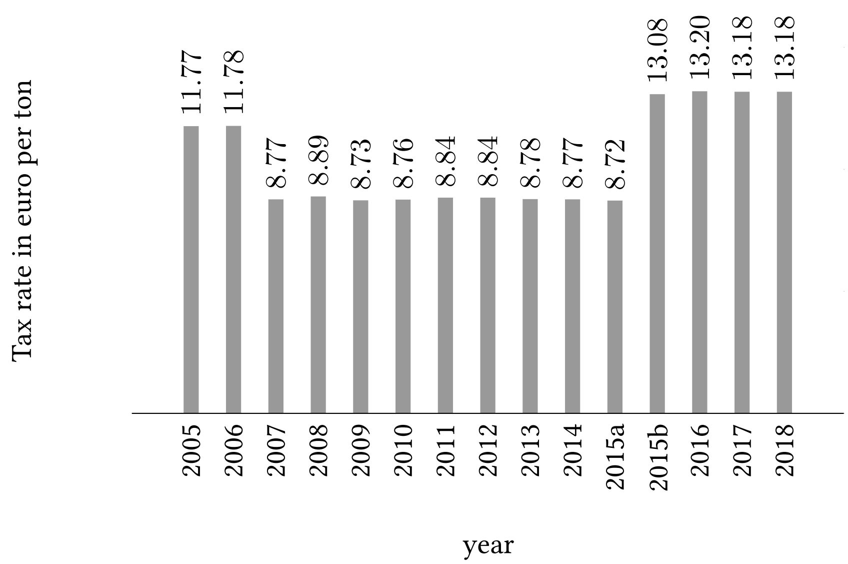
Figure 1: Waste Collection and Treatment Practices in Flanders

Figure 2 provides more information on the incineration tax levied on industrial plastic waste. This tax is called the 'incineration tax on high calorific value waste'. Within the time period of the panel data studied in this paper (2005-2018), the tax rate has known two jumps. In 2007, the tax rate was set at 7 euros per ton (in 2007 euros), while after the second quarter in 2015, the rate increased by 50 percent[8]. Therefore, Figure 2 includes two tax rates for 2015, namely 2015a and 2015b. Note that the 2015b tax rate is used in the analysis. In all other years, the tax rate has been adjusted to the consumer price index on January 1[9]. Note that

[8]Article 46 § 6 Decreet van de Vlaamse Overheid van 23 december 2011 betreffende het duurzaam beheer van materiaalkringlopen en afvalstoffen .

[9]Article 46 § 5 Decreet van de Vlaamse Overheid van 23 december 2011 betreffende het duurzaam beheer van materiaalkringlopen en afvalstoffen .

prices are corrected for inflation, not for the consumer price index, hence the small yearly fluctuations. Since the tax rate has known sudden jumps in 2007 and in 2015, it is clear that the rate is not set according to the external costs generated by the incineration of high calorific value waste. This is unfortunate given the consensus in the literature that incineration tax rates should represent the external costs generated by the incineration [Pigou, 1932, Fullerton and Kinnaman, 1995, Dubois, 2013]. The OVAM does not explain why the tax rate was subject to drastic changes, they only communicate that they aim at promoting sustainable waste treatment through differentiated tariffs, e.g. for low and high calorific value waste [OVAM, SA]. Therefore, more detailed information on the decision concerning the tax rate cannot be provided.



(a) Since the tax rate increased with 50 percent after the second quarter in 2015, two tax rates are reported: 2015a and 2015b.

(b) Note that these tax levels are expressed in 2019 euros as found by the National Bank of Belgium.

Figure 2: Incineration Tax High Calorific Value Waste

3 Model

In this section, a theoretical choice model is developed in which a firm is confronted with a classical cost minimization problem. This model, built upon the information introduced in Section 2, offers the option to a firm to lower its waste generation at a cost. The firm chooses its optimal waste generation so that total costs and taxes are minimized.

Suppose a firm's production is characterized by a material intensity per produced unit, denoted by η_0, in reference year $t = 0$. η is an element of $\mathbb{R}^+$, that follows from the fact that the minimum material used in any production is zero. Suppose the relative waste intensity of the material that is being used per produced unit, i.e. the relative amount of material that is being wasted per produced unit, is denoted by μ_0, in reference year $t = 0$. $\mu \in [0, 1]$, that follows from the fact that the firm cannot waste less than zero and not more than the material it uses as an input. Given that Q is the total production, it follows $\eta_0\mu_0 Q$ represents total waste generation. Suppose the material price is denoted by P^m, and if the country or region in which the firm operates levies a tax on the treatment of industrial waste, and if that tax is fully borne by the waste generating firm, the total cost of waste generation sums up to $\eta_0\mu_0 Q(P^m + tax)$, with tax representing the applicable tax rate.

However, the waste generating firm has the option to lower its relative waste intensity, μ by $\omega \in [0, 1]$. After investing in ω, the firm generates $\eta_0\mu_0(1 - \omega)Q$ waste. The level of ω is chosen by the firm, based on the marginal costs of generating and reducing waste. Following standard microeconomics, it is assumed that the cost for ω per produced unit, follows a strictly increasing, convex, and continuous function that is denoted by $C(\omega)$. This cost function increases because reducing waste is bounded by, i.a. technical limits. The cost function is calibrated by a function $f(\gamma)$ that contains firm-specific and economy-wide characteristics. As a result, every firm experiences an individual cost function for reducing its waste generation. Therefore, also the total cost of waste generation, C_W, is firm-specific:

$$C_W = \eta_0\mu_0(1 - \omega)Q(P^m + tax) + C(\omega)f(\gamma)Q \tag{1}$$

The firms chooses a level ω so that C_W is minimized. This level can be found by differentiating equation (1) to ω.

$$\frac{dC_W}{d\omega} \ [\eta_0\mu_0(1 - \omega)Q(P^m + tax) + C(\omega)f(\gamma)Q] = 0 \tag{2}$$

$$-\eta_0\mu_0(P^m + tax) + C'(\omega)f(\gamma) = 0 \tag{3}$$

$$\iff \omega = C'^{-1}\left(\frac{\eta_0\mu_0(P^m + tax)}{f(\gamma)}\right) \tag{4}$$

The optimal level of ω thus depends upon the material intensity, the relative waste intensity, the material price, the tax rate, and the firm-specific characteristics. Note that the material price has a double effect. Suppose P^m increases, then the firm will try to lower μ, but the firm will also try to waste less material. When μ decreases, ω decreases, when P^m increases, ω increases as well. Therefore, the effect of P^m on ω is expected to be low since opposite dynamics level each other out. On total waste generation an increase of P^m - e.g. after the incineration capacity would be reduced - will of course have a negative influence.

Equation (4) teaches us why certain firms might not react to environmental taxes, while others do. Economically, this situation corresponds with different firm-characteristics, e.g. labour-intensive production processes that increase the marginal waste reduction costs. As long as the marginal cost for wasting is smaller than the marginal reduction cost, firms will not change their waste generation. Therefore, with this simple model, it is shown that in an industrial waste management context, homogeneity amongst firms cannot simply be assumed, e.g. flexible firms will typically have lower marginal waste reduction costs that cause a different reaction to an increasing incineration tax rate. This result closely follows the conclusion of Mazzanti and Zoboli [2008] who researched environmental taxes in a household waste management context. Consequently, the analysis below will investigate which firm-specific or economy-wide characteristics, included in $f(\gamma)$, influence the level of ω significantly.

4 Materials and Method

In this section, the unique data that is used to measure the effectiveness of an incineration tax to change firms' industrial plastic waste generation, is introduced. With this in mind, two datasets are merged; the yearly plastic waste generation per firm in Flanders[10] (from 2005 to 2018) is merged with firm-specific data. The latter data captures the heterogeneity between firms, found to be essential in this

[10]Unbalanced panel data: firms' waste generation over time with a drop-in-drop-out option based on the PRTR threshold

study (see Section 3). These datasets are provided by the OVAM and Orbis Global [Orbis, SA], respectively.

Data on annual waste generation per firm is collected by the OVAM. The resulting dataset is called 'The Integral Environmental Annual Report'. These data are only partly analysed by merely focusing on plastic waste generation. Particularly, on a rest fraction of plastics, reported under the EURAL-code 200139. This fraction contains plastic waste that could not be attributed to a more specific category, such as plastic waste from scrapped cars or plastic waste contaminated with hazardous materials. Within the Integral Environmental Annual Report data, firms are subdivided based upon whether or not their activities are specified in the 'Pollutant Release and Transfer Register' (PRTR). This register, adopted by many countries after the 1992 Rio de Janeiro summit and by the EU in 2007 [EP, 2006], largely focuses on polluting firms. PRTR-registered firms either generate waste beyond a threshold[11,12], or are active in a sector that automatically registers the firm. Once registered in the PRTR, firms have to declare their waste generation on a yearly basis, others do not have this obligation. As a consequence, there exists unbalanced[13] panel data for PRTR-registered firms only. Given the availability of this data, it is chosen to focus on this subgroup of firms in this study. Note that the registration in the PRTR is not random. Therefore, one should be careful when extrapolating results.

The PRTR-registered firms are merged with the Orbis Global dataset. The latter contains firm-specific data that is retrieved from financial statements, balance sheets, etc. With Orbis Global's online tool, around 96 percent of the firms are merged. Firm-specific variables introduced in Section 2.2 are included, but also turnover and a dummy variable for manufacturing firms, based on the NACE-code[14] is included.

After including the firm-specific variables, a fraction of 14 percent of the observations is dropped for two reasons. Firstly, based on the NACE-code and the description of the business activity, all firms that are active in waste collection or treatment are dropped. That is because the OVAM does not correct, e.g. for

[11] The thresholds were set aiming to cover about 90 percent of industrial pollution in Europe.

[12] The possible selection bias was tested by De Weerdt et al. [2020] and was found not to impact results significantly.

[13] Not an observation for every firm in each year of the studied time period.

[14] Nomenclature statistique des Activités économiques dans la Communauté Européenne. This code exists of sections, departments, groups, and classes.

residual waste after processing. As a consequence, waste that is generated by these firms is partly counted double. Secondly, a larger fraction of the firms has missing firm-specific data. Since this type of data is essential in the design of the study, these observations are ignored. The cause for missing data is assumed to be random.

Apart from firm-specific data, also a dummy variable for the financial crisis between 2008 and 2012[15] and a producer price index (PPI) defined for manufacturers of rubber and plastics in the Euro area are included. This index is calculated by Eurostat and is based on ex-factory-gate prices[16]. By including this index, the raw material prices to produce plastics are taken into account. The relation between these prices and waste management is straightforward and elaborated on in Section 3.

The resulting unbalanced data consists of 2,017 observations attributed to 385 different firms, over a time interval of 14 years (2005-2018). For the estimations, presented below, the study concentrates on three time intervals: (i) the entire time interval (2005-2018), (ii) the time interval during which the tax rate was lowered, offering a natural experiment to estimate the effect of a decreasing environmental tax rate (2005-2014), (iii) the time interval during which the tax rate was increased (2013-2018). The second and third time interval are chosen so that they start 2 years before the tax rate changes. The second time interval ends just before the second tax rate change occurred. The third time interval ends in 2018, the last year available in our data. By including more years in the second and third time interval, the consistency of our estimates increases. The effect of firm-specific variables can be measured more precisely, and coincidental changes can be noticed more easily.

Table 1 presents the summary statistics of three time intervals studied. Observe that there are relatively more observations in the third than in the second time interval. This is not entirely unexpected, the use of plastics is ever increasing [OECD, 2018]. Note that waste generating firms also pay a price for waste collection and treatment. Unfortunately, no detailed information on these prices is available. Consequently, this price is not included in the analysis. However,

[15]In 2008, a first bank was bailed-out by the Belgian Government, marking the start of the financial and economic crisis in Belgium. 2012 corresponds with the ‘end’ of the European bail-out of Greece.

[16]Including indirect taxes, except for VAT, and excluding transport costs.

given that the market of collection and treatment is competitive, these prices are assumed to be equal per capacity for every firm. Moreover, these prices are assumed not to be correlated with the tax rate. Hence, omitting this price in the analysis does not cause any problem for the estimations.

Table 1: Summary Statistics

Variable	**Unit**	**Firms**	**Obs.**	**Mean**	**SD**	**Min**	**Max**
2005-2018							
Turnover	euro	385	2,017	$4.28e^{8}$	$1.37e^{9}$	575,345	$2.77e^{10}$
Waste	ton	385	2,017	51.45	213.88	0.00	4,071
Tax	euro/ton	n.a.	n.a.	10.55	2.04	8.72	13.20
Directors	number	385	2,017	4.82	5.04	1	50
Employees	number	385	2,017	739.61	2,001.05	1	25,806
Assets	euro	385	2,017	$5.01e^{8}$	$1.92e^{9}$	552,185.10	$5.46e^{10}$
Profit or loss	euro	385	2,017	$2.13e^{7}$	1.23^{8}	$-1.71e^{8}$	$3.79e^{9}$
PPI	index	n.a.	n.a.	97.34	3.71	89.42	101.49
2005-2014							
Turnover	euro	296	1,259	$4.08e^{8}$	$1.18e^{9}$	575,345	$1.66e^{10}$
Waste	ton	296	1,259	54.64	235.21	0.00	4,071
Tax	euro/ton	n.a.	n.a.	9.28	1.10	8.73	11.78
Directors	number	296	1,259	4.77	4.84	1	50
Employees	number	296	1,259	737.52	1,831.22	1	25,631
Assets	euro	296	1,259	$4.76e^{8}$	$1.46e^{9}$	552,185.10	$1.62e^{10}$
Profit or loss	euro	296	1,259	$1.76e^{7}$	$6.18e^{7}$	$-1.31e^{8}$	$8.31e^{8}$
PPI	index	n.a.	n.a.	95.71	3.63	89.42	100.20
2013-2018							
Turnover	euro	331	1,104	$4.40e^{8}$	$1.55e^{9}$	594,241.90	$2.77e^{10}$
Waste	ton	331	1,104	47.88	174.16	0.02	2,967.55
Tax	euro/ton	n.a.	n.a.	11.63	2.10	8.72	13.20
Directors	number	331	1,104	4.78	5.07	1	50
Employees	number	331	1,104	695.61	2,021.28	1	25,806
Assets	euro	331	1,104	$5.17e^{8}$	$2.25e^{9}$	552,185.10	$5.46e^{10}$
Profit or loss	euro	331	1,104	$2.41e^{7}$	$1.57e^{8}$	$-1.71e^{8}$	$3.79e^{9}$
PPI	index	n.a.	n.a.	100.31	0.62	99.62	101.49

In real 2019 prices.

Before performing any estimation, the data is transformed. Firstly, the tons of waste, number of directors and employees, and profit or loss, are divided by the turnover of the firm. After this transformation, the concerning variables are expressed relative to turnover. Consequently, the comparisons between firms is easier. In the remainder of the study these variables are referred to as relative, e.g. relative industrial plastic waste generation (dependent variable). Secondly, the natural logarithm of all continuous non-negative variables is taken.

Note that three types of variables are included in our estimations: (i) natural logarithms of non-negative continuous variables, (ii) continuous variables, and (iii) dummy variables. Since the dependent variable is expressed as $ln\left(\frac{waste_{jt}}{turnover_{jt}}\right)$, coefficients of (i) natural logarithms of non-negative continuous variables should be interpreted as elasticities. Coefficients of (ii) continuous variables should be interpreted as: a unit change of the variable generates a 100 $\times$ (coefficient) percent change of the dependent variable. Coefficients of (iii) dummy variables should be interpreted as: the change from 0 to 1 generates a 100 $\times$ (coefficient) percent change in the dependent variable. Note that also interactions between the variables are included. The rationale for interactions is clear, different types of firms might react differently to a changing tax rate[17]. The interaction is only included if significant estimates for that interaction is found in one of our estimations. All other possible interactions are not included since estimates are consistently insignificant.

The analysis starts by defining which model is most appropriate to estimate the dynamics sought for in our data. According to the Breusch and Pagan Lagrangian Multiplier (BPLM) test, a pooled model, i.e. a model that does not take any possible firm heterogeneity into account and thus ignores the panel characteristic, does not fit our data. Therefore, panel techniques are used in this study. Throughout all our estimations, the Hausman test consistently indicates that the random effects model is consistent. Note that the fixed effects model is based on the ordinary least squares estimator and that the random effects model is based on the generalized least squares estimator. In large samples, the latter reports smaller variances compared to the former. Hence, in our case, the random effects model is preferred[18]. Therefore, only the estimates of the efficient and consistent random effects model are presented. Unfortunately, the Akaike and the bayesian information criterion to choose between models and variables can-

[17] A firm with characteristic A might react differently compared to a firm with a characteristic B. However, a firm with characteristic A and B will not necessarily have the reaction found by the sum of the reactions, but will have a unique reaction linked to the combination of characteristics A and B.

[18] Note that, contrary to De Weerdt et al. [2020], after including firm-specific data, there exists no autocorrelation in the data. As a consequence non-dynamic models fit our data.

not be included. That is because the random effects model is not estimated by a maximum likelihood estimator. As a consequence, the information criterions are not defined for the random effects model. Nevertheless, the R^2 measures are reported. The overall R^2 is a weighted average of the R^2 measuring the variation between firms and within a firm.

5 Estimations and Discussion

Table 3 reports the estimates of the random effects model, applied to the data of the first time interval (2005-2018). In Table 2, 3, and 4, the first column with estimates represents the estimates without interactions, the second column with estimates includes interactions. During the time interval (2005-2018), the incineration tax rate changed twice. In 2007 the tax rate was lowered; in 2015 it was raised (see Figure 2). It is found that the incineration tax has a negative significant effect on relative industrial plastic waste generation (elasticity of approximately -0.55 to -0.60). If the tax rate would increase with, e.g. 10 percent, relative industrial plastic waste generation would decrease with more than 5.5 percent. Firms are thus inelastic with regard to the incineration tax.

The relative number of directors and employees in a firm also have a significant effect on the dependent variable. It is found that firms with relatively more directors generate relatively more industrial plastic waste. At this stage, a highly insignificant estimate for the interaction between the relative number of directors and the incineration tax is found. Table 2 indicates that relatively labour-intensive production processes generate relatively more industrial plastic waste. As introduced in Section 2.2, it is argued that relatively labour-intensive production processes are characterized by high waste generation, since expensive labour time is needed to reduce waste generation.

Our estimates imply that the relative total assets of a firm have a significant positive effect on the dependent variable when an interaction with the tax rate is included. Also when the interaction effect is accounted for, the coefficient should still be interpreted as an elasticity. However, the elasticity now also depends on the tax rate. Since the interaction term's estimate has a negative sign, it is concluded that firms backed by relatively more assets, generate relatively more industrial waste, but that these firms react to a strong incineration tax rate change.

None of our estimations find that the relative profit or loss has a significant effect on the dependent variable. Since waste generation is a marginal decision, the lack of significance could be expected. These estimates thus confirm our model. However, we also draw the attention to the fact that Belgian firms are taxed on their profits. Since our data is retrieved from financial statements - typically containing artificially low profits in order to avoid taxes - we advocate for care in drawing conclusions. In order to be sure that a performance indicator, such as the relative profit or loss, is not creating an endogeneity, estimations in which the relative profit or loss is included are presented in Appendix, it is found that estimates are highly robust.

The PPI has a significant negative, albeit small, effect on the dependent variable. This result follows our intuition. The estimates of the dummy variable for manufacturing firms is not significant. However, the p-value in parentheses, especially in the first column, is only just large enough to accept the null hypothesis, which states that the estimate is zero. Finally, it is found that the estimate of the dummy variable for the financial crisis (2008-2012) is significant and negative.

Table 3 reports the estimates of the random effects model applied to the data of the second time interval (2005-2014). During this time interval the tax rate changed once. In 2007 the tax rate was drastically lowered. Two variables stand out when Table 2 is compared with Table 3. Firstly, the incineration tax has no significant effect on relative industrial plastic waste generation. These estimates show that firms do not disinvest or indicate that the theory of loss aversion[19], introduced by Kahneman and Tversky [1979] and Tversky and Kahneman [1991], might apply to firms in a waste management context. This theory would state that firms show a more pronounced reaction to a raised incineration tax rate, than to a lowered one, because the incineration tax - a loss and therefore highly valued - can be avoided by relatively reducing the industrial plastic waste generation. Secondly, the relative total assets and the interaction with the tax rate do not have a significant effect on the dependent variable.

Table 4 reports the estimates of the random effects model applied to the data of the third time interval (2013-2018). During this time interval, the incineration tax rate was raised by 50 percent in 2015. When comparing Table 4 with Table 2,

[19]This theory implies that people experience a greater impact when they loose than when they win.

and after performing a t-tests, it is found that the estimates for the incineration tax in Table 4 are, in absolute value, significantly larger than the estimates presented in Table 2. We argue the reason is that the third time interval only studies the increase of the incineration tax rate. Therefore, these estimates follow the previously introduced results, stating that firms do not disinvest or that the loss aversion theory applies.

Moreover, the relative total assets are found to have a significant effect on the dependent variable. Note this estimate is reported in the model without interactions between the variables. Comparing this estimate with the estimates found by the model with interactions (in Table 2 and Table 4), teaches us that the negative sign is probably driven by the increased incineration tax rate. Additionally, we are surprised by the insignificant estimates for the PPI. Since no detailed information on the drivers of the index is available, the insignificance of the estimates cannot be attributed to a certain market dynamic. Furthermore, it is found that the interaction between manufacturing firms and the relative number of directors has an almost significant positive effect on relative industrial plastic waste generation. This implies that formal and rigid manufacturing firms generate even more relative industrial plastic waste compared to solely formal and rigid or solely manufacturing firms.

In general, we are confident to say that our study joins the strand of literature which finds that environmental taxes in an industrial waste management context are effective. However, our estimates suggest an important nuance. Table 3 clearly indicates that a decrease of the incineration tax rate is not effective in terms of changing firms' relative industrial plastic waste generation. This result stands in stark contrast with the estimates found for an increasing incineration tax rate. Note that there was only one decrease of the incineration tax rate, the persistence of this effect is unclear. Moreover, our estimations also clarify the relation between organizational strategies and reactions to environmental taxes in a waste management context. It is found that efficient firms generate more relative industrial plastic waste than flexible firms do. However, one cannot conclude that efficient firms lack flexibility. On the one hand, hierarchical firms tend to generate relatively more industrial plastic waste, indicating a possible lack of flexibility in the past. On the other hand, the interaction between the tax rate and the relative total assets, suggests that asset backed firms - typically efficient firms - show a strong reaction. One can conclude that labour-intensive production processes - typically run by flexible firms - are waste-intensive. This is driven by high marginal reduction costs arising form high labour costs.

In summary, it is found that heterogeneous firms generate industrial plastic waste heterogeneously, confirming our model. Only indications are found confirming that heterogeneous firms show heterogeneous reactions to a changing incineration tax rate. Nevertheless, we argue the incineration tax rate is low and only accounts for a small fraction of the waste management cost. As a consequence, the incineration tax only impacts marginal costs moderately, leading to very moderate and only slightly heterogeneous reactions of firms.

Table 2: Estimation Results 2005-2018

	no interactions ln(relative waste)	interactions ln(relative waste)
ln(tax)	-0,562**	-0,635***
	(0,012)	(0,005)
ln(relative directors)	0,879***	0,790***
	(0,000)	(0,000)
ln(relative employees)	0,297***	0,291***
	(0,002)	(0,002)
ln(relative total assets)	-0,0746	1,194**
	(0,366)	(0,042)
relative profit or loss	0,0483	0,106
	(0,919)	(0,823)
manufacturing	0,267	2,290
	(0,162)	(0,234)
PPI	-0,0301***	-0,0304***
	(0,009)	(0,008)
crisis	-0,162*	-0,167*
	(0,075)	(0,067)
ln(tax) $\times$ ln(relative total assets)		-0,547**
		(0,029)
manufacturing $\times$ ln(relative directors)		0,120
		(0,290)
constant	6,530***	5,171**
	(0,000)	(0,017)
obs.	2,017	2,017
firms	385	385
R^2 between	0.44	0.44
R^2 within	0.06	0.06
R^2 overall	0.34	0.35

p-values in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Table 3: Estimation Results 2005-2014

	no interactions ln(relative waste)	interactions ln(relative waste)
ln(tax)	-1,087	-1,028
	(0,128)	(0,165)
ln(relative directors)	0,858***	0,814***
	(0,000)	(0,000)
ln(relative employees)	0,266**	0,261**
	(0,010)	(0,012)
ln(relative total assets)	-0,00321	-0,570
	(0,972)	(0,750)
relative profit or loss	-0,347	-0,333
	(0,533)	(0,551)
manufacturing	0,329	1,362
	(0,127)	(0,552)
PPI	-0,0381**	-0,0387**
	(0,018)	(0,016)
crisis	-0,201**	-0,203**
	(0,034)	(0,033)
ln(tax) $\times$ ln(relative total assets)		0,259
		(0,751)
manufacturing $\times$ ln(relative directors)		0,0602
		(0,650)
constant	7,792**	6,886*
	(0,011)	(0,052)
obs.	1,259	1,259
firms	296	296
R^2 between	0.45	0.45
R^2 within	0.05	0.05
R^2 overall	0.36	0.36

p-values in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Table 4: Estimation Results 2013-2018

	no interactions ln(relative waste)	interactions ln(relative waste)
ln(tax)	-0,672***	-0,723***
	(0,007)	(0,004)
ln(relative directors)	0,916***	0,753***
	(0,000)	(0,000)
ln(relative employees)	0,302**	0,289**
	(0,018)	(0,025)
ln(relative total assets)	-0,340***	0,901
	(0,007)	(0,264)
relative profit or loss	0,384	0,388
	(0,625)	(0,621)
manufacturing	0,346	4,138*
	(0,127)	(0,084)
PPI	0,0353	0,0353
	(0,650)	(0,650)
ln(tax) $\times$ ln(relative total assets)		-0,504
		(0,124)
manufacturing $\times$ ln(relative directors)		0,225
		(0,111)
constant	0,832	-1,962
	(0,915)	(0,807)
obs.	1,104	1,104
firms	331	331
R^2 between	0.43	0.43
R^2 within	0.03	0.04
R^2 overall	0.36	0.36

p-values in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

6 Conclusion

This study presents new and nuanced evidence on the effectiveness of environmental taxes in an industrial waste management context, in Flanders (Belgium). Our empirical findings, based on a non-random sample, show that an incineration tax is only effective in minimizing industrial plastic waste generation if the tax rate increases. In other words, our empirical findings indicate that a decreasing incineration tax rate has no effect on industrial plastic waste generation. Note this result is based on a unique reduction in the incineration tax rate in 2007. Hence, the recurrence of this absent effect is unclear.

Estimates also imply that firm-specific variables have a substantial effect on a firm's industrial plastic waste generation. Efficient firms generate relatively more industrial plastic waste compared to flexible firms. Estimates indicate that heterogeneous firms might show heterogeneous reactions to an increasing incineration tax rate. Consequently, the policy choice of the OVAM to tax firms uniformly, can be questioned from a policymaker's point of view. From an environmental economics point of view, a homogeneous tax resembles a Pigouvian tax best.

These findings entail two important policy implications. Firstly, there is no compelling argument, but only indications, for differentiating the tax rate. However, it is found that firm heterogeneity leads to different approaches to industrial plastic waste generation. Therefore, policymakers should devote their efforts to firms that generate relatively more plastic waste, e.g. efficient firms. Influencing these specific firms could lead to relative waste reduction. Secondly, it is found that an increasing tax rate leads to the minimization of industrial plastic waste generation. Therefore, we advocate a steady but cautious increase of the incineration tax rate to a level equal to the external cost caused by the incineration. Since the marginal reduction cost curve steepens, the minimizing effect of an incineration tax will disappear. Therefore, it is important that policies that stimulate the investment in more sustainable waste treatment options, if the waste can be treated more sustainably, are put in place. Note that if plastics cannot be recycled or substituted with a different recyclable material, the tax rate will become an unnecessary burden on firms. Therewith, highlighting the importance to take into account recyclability in the product design phase.

In this study, estimates indicate that the loss aversion theory might apply to firms that are faced with environmental taxation in a waste management context.

It would be very interesting for future research to look into this hypothesis. We believe that studying different material flows and different environmental taxes could lead to conclusive evidence. Furthermore, better data collection with regard to the final treatment of industrial plastic waste will become important soon. Without more details, the follow-up of the dynamics caused by the incineration tax will become challenging. Since the analysis is performed on a non-random sample, it would be interesting to perform a similar study on a random sample. A possible extension in that case would be to include a sustainability parameter in the analysis.

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Appendix

Table 5: Estimation Result Excluding Relative Profit or Loss

	2005-20018	**2005-2014**	**2013-2018**
	ln(relative waste)	ln(relative waste)	ln(relative waste)
ln(tax)	-0.562**	-1.086	-0.672***
	(0.012)	(0.128)	(0.007)
ln(relative directors)	0.878***	0.859***	0.917***
	(0.000)	(0.000)	(0.000)
ln(relative employees)	0.294***	0,270***	0.293***
	(0.002)	(0.009)	(0.020)
ln(relative total assets)	-0.0775	-0.0118	-0.319***
	(0.340)	(0.895)	(0.007)
manufacturing	0.268	0.325	0.354
	(0.159)	(0.133)	(0.117)
PPI	-0.0300***	-0.0386**	0.369
	(0,009)	(0,016)	(0.636)
crisis	-0.162*	-0.198**	
	(0.075)	(0.036)	
constant	6.460***	7.885***	0.592
	(0.000)	(0.010)	(0.939)
obs.	2,017	1,259	1,104
firms	385	296	331
R^2 between	0.44	0.45	0.43
R^2 within	0.06	0.05	0.03
R^2 overall	0.34	0.36	0.36

p-values in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$