Working Paper Series
No. 42

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November 2011

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Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA E DA TECNOLOGIA

Achieving compliance with healthcare waste management regulations: empirical evidence from small European healthcare units

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Abstract

Healthcare units generate substantial amounts of hazardous or potentially hazardous wastes as by-products of their medical services. The inappropriate management of these wastes poses significant risks to people and the environment. In Portugal, as in other EU countries, the collection, storage, treatment and disposal of healthcare waste is regulated by law. Although legal provisions covering the safe management of healthcare waste date back to the 1990s, little is known about the compliance of Portuguese healthcare units with the relevant regulations.

In this study we evaluate the extent of compliance by small private healthcare units with current waste management regulations, and its determinants. Recent estimates indicate that these units account for at least 20% of the healthcare waste produced at the national level. Their large numbers, however, make monitoring and government control of their compliance with legislative requirements problematic. Using data collected by a national survey of over 700 private healthcare units, we find that the majority of these units do not comply with current waste management regulations. An estimated generalized linear model uncovers a regional effect on the degree of compliance, which is also influenced by the type of healthcare delivered, use of service providers, implementation of regular internal audits, etc. The strongest factor influencing the degree of compliance is, however, education and training.

This result is extremely important for policy because it shows empirically that providing education and training for all healthcare workers on medical waste issues is crucial in order to attain proper practices in healthcare waste management and compliance with regulations.

Keywords: Waste management, medical waste, legislation, compliance

JEL Classifications: I18, Q53

1. Introduction

Healthcare units generate substantial amounts of hazardous or potentially hazardous wastes as by-products of their medical services. Based on official data, Ferreira and Teixeira (2010) indicate that total healthcare waste produced in Portuguese hospitals in 2005 was 3.5 Kg/(occupied bed.day); more recent data (APA, 2010) indicates a corresponding measure of about 7.0 Kg/(occupied bed.day) in 2006. These figures are in line with those estimated for high-income countries (Pruss et al., 1999). In addition, about 20% of this waste is deemed hazardous (APA, 2010; Tavares and Barreiros, 2004), potentially generating a variety of risks, including HIV/AIDS and hepatitis B and C as a result of exposure to these wastes, particularly among healthcare workers (Pruss et al., 1999). Extensive research conducted in the last decades has established that the appropriate management of these wastes significantly reduces the risks to people and the environment caused by healthcare waste, as well as the costs associated with its disposal (eg., Fay et al., 1990; Bencko and Culikova, 1993; Pruss et al., 1999; Silva et al., 2004; Tudor et al., 2005; Tsakona et al., 2007, Harhay et al., 2009).

In Portugal, as in other EU countries, the collection, storage, treatment and disposal of healthcare waste is regulated by law. Although legal provisions covering the safe management of healthcare waste date back to the 1990s, little is known about the compliance of Portuguese healthcare units with the relevant regulations. Recently, Ferreira and Teixeira (2010) evaluated the healthcare waste management practices in three hospitals (two private and one public) in the Algarve region of southern Portugal, and concluded that they are generally satisfactory (but for waste separation procedures). This region, however, is the lowest regional producer of healthcare waste in Portugal, contributing with just 1.6% of total healthcare waste production in the country in 2005

(Ferreira and Teixeira (2010)). In addition, the production of hazardous healthcare waste does not occur only in hospitals and public healthcare centers; other producers, such as private nursing homes, dental offices, outpatient clinics, clinical laboratories, physicians' offices etc., also contribute significantly to the total amount of healthcare waste produced in the country. Using the official data reported in APA (2010), Almeida (2010) estimates that these healthcare units account for at least 20% of the healthcare waste produced at the national level. Their large numbers, however, make monitoring and government control of their compliance with legislative requirements problematic.

The objective of this paper is to present an assessment of the current situation in small private healthcare units in Portugal, and analyze possible determinants of their compliance behavior with current waste management regulations. The data used was collected by a national survey of private healthcare units registered at the office of the Portuguese Health Regulatory Entity conducted in March – May 2010. The paper is organized as follows. Section 2 provides a summary of Portuguese legislation on healthcare waste management. Section 3 presents the survey instrument elaborated to investigate the degree of compliance with those regulations by healthcare units. Section 4 contains the characterization of compliant versus noncompliant units, and an analysis of the determinants of compliance. Concluding remarks and recommendations are underlined in Section 5.

2. Legislative framework

A definition of healthcare waste was established for the first time in Portuguese legislation in November 1995 (Dec. Lei 310/95) concerning a restricted number of healthcare activities. That definition has been subject to modifications over the years in order to cover a larger and more diversified number of healthcare activities. The current

legal definition of healthcare waste is established in a legal text issued in September 2006 (Dec. Lei 178/2006) as "*the waste resulting from medical activities taking place in healthcare facilities, prevention activities, diagnosis, treatment, rehabilitation and research, related to human beings or animals, in pharmacies, in forensic medicine, in teaching, and in any other involving invasive procedures such as acupuncture, piercing and tattoos*". The same legal text establishes that the responsibility for the management of healthcare waste belongs to the *producers* of such waste.

The existing legislative framework also establishes that the treatment of healthcare waste must be differentiated in accordance with the type of waste produced. A classification system for healthcare waste is established by law (Despacho 242/96, 13 August), separating healthcare waste in four categories or groups: Group I – this waste is considered to be equivalent to urban waste, presenting no special requirements in its treatment; Group II – this is non-hazardous medical waste, not subject to specific treatments, and may be treated as urban waste; Group III – this is considered as biohazard medical waste, requiring incineration or other effective pre-treatment with a view to subsequent disposal as urban waste; Group IV – this group comprises various types of hazardous waste subject to mandatory incineration. Thus, the first two groups of waste are deemed non-hazardous waste, while the last two are deemed hazardous waste.

In addition to this classification system, the same legal text establishes specific requirements to handle healthcare waste. In particular, is specifies that waste must be segregated at the point of generation, and stored at a temporary storage place in specific colored containers (black containers for Group I and II waste; white containers marked with a biohazard sign for Group III waste; red containers for Group IV waste). It also specifies that Group III and Group IV waste must be stored at a different place from the

waste belonging to Groups I and II. The storage place must have a minimum storage capacity corresponding to 3 days of production, and, in case the collection period exceeds those 3 days, the storage place must be equipped with a refrigeration system. In any case, the period between collections cannot exceed 7 days. Finally, each healthcare unit must have a waste management plan.

3. The survey

In order to evaluate the extent of compliance by healthcare units with current waste management regulations, a survey was designed and sent out to the healthcare units based in continental Portugal, and registered at the office of the Portuguese Health Regulatory Entity (PHRE). Answers to the survey were collected during March – May 2010 using an electronic survey platform developed by PHRE. Rough estimates based on the HRE data indicate a response rate of about 20% from the private health care units without admittance (this relatively low response rate is similar to those found in other countries – eg, Marinkovic et al., 2008).

The survey was composed of two broad parts. The first part consisted on questions regarding a general characterization of the unit. Some questions were on the date of birth, number of workers, type of services provided (each healthcare unit coulde indicate several types of services, if applicable), etc. The second part consisted on questions concerning the amount of various types of medical waste generated, to what extent it is sorted at the point of generation, the usage of appropriate containers, the availability of a waste storage place for Groups III and IV waste (different from that used for Groups I and II), the periodicity of waste collection for the various types of waste produced. Further questions were related to the existence of a contract with authorized companies for Groups III and IV waste treatment, whether the waste

management plan has been prepared and followed, who (if any) in the unit is responsible for healthcare waste management, whether internal waste audits have been regularly conducted, and whether training opportunities on waste handling issues have been provided to the unit's staff.

4. Results and discussion

A. Descriptive statistical analysis

After discarding observations with missing values for the relevant questions asked in the survey, the working sample consists of 741 private healthcare units in continental Portugal. These units do not have beds for hospitalization, and are in general visited by patients for basic medical examinations and treatments, medicine prescriptions, medical advice, etc. A characterization of their compliance with the legal requirements identified in the previous section is presented in Table 1.

All of these units indicate that the produced waste is segregated at the point of generation as required by law. In addition, about 91% indicate that the produced waste is stored at a temporary storage place in the colored containers specified in the legislation. However, only 30% of the healthcare units in the sample comply with the requirement of storing the Groups III and IV waste in a different place from that used to store the waste belonging to Groups I and II. Compliance with the requirement that the period between collections is not to exceed 7 days is observed by only 23% of the units. Finally, only 34% of the healthcare units indicate having the waste management plan as required. Thus, apart from segregation, compliance with waste management regulations is in general quite unsatisfactory.

Table 1 – Compliance with legal requirements

Specific Legal Requirements	Percentage of compliant units
§0. Segregation at the point of generation	100.00
§1. Appropriate colored containers	90.55
§2. Availability of required waste storage place	30.09
§3. Period between collections ≤ 7 days	23.08
§4. Waste management plan - WMP	34.14

A description of the healthcare units in the sample, and of those compliant with each of the above identified legal requirements (§1 - §4), is presented in Table 2. The figures in the Table show that the majority of the sample is comprised of dental clinics, followed by medical offices. Laboratories, nursing offices, and physical medicine & rehabilitation, represent 10%, 9%, and 8% in the sample, respectively. Other types of healthcare units, such as radiology offices, anatomical pathology, etc, make up about 9% of the sample. It is important to notice that these percentages do not add up since each unit may be classified in more than one category.

The percentage of units indicating the delivery of dental services is higher amongst those that are compliant with legal requirements §1 (containers), §2 (waste storage place), and §4 (WMP), but substantially lower than the overall in the sample amongst those compliant with legal requirement §3 (collection period). In fact, out of those compliant with this requirement, only 31% indicated the delivery of dental services.

About 55% of the units are located in the Center and Lisbon regions of Portugal, and 31% of them are located in the North. The remaining 8% and 5% of the units in the sample are located in the Alentejo and Algarve regions, respectively. The relative distribution of compliant firms with each of the legal requirements with respect to their location follows that of the overall sample.

On average, these units were created 13 years ago, and have about 7 collaborators. The average age of the units (and the average number of collaborators) does not differ greatly amongst those compliant with each of the legal requirements, and amongst these and noncompliant units.

The healthcare units in the sample indicated an average production per year of 173 kg, 444 kg and 39 kg of Groups I&II, Group III, and Group IV waste, respectively. This corresponds to an average weekly production of 9.3 kg of Group III and Group IV waste, a figure that sits well with the production estimate for small producers in Portugal as indicated by the Portuguese League for the Protection of Nature (LPN, 2010). In addition, the average sample production of Group IV waste corresponds to 8% of the total production of Group III and Group IV waste as predicted by the Portuguese Environmental Agency (A.P.A., 2010). Thus, although we have no means to assess the representativeness of our sample due to lack of information concerning the relevant population, we take these data as reassuring in the sense that the sample information conforms to predictions made by relevant national entities.

On average, compliant units tend to produce more waste than noncompliant units. In particular, units compliant with legal requirement §3 (collection period) produce 3.5 times more of Group III waste, and 2.4 times more of Group IV waste than the total in the sample. To a degree, this finding adds some weight to the often voiced concerns (eg. LPN, 2010) that legal requirement §3 is too costly and unfeasible for very small waste producers, and that it should be modified in order to make the collection periods more suitable to (realistic) production volumes, and their associated risks for people and the environment.

The majority (66%) of the units that produce Group III and Group IV waste indicated that they have a contract with authorized companies for waste treatment; an

even higher percentage of units holding a contract is observed amongst compliant units, with an exception concerning the units compliant with legal requirement §3 which are, as discussed above, also the highest producers of Group III and Group IV waste.

About 59% and 19% of the units in the sample indicated that a responsible for the management of the healthcare waste has been appointed within the unit, and that internal waste audits have been regularly conducted, respectively. In all cases, these percentages are highest amongst compliant units with the legal requirements.

Finally, only about 5% of the units in the sample provide regular (ie, at least once a year and lasting for more than 2 hours) education and training opportunities on waste handling issues to their staff. Again, the percentage of units providing these opportunities is higher amongst compliant units, particularly within those compliant with legal requirements §2 (waste storage place) and §4 (WMP).

Table 2 –Characteristics of healthcare units

	Compliant with:				Total
Unit Characteristics	§1	§2	§3	§4	Sample
Type of Healthcare Unit (%)					
Dental Clinic	56.93	63.23	30.99	60.08	52.90
Medical Office	35.47	29.60	39.77	28.85	37.25
Laboratories	11.33	13.90	21.64	19.76	10.26
Nursing Office	9.84	8.07	10.53	9.49	9.04
Ph.med.&rehab.	6.71	5.83	7.02	6.72	7.56
Other	7.60	9.42	14.04	6.32	8.77
Region of location (%)					
North	31.45	28.70	37.43	28.46	31.44
Center&Lisbon	56.18	57.40	50.29	53.75	55.47
Alentejo	7.60	6.28	5.85	9.88	7.83
Algarve	4.77	7.62	6.43	7.91	5.26
Average Age of the Unit (Years)	13.29	13.03	14.77	14.26	13.28
Average Number of Workers	6.78	7.54	8.81	7.86	6.67
Average Waste Production (Kg/year)					
Group I & II	167.71	265.54	328.91	153.07	172.96
Group III	489.07	1163.25	1538.51	365.16	444.01
Group IV	42.39	62.44	94.01	73.58	38.53
Contract with authorized companies (%)	72.13	79.37	63.74	79.05	65.86
Appointment of Responsible for WM (%)	62.30	70.40	66.08	81.82	58.57
Regular Audits (%)	19.97	26.01	22.81	33.99	18.89
Education and Training Opportunities (%)	5.07	8.97	5.26	8.70	4.86

As seen above, all of the units in the sample comply with legal requirement §0, but not all of them comply with legal requirements §1 - §4: the majority, though, complies with legal requirement §1, but only relatively small percentages comply with the remaining three requirements. Considering these 4 requirements (§1 - §4) only, some firms might comply with none, some with just one of them, etc, or with the four of them.

Table 3 displays the compliance rate with these 4 requirements by the units in the sample. As shown in the Table, only 4.99% of the sample units comply with the four legal requirements simultaneously (a 100% compliance rate). The percentage of units that do not comply with any of these requirements is smaller: 0.40%. About 39% comply with one of the requirements (a 25% compliance rate), 37% comply with two of the requirements (a 50% compliance rate), and 19% comply with three of the requirements (a 75% compliance rate). On average, the compliance rate is 0.47 with a variance equal to 0.05 (standard deviation equals 0.22).

Table 3 – Compliance rate with legal requirements §1 - §4

Number of legal requirements	Compliance rate	Percentage of units in the sample
0	0.00	0.40
1	0.25	38.73
2	0.50	36.57
3	0.75	19.30
4	1.00	4.99

B. Conditional statistical analysis

In order to uncover significant determinants of units' compliance with the applicable legislation, the data is analyzed using the units' compliance rate as the dependent variable in a multiple regression model. Although it is common practice to estimate the effects of possible covariates on fractional dependent variables through OLS (Kieschnick and McCullough, 2003), such an approach ignores key features of

fractional data: (i) non-normality, since fractions are not defined over $\Re$ and, therefore, the conditional expectation function must be nonlinear so as to generate predictions naturally bounded between 0 and 1; (ii) heteroskedasticity, since the variance of fractional data approaches zero as its mean tends to either 0 or 1 and, therefore, the conditional variance function must be a function of the mean. Thus, estimation of a linear function relating proportional data to a number of covariates using standard OLS may fail to provide a good understanding of the phenomenon under study.

A number of alternatives to OLS when modeling fractions have recently been proposed in the literature. Amongst these, parametric regression models based upon the beta distribution are the most commonly used (Kieschnick and McCullough, 2003; Paolino, 2001). However, as pointed out by Papke and Wooldridge (1996), the use of the beta distribution is not appropriate in applications where the dependent variable takes the boundary values of 0 or 1 for some portion of the sample, as happens in the present application. To handle these cases, Papke and Wooldridge (1996) developed a quasi-likelihood regression model that circumvents the problems described above, while accommodating the existence of boundary observations (0s or 1s).

Using this estimation approach in the present analysis, the log-likelihood of observation i is specified as $l_i(\beta) = y_i \log[G(x_i\beta)] + (1-y_i)\log[1-G(x_i\beta)]$ for compliance rate y_i, vector of explanatory variables x_i, parameter vector β, and some known function $G(.)$ satisfying $0 < G(z) < 1$ for all $z \in \Re$. Like in Papke and Wooldridge (1996), $G(.)$ is the logistic function in the present analysis. The function is well defined even if y_i takes the boundary values of 0 or 1 with positive probability, and maximization of this log-likelihood function ensures that the predicted values of y_i lie within the unit interval. In addition, the quasi-likelihood estimation procedure does

not require the specification of the full conditional distribution for the fractions under study, but only the specification of the mean function of the data (the first moment of the conditional distribution) and the relationship between this function and the variance function (the second moment of the conditional distribution).

Following closely Papke and Wooldridge (1996)'s empirical application of these methods, conditional statistical analysis of the compliance rate data using the econometric package STATA® (version 11.1) is accomplished through the estimation of a generalized linear model (GLM) with the binomial family and the logit link (see, for example, Hardin and Hilbe, 2001, for the nature and scope of generalized linear models). By default, estimation of standard errors in this model proceeds assuming a dispersion (scale) parameter equal to unity, as is suitable for binary models whose response is zero/one or for equi-dispersed count data. However, because the present data are fractions instead of counts or binary data, there is no a priori theoretical reason that the dispersion parameter should be near one. In fact, the compliance rate is underdispersed, and the procedure suggested by Papke and Wooldridge (1996) to the estimation of the standard errors is used in the present analysis whereby the standard errors are adjusted by a scale parameter set equal to the Pearson chi-squared statistic divided by the residual degrees of freedom (see Papke and Wooldridge, 1996, and StataCorp, 2009, for details). Finally, because the conditional expectation function is nonlinear, the parameter value β_k does not directly measure the effect of a change in explanatory variable x_k on the mean of the dependent variable. In the present application, the marginal effect of x_k on the conditional expectation function is given by $g(x\beta)\beta_k$, where $g(z) = dG(z)/dz = \exp(z)/(1+\exp(z))^2$.

Table 4 reports the partial derivatives of the conditional expectation function of the estimated model with respect to the different regressors, evaluated at the sample

means of the regressors. For the dummy variables the effect of a change from 0 to 1 is calculated by computing the change in the compliance rate evaluated at the mean index function for the other regressors.

Table 4 –Estimates of the marginal effects of regressors on compliance rate

Variable	Estimate	SE	p-value	95% CI	
Type of Healthcare Unit					
Dental Clinic	0.010	0.020	0.624	-0.030	0.050
Medical Office	0.015	0.020	0.445	-0.024	0.055
Laboratories	0.145	0.030	0.000	0.086	0.203
Nursing Office	-0.038	0.031	0.218	-0.099	0.023
Ph.med.&rehab.	0.007	0.032	0.837	-0.056	0.069
Region of location					
North	0.013	0.017	0.467	-0.022	0.047
Alentejo	-0.029	0.030	0.331	-0.088	0.030
Algarve	0.069	0.036	0.054	-0.001	0.140
Age of the Unit (years)	-0.001	0.001	0.221	-0.003	0.001
Number of Workers	0.001	0.001	0.425	-0.001	0.003
Waste Production (Kg/year)					
Group I & II	-4×10^{-6}	1×10^{-5}	0.642	-2×10^{-5}	1×10^{-5}
Group III	1×10^{-5}	1×10^{-6}	0.008	3×10^{-6}	2×10^{-5}
Group IV	8×10^{-5}	4×10^{-5}	0.043	3×10^{-6}	2×10^{-4}
Contract	0.030	0.019	0.106	-0.006	0.067
Responsible for WM	0.089	0.016	0.000	0.057	0.121
Regular Audits	0.050	0.022	0.021	0.008	0.093
Education and Training	0.109	0.036	0.003	0.038	0.180

Note: N=741; Log-pseudolikelihood value is -355.41; Wald test for the null hypothesis that all coefficients are zero has a χ^2 value of 140.47 with 17 df, implying a *p*-value less than 0.001.

The type of healthcare unit is identified through five binary (dummy) variables, each taking the unit value for the corresponding case, and the zero value otherwise (Other is the omitted category, so estimates are interpreted relative to this category). The results in Table 4 reveal that, all else the same, laboratories have on average a 14.5 percentage points higher compliance rate than Other types of healthcare units. The compliance rate does not differ amongst all other healthcare units at any conventional significance levels. The estimated effect of Laboratories on the compliance rate might be due to a greater incidence of inspections on these types of healthcare units. In fact,

the Portuguese inspection agency on waste issues (*Inspecção-Geral do Ambiente e do Ordenamento do Território*) included public and private medical Laboratories (in addition to hospitals) as a major subject in its monitoring activities since 2004 (IGAOT, 2006). The conjecture that, all else the same, Laboratories' higher rate of compliance with the applicable legislation is due to higher inspection/monitoring activities by the relevant public agency is in line with Botelho *et al.* (2005) finding that greater inspection efforts positively impacts the compliance behavior of Portuguese small-size firms with environmental regulations.

The results uncover regional effects on the degree of compliance by the healthcare units. The compliance rate of units located in the Algarve region of southern Portugal is, on average, 6.9 percentage points higher than that of units located in the Center and Lisbon regions of Portugal (the omitted category). Wald tests (not shown) on the equality of the regional coefficients confirm higher and statistically significant compliance rates in the Algarve region compared with units located in the North and Alentejo regions. The compliance rate of units located in the North, Center and Lisbon, and Alentejo are not statistically different. Although far from directly comparable, this result suggests that the findings in Ferreira and Teixeira (2010) concerning the waste management practices of hospitals in the Algarve region may not transfer readily to similar institutions located in other regions of the country.

Other control variables, such as the age of the units, their number of collaborators, and the volume of Group I & II waste produced do not, on average, impact their compliance rate. The volumes of Groups III & IV waste produced do, however, exert a statistically significant positive effect on the compliance rate, but the magnitude of these effects is in either case considerably trivial.

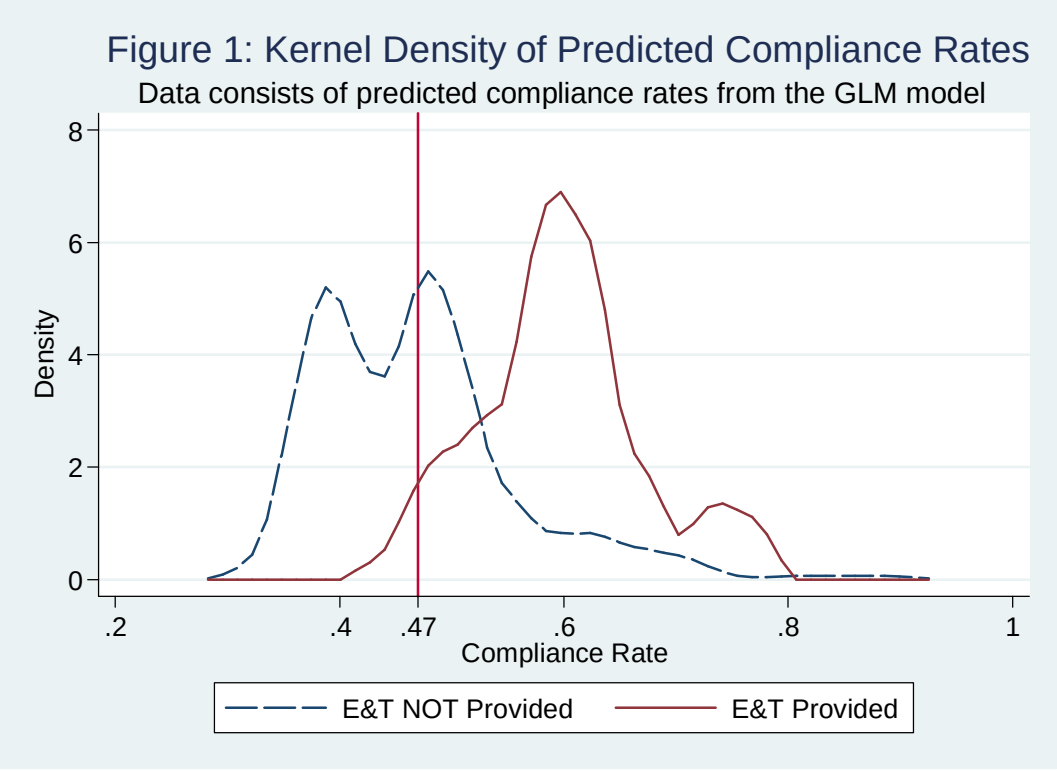
Turning to the analysis of policy variables, the results show that, all else the same, having a contract with authorized companies for Groups III & IV waste collection and treatment increases the units' compliance rate, although this effect is just on the boundary of conventional statistical significance (p=0.11). The relatively small magnitude of this effect, and its weak statistical significance, is somewhat surprising. In fact, given that the Portuguese legislation (Dec. Lei 178/2006) transfers most of the responsibility for the management of healthcare waste from the producers to specialized service providers once a contract for waste treatment is established between them, we would expect those units to exhibit a substantially higher compliance rate with the relevant regulations than units without a contract. The estimated effect, therefore, raises concerns about the service providers' compliance with existing regulations, and suggests the need for more public investments in monitoring contractor performance and compliance.

As expected, the nomination of an individual responsible for the management of the healthcare within the unit, and the implementation of internal waste auditing significantly contribute to the achievement of higher compliance rates. The results show that, ceteris paribus, units that designate a staff member to manage or coordinate waste management have on average a 9 percentage points higher compliance rate than units that do not do so. Likewise, the compliance rate is predicted to increase by 5 percentage points through the implementation of regular internal audits.

Importantly, the results also show that providing education and training opportunities on waste handling issues strongly influences the units' compliance rate with the relevant regulations. Ceteris paribus, it is predicted that the provision of employee training increases the compliance rate by 11 percentage points. This is,

therefore, the strongest policy variable affecting units' compliance rate with the relevant regulations.

Figure 1 reports kernel density estimates of the predicted compliance rates across the sample, stratified by the delivery of education and training opportunities (E&T). Kernel density estimates may be viewed as generalizations of histograms as a way of visualizing continuous univariate data. The common Epanechnikov kernel function, and the so-called "optimal bandwidth" are employed in the present estimation procedure (see, for example, Silverman (1986) for a detailed discussion of density estimation issues). The predicted mean compliance rate from the estimated generalized linear model for the overall sample is .47, which is shown in the Figure as a vertical line.



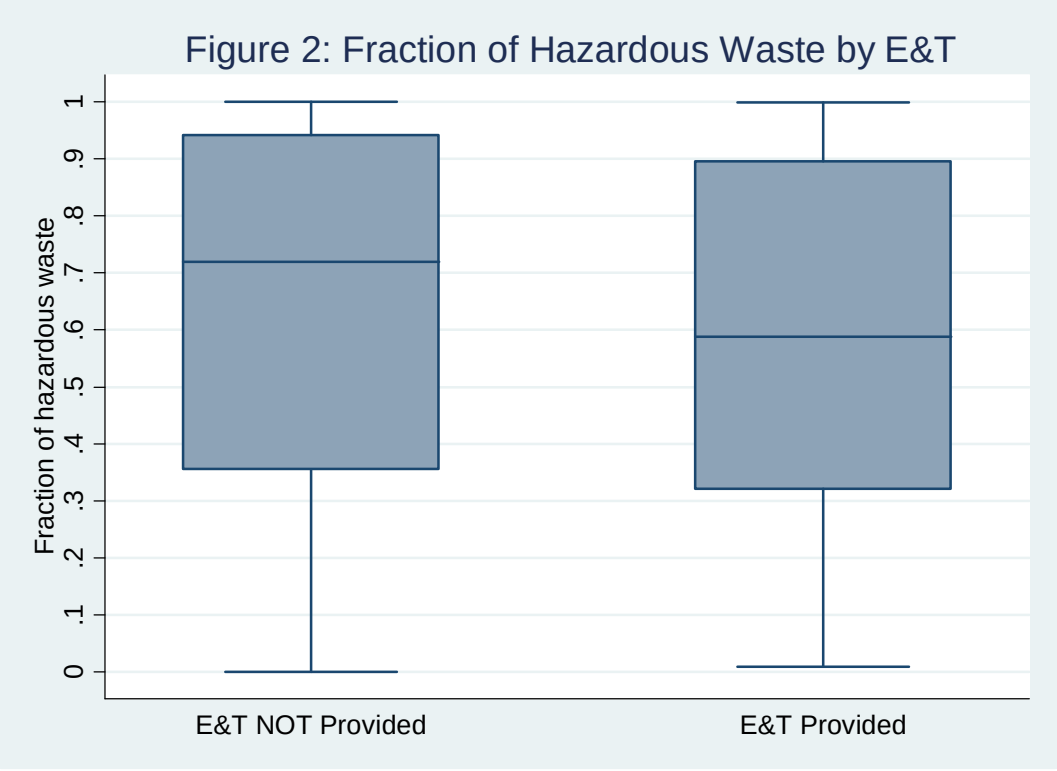
The data displayed in Figure 1 reveal a remarkable pattern. Consistent with the estimates in Table 4, after correcting for all other determinants, the contrast between the compliance rates by units that provide education and training opportunities (solid line) to their staff and those that do not do so (dashed line) is quite clear. This finding indicates that one important way to improve the compliance of healthcare providers with current waste management regulations is to increase staff training and awareness on medical waste issues.

In addition to its effect on compliance rates, the delivery of education and training opportunities on all subjects of waste management should lead to better waste segregation procedures, a deficiency that was identified by Ferreira and Teixeira (2010) in their assessment of the healthcare waste management practices hospitals. In fact, although all the sample units indicate that the produced waste is segregated at the point of generation, the relatively high hazardous waste fraction of the total waste produced suggests that poor segregation practices may be in place. Overall, waste classified as hazardous (Groups III & IV) accounts for 74% of the mean waste produced (Table 2), a figure that substantially exceeds the 10%-25% predicted in the World Health Organization (WHO, 2005) guidelines.

Although such high hazardous waste fractions are not unheard of for the type of healthcare units in this sample (eg., Da Silva et al., 2005, found hazardous waste accounting for 74.7% and 38.4% of the total waste produced in dental offices and clinical laboratories in the State of Rio Grande do Sul- Brazil, respectively), or might be related to the waste classification currently adopted in Portugal (eg., Muhlich et al., 2003, shows that different proportions of hazardous waste across countries may be attributable to differences in the adopted classification of waste), we cannot preclude the hypothesis that they are due to incorrect waste separation procedures. Ferreira and

Teixeira (2010) report that, invariably, inadequate knowledge of waste separation translates into unwarranted “white-bag” (Group III) and “red-bag” (Group IV) waste.

In fact, considering only the sub-sample of units that provide education and training opportunities, waste classified as hazardous (Groups III & IV) accounts for 41% of the mean waste produced. This fraction is noticeably lower than that found for the overall sample. A boxplot depicting the distribution of the fraction of hazardous waste produced by units revealing positive production of all types of waste, stratified by the delivery of education and training opportunities, is presented in Figure 2. The vertical lines demarcate the minimum and maximum sample values. The upper and lower limits of the boxes represent the lower and upper quartiles of the fraction. The median for each group is represented by the horizontal bar in the middle of each box.



The data summarized in Figure 2 clearly suggests a significant difference in the proportion of hazardous waste produced between units that provide education and training programs on medical waste issues and those that do not do so. This impression is supported by a quantile (median) regression of the distribution of the fraction of hazardous waste produced conditional on E&T. The test is two-tailed with no prediction as to whether the effect of E&T is stochastically positive or negative. The test statistic yields a *p-value*=0.006, thereby rejecting the null hypothesis of a nil effect of E&T on the fraction of hazardous waste produced. These findings, therefore, lend some support to the conjecture that the provision of E&T on healthcare waste management improves waste separation procedures thereby contributing to smaller amounts of misclassified "hazardous" waste and, as a consequence, to lower waste management costs. Thus, although the observed full compliance with legal requirement §0 (segregation at the point of generation) is an important finding, the results suggest that lack of E&T opportunities may defeat the overall goal of the segregation requirement**.**

5. Conclusions

Regulation, monitoring, and enforcement are major devices to protect human health and the environment from the risks caused by healthcare waste in an economically sustainable way. In Portugal, as in other European Union countries, the management of healthcare waste is regulated by law. Although legal provisions covering the safe management of healthcare waste date back to the 1990s, little is known about the compliance of Portuguese healthcare units with the relevant regulations, as indicated by the paucity of published research on healthcare waste management issues in Portugal. The lack of information is particularly intensified for small private healthcare waste producers. Despite the fact that only small amounts of

healthcare waste are generated in these types of healthcare units, they are numerous and distributed throughout the country, thereby representing a major public health and environmental risk to the communities if wastes are not properly managed. Their large numbers, however, make monitoring and government control of their compliance with legislative requirements problematic. In an attempt to assess their degree of compliance with existing healthcare waste regulations, and to identify important sources of variability in compliance rates, this study uses data collected by a large survey of over 700 small private healthcare units distributed all over the country.

The results indicate that compliance with the requirements stated in Portuguese legislation is far from ideal. In fact, it is found that only 5% of the units in the sample comply with the full set of requirements stated in the legislation. On average, units comply with just about half of these requirements. Compliance with availability of proper storage places, and development of a waste management plan is limited to less than 35% of the units in the sample. The most problematic requirement appears to be the required periodicity between collections, with more than 75% of the units failing to comply with it. This suggests that the required periodicity might be too costly and unfeasible for small waste producers, and a review of the legislation is recommended.

Formal conditional statistical analysis of the data supports this finding, and uncovers other significant determinants of the units' compliance rate. Amongst these, it is found that, all else the same, types of healthcare units subject to more inspection efforts by the national inspection agency on waste issues reveal a substantially higher degree of compliance. This suggests that the observed low compliance rates amongst the sample units is in parte derived from weak monitoring and enforcement efforts by the relevant governmental agencies. A related finding is the weak effect of engagement with authorized companies for hazardous waste collection and treatment on compliance

rates, raising concerns about those companies' compliance with existing regulations. Taken together, these findings reveal that monitoring and enforcement is a weak link in the Portuguese waste management program, indicating a serious need to establish and implement a proper healthcare care monitoring/enforcement strategy to improve the current situation in Portugal.

In addition, an important finding in this study is that education and training programs are seldom provided by the healthcare units to their personnel. Indeed, it is found that just about 5% of these units provide their collaborators with education and training opportunities on healthcare waste issues. All else the same, however, the delivery of such education and training programs is found to be the strongest policy factor influencing positively the units' compliance rate. Moreover, a related finding is that the lack of education and training opportunities impairs the adequate implementation of legal requirements even when compliance is fully pursued at the unit level. Thus, in addition to monitoring/enforcement issues, the results indicate that lack of education and training is a major bottleneck to sound waste management by small healthcare providers in Portugal.

Although the literature on healthcare waste management issues recurrently emphasizes that staff training and education is an important component of sound healthcare waste management programs, the empirical evidence herein provided clearly shows that education and training is crucial in order to attain proper practices in healthcare waste management and compliance with regulations. The development of national strategies, namely at the legislative level, to promote and ensure training and awareness amongst all healthcare workers and the general population on subjects pertaining to healthcare waste management is therefore strongly recommended.

Acknowledgments and Disclaimer
The author acknowledges the pivotal input of Professor Lígia Pinto and the Portuguese *Entidade Reguladora da Saúde* in the collection of data. Contributions by Professor Lígia Pinto to earlier drafts of this paper are also gratefully acknowledged, as well as comments of participants of the Environmental Health 2011-Resetting Our Priorities Conference in Salvador, Brazil, 2011. The author alone is responsible for the analysis and views expressed in this paper, and they do not necessarily represent the decisions, policies or views of the *Entidade Reguladora da Saúde*. This research was partially funded by Fundação para a Ciência e a Tecnologia (FCT) through the Applied Microeconomics Research Unit (NIMA) award no. PEst-OE/EGE/UI3181/2011.

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