On the causes of illegal waste dumping in Slovakia

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Abstract

This paper examines the determinants of illegal waste dumping at the county-level (77 counties) in Slovakia, using data on illegal waste dumping, provided by TrashOut platform. The results revealed a negative relationship between costs of illegal waste disposal and dumped waste volumes and a positive relationship between costs of legal waste disposal and dumped waste volumes. Moreover, it was shown that higher level of expected waste production results into higher rate of illegally dumped waste. More precisely, income has a positive impact on the rate of illegal waste dumping, poverty influences the rate of illegal dumping negatively and higher level of education does not result into more responsible waste management. On the contrary, higher education has a positive influence on the rate of dumping.

Keywords: illegal dumping; truncated model; waste management

JEL Classification: C24; K42; Q24; Q53; Q58

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1. Introduction

Illegal waste dumping imposes significant risks in various areas such as human health, environment, esthetics, ethics and economy (U.S. EPA 1998, 3-4). According to the unofficial estimates, there are approximately 6000 illegal dumps in Slovakia (TASR cited August 2013) and so this issue represents one of the significant challenges for the country. As a response to the striking illegal dumping situation, project TrashOut has been created to represent a simple way to locate illegal dumps. The main purpose of the TrashOut project is to provide detailed information to the public authorities about the degree of illegal dumping in their region so that appropriate measures can be adopted. However, despite the fact that since 2012 more than 2000 illegal dumps have been localized, only a very small fraction has been cleaned up.

Currently, a new waste management law is being prepared in Slovakia, where one of the main aims is the fight against illegal dumping. This study, conducted by the Department of Economic Instruments and Analysis of the Ministry of Environment of the Slovak Republic, analyzes the determinants of illegal waste dumping in Slovakia and should also serve as a source of relevant, scientific information for the public authorities preparing the new legislative. The empirical research is mainly inspired by Ichinose and Yamamoto (2011) and Matsumoto and Takeuchi (2011). Ichinose and Yamamoto (2011) studied the relation of sufficient provision of waste treatment facilities and frequency of illegal dumping in Japan. Matsumoto and Takeuchi (2011) examined the impacts of community characteristics on frequency of illegal dumping of electric appliances by households in Japan. This study analyzes the determinants of illegal waste dumping in Slovakia. The empirical research uses truncated regression model. The dependent variable monitors the county-specific (there are 79 counties in Slovakia and the sample contains 77 observations) volume of illegally dumped waste. Its determinants are divided into three groups (as it also has been done by Matsumoto and Takeuchi (2011)): costs of illegal waste disposal, costs of legal dumping and expected volume of waste production. The results provide evidence of a statistically significant negative relationship between the costs of illegal waste disposal and dumped waste volumes and a statistically significant positive relationship between costs of legal dumping and dumped waste volumes. Lastly, it is shown that higher level of expected waste production results into higher rate of illegal waste dumping.

The rest of the paper is organized as follows. The next section provides a theoretical background on the problem of illegal waste dumping in general. Section 3 provides more detailed information on scope of this problem in Slovakia. Section 4 describes the data and specifies variables used for the analysis. Further, section 5 discusses the empirical models and the estimated results. Finally, resulting policy implications and some concluding remarks are presented in section 6.

2. Literature review

According to the published literature and various country-specific research reports, illegal dumps occur in urban as well as in regional areas that are abandoned, unsecured, poorly lit, remote or with poor access. Common places for their occurrence are for example undeveloped lots, unused industrial facilities, areas along railways, wooded areas, forest preserves, farms or borders of cities and counties. The main factor that plays role is that in these areas the chance of being caught or sighted while dumping is relatively low. (U.S. EPA 1998, pg. 4).

The literature further mentions several reasons contributing to the emergence of illegal dumps. These comprise high costs of legal ways of waste disposal, convenience of illegal dumping (relative to legal waste treatment), illegal business establishment (Public Health Department of Imperial County California 2007, pg. 6), little storage room available to the dumpers, the fact that it is already a habitual practice with residents (Department of Environment and Conservation NSW 2004, 36-43), lack of information of the dumpers considering the harm they are causing by their action, higher proportion of renters than the property owners, or prohibition of materials for legall ways of waste treatement. On the contrary, the pay-as-you throw system, or eventually the unit based disposal system do not cause an increasing number of dumps in the long term (U.S. EPA 1998, pg. 4). Also fines, when caught for dumping, play an essential role considering this issue. If the probability of getting caught multiplied by the imminent fines is lower than the costs of legal ways of waste disposal, then the dumpers are not motivated to follow the legal path. Hence, setting and enforcing of dumping fines is essential in this case.

This paper should be, however, most closely related to the Ichinose and Yamamoto (2011) and Matsumoto and Takeuchi (2011). Ichinose and Yamamoto (2011) studied the relation of the sufficient provision of the waste treatment facilities and the frequency of illegal dumping. They developed a theoretical model, which concluded that an increase in the provision of the waste treatment facilities decreases the number of illegal dumping incidents, the high illegal dumping costs lead to a lower rate of illegal dumping, the larger is the amount of the discharged waste - the higher is the number of illegal dumps and lastly that a strict punishment lowers the rate of illegal dumping. Afterwards, they tested their theoretical results empirically using a prefecture-level panel data of illegal dumping in Japan. However, not all of their theoretical results were confirmed. They found that raising the number of the intermediate waste treatment facilities, indeed, lowers the rate of illegal dumping, though the number of the official landfill sites causes increased illegal dumping. Furthermore, they found that the higher the weight of discharged waste, the higher is the dumping rate. Lastly, they concluded that if the illegal dumping would be punished more severely, its rate would decrease.

Matsumoto and Takeuchi (2011) examined the impact of the community characteristics on the frequency of illegal dumping of the electric appliances by the

households in Japan. They regressed the frequencies of illegal dumping incidences of four specific electric appliances per person per municipality on the variables that can be aggregated into three main groups: the expected number of used electric appliances, the cost of legal waste disposal and the cost of illegal dumping. They provided evidence that illegal dumping is higher in communities with high unemployment rates and that high disposal costs and lower ability of law enforcement raise the rate of dumping. Moreover, the paper examined the importance of the community participation in the prevention of illegal dumping. It has been shown that a properly developed reporting system and surveillance decrease the dumping rate.

3. Illegal dumping in Slovakia

Since the Slovak legislative does not officially recognize the term "illegal landfill" (illegal dumping), for the purposes of this paper following definition is used:

> "Illegal dumping is the improper, waste disposal at any location which is not a permitted landfill or facility. It is not only against the law, moreover illegal dumping also negatively impacts human health and the environment (DHEC's Office of Solid Waste Reduction and Recycling 2011). Dumping is always an intentional act (Public Health Department of Imperial County California 2007, 5-6). An illegal dumping usually contains amount of waste, which tends to be larger than litter. More precisely, it ranges from small bags of rubbish to larger scale dumping of materials (Department of Environment and Climate Change NSW 2008, 8-12)."

3.1. Estimated situation in Slovakia

Based on the data gathered from TrashOut (more on the data in the section 4.) (Figure 1) depicts the degree of illegal dumping across the counties in Slovakia measured by the county-specific number of dumps. It shows the geographical distribution of the 2018 localized illegal dumps regardless of their size. Obviously, the dumping problem is more severe in the counties of the biggest cities such as Bratislava, Trnava, Trenčín, or Žilina. An exception is the second biggest city Košice, where the dumping problem reaches lower intensity.

39.95% (805 dump sites) of the localized dumps have the volume of a truck, 39.84% (804 dump sites) of them have the volume of a wheelbarrow and the remaining 20.27% (409 dump sites) are able to fit a bag. Using the quantitatively expressed volumes, these 2018 localized illegal dumps represent an estimated average of 2706.91 m^3 (for the exact estimation methodology of the dump volumes see Appendix 1), which corresponds to 2,706,915 liters (l) of localized illegally dumped waste in Slovakia. This means that there are on average 0.5 l of localized illegally dumped waste per person. Already in 2012 110 (estimated 141.28 m^3) of these

localized dumps were cleaned and from January 2013 until the 26th of June 2013, additional 23 (estimated 30.35 m^3) of them have been cleaned. Hence, out of the 2018 localized dumps, 133 (estimated 171.63 m^3) have been cleaned, leaving 1885 uncleaned illegal dump sites in Slovakia. This represents estimated 2,535,290 l of localized, uncleaned dumped waste. (Table 1) indicates, what kind of waste is mostly dumped (the estimation of the volumes uses the method as described in the Appendix 1). Obviously, the major components of illegally dumped waste are the construction waste (28.72%), followed by household waste (22.39%) and the automotive waste (11.85%). On the other side, liquid waste (1.13%) and dangerous waste (2.11%) are dumped at the lowest rate.

///Include Figure 1 around here ///

Slovakia is divided into 8 regions, where this geographical division corresponds to the NUTS 3 level[1] (Eurostat cited August 2013). (Table 2) indicates that in terms of absolute volumes of reported illegally dumped waste, Bratislava region is the worst off with 893.56 m^3 of dumped waste followed by Nitra region (380.85 m^3), where the absolute volume of reported illegally dumped waste is lower by more than a half. The region, which is the best off in terms of reported illegally dumped waste is Prešov region with the volume of 128.45 m^3. The ranking of the regions, however, partially changes when it comes to the volumes of reported illegally dumped waste per person, as shown in the (Table 3). In this case, Bratislava still remains the region with the worst profile with 1.47 l of reported illegally dumped waste per person, but it is followed by Trnava with 0.60 l and Nitra with 0.55 l. The region, which has the best profile considering the reported illegally dumped waste per person is Prešov with 0.16 l.

At the LAU 1 level [2], Slovakia is divided into 79 counties (Eurostat cited February 2011). Via TrashOut application, illegal dumps were localized in 77 of them. All of the five counties with the worst profiles considering the reported illegally dumped waste volumes in absolute terms are located in Bratislava region (Senec with 139.09 m^3, Bratisava II with 137.95 m^3, Malacky with 125.19 m^3, Bratislava III with 120.86 m^3 and Bratislava IV with 119.15 m^3). Taking a look on volumes of reported illegally dumped waste per person in the counties, Senec still remains the county with the worst profile with 2.06 l of reported illegally dumped waste per person, followed by Bratislava III and Malacky with 1.97 l and 1.85 l per person respectively. The last two counties considering these criteria are Banská

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[1]NUTS - Nomenclature of territorial units for statistics. It is a hierarchical system for dividing the economic territory of the EU into geographically comparable territories. At NUTS 3 level, EU 27 is divided into 1294 regions for the purpose of region-specific diagnoses (Eurostat cited August 2013).

[2]LAU - Local administrative units. LAUs belong to the system, which divides the economic territory of the European Union (EU) for the statistical purpose at local level Eurostat (cited September 2013).

Štiavnica with 1.80 l per person and Pezinok with 1.77 l per person. (Figure 2) depicts the significance of the dumping problem across all Slovak counties measured by the illegally dumped waste per person.

///Include Figure 2 around here ///

4. Data

Thanks to the environmental project TrashOut, it was possible to obtain relevant information on illegal dumping in Slovakia. TrashOut monitors illegal dumps all over the world, enabling ordinary people to participate and to have a positive impact on the environment. People are able to report and localize illegal dumps via the free mobile application TrashOut available for smartphones (Android, Windows Phone and iPhone). According to the reported information a database describing the location, the composition and the size of the dumps has been created and has been accessible on the project's web page, www.trashout.me, since 2012. The main aim of the project is to inform the public authorities about the urgency of illegal dumping problem in their country so that appropriate measures can be taken to deal with this issue (TrashOut cited August 2013). Since 2012, TrashOut has reported 2018 confirmed dumping incidences in Slovakia, till the time when the data set (26.06.2013) was obtained[3]. Despite the fact that the data is provided at the municipality-level, the main analysis has merged them to the county-level due to the lack of detail of the explanatory variables. Slovakia is divided into 79 counties and the dataset contains observations on 77 of them. Remaining part of the data used in the analysis was obtained from Statistical Office of the Slovak Republic and the Ministry of Labor, Social Affairs and Family of the Slovak Republic. Summary statistics are reported in the (Table 4).

4.1. Dependent variable

Ichinose and Yamamoto (2011) claimed that it was possible to use two types of data as indicators of the illegal dumping rate: the number of illegal dumps, or the volume of illegally dumped waste. The number of illegal dumps might be misleading, since it doesn't take into account sizes of dumps. To overcome this issue, the average volumes of the dumps are estimated (for the exact estimation methodology see Appendix 1). The volumes of the dumps are afterwards merged to the county-level. Consequently, the logarithm of the county-specific (LAU 1 level) volume of reported illegally dumped waste expressed in liters per capita (*WPPln*) is used as an indicator of illegal dumping rate.

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[3]According to the unofficial estimates, there are approximately 6,000 illegal dumps in Slovakia (TASR cited August 2013). This analysis only works with the data from TrashOut, since it provides confirmed and reliable information on existing illegal dumps.

The data on the illegal dumps gathered from the TrashOut platform has been reported since the start of its existence - March 2012. The emergence of the reported illegal dumps could have been much earlier than in e.g. 2012 or 2013. In other words, its time of reporting is dependent on the year when the TrashOut application was introduced and does not necessarily monitor the year of emergence of a particular dump. Therefore, all the dumps that are monitored and covered in the dataset are treated as equal independent of the year of reporting and independent of whether they have already been cleaned up or not. Only the fact that they have emerged, existed and been monitored during the time span March 2012 - June 2013 (when the dataset was obtained) matters.

(Table 4) shows that in every county included in the dataset, there are on average 26.21 reported illegal dumps (number of dumps is denoted as $DUMPSNR$), independent of their volume. The county with the lowest number of dumps has 1 dump, whereas the county with the highest number of dumps has 139 dumps. Considering the volume of waste per person, on average 0.5 l of reported waste per person have been dumped (liters of illegally dumped waste per person are denoted as Wpp). The variation of the reported dumped waste per person is relatively large likewise, the value ranges from 0.0004 l to 2.0580 l.

4.2. *Explanatory variables*

To examine the determinants of illegal dumping, explanatory variables are divided into three categories (similarly to as it has been done by Matsumoto and Takeuchi (2011)): costs of illegal waste disposal, costs of legal dumping and expected volume of waste production. Moreover, all explanatory variables take on values from 2011. This is due to the fact that in 2011, there was a population census and a lot of relevant data is available precisely from this year. It is also assumed that since the dumpings were only reported in 2012 or 2013, they have existed at least since these years but probably even longer and hence the latest events that could have had impact on their emergence were those from year 2011.

Costs of illegal waste dumping are connected to various factors, such as the detection probability and the applied penalty for illegal dumping. The penalty is determined nationally and so it remains uniform in all counties. Therefore, the focus is placed on the detection probability. Matsumoto and Takeuchi (2011) explained costs of illegal dumping by the arrest rate of criminal offenses. The accessibility and quality of data on topics criminality is, however, highly limited in Slovakia. Ichinose and Yamamoto (2011) used the population density believing that higher population density leads to higher probability of detection of the dumpers, together with ratio of cultivated acreage, assuming that the illegal dumping costs decrease with an increasing ratio. The intuition is that with larger cultivated acreage ratio it becomes easier to find a place to dump and the chances of being spotted by other people are lower. Within this analysis both of the indicators, namely the population density ($PDENS$), as well as the ratio of cultivated acreage (ACR) are used simultaneously.

It is assumed that for a person, who dumps waste illegally and is not concerned with environmental preservation, a legal alternative to dumping is landfilling. Especially in the case of Slovakia, this is a plausible assumption due to the fact that landfilling has been relatively cheap, easy and popular way of waste disposal. According to the Slovak Statistical Office, in 2011 74.7% of the municipal waste was landfilled (Statistical Office of the Slovak Republic 2012). Therefore, inspired by Matsumoto and Takeuchi (2011), this paper uses a variable named *EFFORT*, which describes the county-specific difference of the following two county-specific distances: the average bee-line geographical distance from the middle of the municipality to the closest official landfill and the average bee-line geographical distance from the middle of the municipality to the illegal dump[4]. If the number is negative, the official landfills in a county are on average closer or more accessible than the dumping spots. Hence, for the inhabitants of such a county the legal waste disposal represents on average smaller effort (and so lower costs in the form of time, transport expenses and furthermore) than illegal dumping.

It is assumed that the expected volume of general waste production impacts the illegal dumping rate and is dependent on factors such as level of income, poverty rate or education. Regarding poverty rate and income level, it is believed that these two factors have impact on the consumption intensity and hence indirectly on the waste production. For the purpose of interpreting the income variable, nominal wage has been log-transformed (*NOMWAGEln*). Income only concerns people who are employed. Based on the analysis in the Appendix 2, it is believed that higher income is positively related to the municipal waste production. However, there remains the question whether more financial resources enable people to manage their waste more responsibly (sufficient financial resources to overcome the financial burden of legal waste disposal), or whether the higher waste production only results into a higher rate of waste dumping. Similar logic is behind using the variable on poverty. In regard to poverty, the percentage of population dependent on material need benefits (including children, life partner or parents living in the same household as the beneficiary) (*POVERTY*) is used. The sensitivity of results considering the poverty rate is tested via unemployment rate (*UNEMPL*), see section 5.3.. Moreover, it is assumed that the level of education impacts the consumption patterns and so the waste production and disposal behavior. According to the analysis in the Appendix 2 higher education is positively correlated with the rate of municipal waste production. Besides, United States Environmental Agency identifies the lack of information of the dumpers as one of the reasons for illegal dumping U.S. EPA (1998, 4-6). In order to investigate this relation, a variable on education is employed. More precisely, the variable describes the proportion of the county inhabitants that have finished any level of tertiary education (*EDUCT*). The main hypothesis is though that higher education makes people act more responsibly towards the environment.

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[4]The distances have been calculated as the differences between two longitude and latitude GPS points bluemm.blogspot.sk (cited January 2007).

5. Determinants of illegal waste dumping

5.1. Empirical model

In this section, the empirical model of illegal waste dumping is introduced. TrashOut only provides information on the geographical units with illegal dumpings. If there are geographical units, where no illegal dumpings were localized, they are not included in the database. This corresponds to a truncated dataset, where information about a certain segment of the population is simply unobserved. In a truncated dataset, the sampling is not random, however the rule according to which the data has been included in the sample is known. The rule is whether y reaches values above or below a certain threshold t. More precisely, random sampling is observable only within the truncated sample (Wooldridge 2003, 555). This analysis uses the logarithm of the reported illegally dumped waste per capita (see section 4.1.) as the dependent variable. The variable on the volume of the reported illegally dumped waste per person is rounded to four decimal places. Therefore, the threshold for our truncated regression model t, is the logarithm of the smallest possible value for the volume of the reported illegally dumped waste per person, namely 0.0001, which is -9.2103. The rule according to which the data is included in the dataset is $log(y_k) \geq -9.2103$, where y denotes to the volume of dumped waste and k stands for one of the 77 counties ($k = \{1, 2, 3, ..., 77\}$) included in the dataset. In a truncated regression model, the distribution of the truncated y is essential. If it is possible to assume that the whole (non-truncated) population is normally distributed, then the error term in the truncated regression model has a truncated normal distribution. This is a normal distribution that has been scaled upward so that the distribution integrates to one over the restricted range [5]. The expected marginal effects in our truncated regression model for the subpopulation look as follows (Greene 2003, 759-761):

$$E(\log(y_k)|\log(y_k) \geq -9.2103) = \beta X_k' + \sigma\lambda(\alpha_k) \tag{1}$$

where X' comprises all the explainanatory variables at their mean value, λ is the inverse Mills ratio and σ is the standard deviation [6]. The coefficient β captures the marginal effects within the whole population (Greene 2003, 761).

5.2. Results - main analysis

In this section the empirical results of illegal waste dumping model, as presented in the (Table 5), are assessed. The interpretation of the coefficients from the regres-

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[5]The inverse Mills ratio, which is the second term on the right-hand side of the Equation (1) multiplied by σ renormalizes the distribution by dividing the population density for y, given x by the probability that y_i is more than or equal to t_i (given x_i) (Wooldridge 2003, 556).

[6]It is assumed that x has a normal distribution with mean $\mu = x_k'\beta$ and standard deviation σ and $\alpha_k = (t - x_k'\beta)/\sigma$.

sions ((Table 5) and (Table 6)) comprises the whole population and is conducted in the same manner as an interpretation of OLS regression coefficients.

The first two variables, namely the ratio of cultivated acreage and the population density, provide results on the costs of illegal waste dumping. In the main model (regression (1)) both variables are significant at least at 10% significance level. Their signs provide evidence consistent with the findings of Ichinose and Yamamoto (2011) and Matsumoto and Takeuchi (2011) that if the illegal dumping costs increase, the volume of illegally dumped waste falls. The positive sign of ACR shows that if the cultivated acreage in a county increases by 1 percentage point, the volume of illegally dumped waste raises by almost 1.6%. The negative sign of $PDENS$ indicates that higher probability of being spotted while dumping decreases the volume of illegally dumped waste. The magnitude of the coefficient on $PDENS$ is, however, so low that its actual impact on the illegal dumping intensity remains questionable.

In order to express the costs of legal ways of waste disposal, variable $EFFORT$ has been employed. In the main model, the estimate is significant at 5% significance level. The positive sign of the coefficient provides evidence for the hypothesis that higher costs of legal waste disposal lead to higher volumes of illegally dumped waste. If the average county-specific difference of distances of the legal and illegal waste disposal places increases by 1km (the average county-specific distance to the legal waste disposal place raises by 1 km compared to the average county-specific distance to the illegal dumping spot), the volume of illegally dumped waste increases by 0.625%. Also in this case, the results are consistent with the findings of Ichinose and Yamamoto (2011), as well as, with the findings of Matsumoto and Takeuchi (2011).

Considering the third category of the explanatory variables, namely the expected volume of waste production, we obtain three results. Firstly, the positive and significant coefficient on $NOMWAGEln$ variable indicates that with an increasing income in the counties (and so with higher levels of consumption and waste production (see Appendix 2)) the dumping rate increases. In other words, if the nominal wage increases by 1%, the volume of illegally dumped waste raises by almost 2.63%. This indicates that sufficient financial resources (which could eventually be used to bear the costs of legal waste disposal) do not seem to be the key to the responsible waste management behavior. Secondly, the negative significant coefficient on $POVERTY$ confirms the previous finding. It shows that if the population dependent on the material need benefits increases by 1 percentage point, the volume of illegally dumped waste falls by almost 10.4%. Hence, these two findings show that in order to decrease the dumping rate, the general waste production needs to be lowered [7]. Lastly, the coefficient on $EDUCT$ is pos-

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[7]The relation between dumping and income has been tested for potential nonlinearities (in the sense of confirming or rejecting the inverse-U-shaped relationship - Environmental Kuznetz Curve, or the U-shaped relationship between these two variables). Similarly, nonlinearities have also been tested between the dependent variable and the variables

itive and significant at 5% significance level. The coefficient expresses following dependence: if the population that has completed any level of tertiary education raises by 1 percentage point, the volume of illegally dumped waste increases by approximately 10%. Put in other words, higher education does not make people more conscious towards the environment and act environmentally responsible in terms of waste management, but just on the contrary.

5.3. Results - sensitivity tests at LAU 1 level

Despite assuming that the whole (non-truncated) sample population is representative, in order to prove the validity of the results obtained from the main model, two more sensitivity tests have been conducted at the LAU 1 level.

First, it is examined, whether the results from the main analysis change considerably after employing a proxy variable on poverty, namely the unemployment rate (*UNEMPL*) into the main model. These estimates are provided in the (Table 5), regression (2). The most obvious difference is that two variables, namely *ACR* and *NOMWAGEln* lose their significance. Taking a look on the rest of the variables, the level of significance and signs remain unchanged and the magnitudes change only slightly with the exception of the variable on poverty. As a proxy for *POVERTY*, the coefficient on *UNEMPL* shows that if the unemployed population increases by 1 percentage point, the volume of illegally dumped waste falls by almost 0.09%.

Second, the number of illegal dumping incidences is used as the dependent variable. Until this point, the paper has focused especially on the analysis of the dumped waste volumes rather than on the number of illegal waste dumpings. However, according to Sigman (1998) "the number of incidences may be an important outcome, because it reflects the geographical diffusion of contamination". In addition, the reliability of the reported volumes of dumps is also partially questionable. To assess the significance of the results obtained from the main model, this section analyzes the number of reported dumping incidences. Similarly to the main analysis, a truncated regression model is used. The dependent variable is the county-specific number of illegal dumps (*DUMPSNR*). The explanatory variables remain equal to the ones in the main model, following the same intuition. Results of this estimation are depicted in the (Table 5), regression (3). The most obvious difference to the main results represents the coefficient on the variable *EFFORT*, which becomes insignificant. The signs of the remaining variables remain consistent with the ones from the main model and their significance reaches in some cases even 1% significance level. Hence, it is clear that conducting the analysis while using number of dumping incidents as the dependent variable provides a relatively consistent results with the main analysis.

expressing poverty. In any of the cases, these terms were not significant and so not included in the model.

5.4. Results - sensitivity tests at LAU 2 level

Reporting the illegal dumps to TrashOut could be impacted by factors such as whether an individual is familiar with the TrashOut application, whether it is computer literate, whether it possesses equipment (such as a smart phone) to report it etc.. This would, however, make the reliability of our results questionable. Moreover, the validity of the results from the main model could also be questioned due to the limited sample size (only 77 observations). In order to prevent these doubts and prove the significance of the results from the main model, the analysis has been conducted at the municipality-level for two different samples: firstly only for municipalities, where at least 50 % of the population[8] is Internet literate; secondly only for municipalities, which have minimum of 4 reported illegal dumps[9]. The accessibility of the relevant data at the LAU 2 level is quite limited. In order to assess poverty at the municipality-level the variable *UNEMPL* is used. The variable *NOMWAGE* is not accessible as detailed as the municipality-level. Hence, the same value has been used for the municipalities located in the same county, in the form of county-specific fixed effects.

Internet literacy is a necessary condition for reporting the illegal dumps. Illegal dumps have been reported in 471 of the Slovak municipalities and in 332 of them, at least 50% of the inhabitants is Internet literate. Comparing the results from the main model with the results presented in the (Table 6) regression (1), there are two main differences, namely that the variables *UNEMPL* and *EDUCT* become insignificant. The rest of the variables keep the same sign as in the main model, though their magnitude slightly changes. Moreover, considering the significance level, *ACR*, as well as *NOMWAGEln* become significant even at 1% significance level.

In order to prove the validity of the results from the main model and to demonstrate that the dependent variable describes the dumping rate rather than the reporting intensity, the model was tested on the sample composed from the most polluting municipalities. Illegal dumps have been reported in 471 of the Slovak municipalities and in 122 of them, there are at least 4 localized illegal dumps. Taking a look on the results as presented in the (Table 6) regression (2) and comparing them with the results from the main model, three main changes are obvious, namely that the coefficients on *EFFORT*, *UNEMPL* and *EDUCT* lose their significance. The rest of the variables remain consistent in their signs, though their magnitude slightly changes and *POPDENS* becomes significant at 1% significance level.

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[8]This number was chosen so that the sample captures the most Internet literate municipalities, as well as in order to have a sufficiently big sample size.

[9]This number has been chosen so that the sample captures the municipalities with the higher number of dumps, as well as in order to have a sufficiently big sample size.

6.   Policy recommendations and concluding remarks

Based on the results, evidence is provided that the costs of illegal waste dumping are negatively correlated with the illegal waste dumping rate. These results were confirmed almost in all the model specifications with one exception, regression (2), where the variable ACR has lost its significance. As mentioned previously in the Section 4.2., the costs of illegal waste dumping are connected to various factors, such as the applied penalty and the detection probability. The penalty for illegal waste dumping is uniform across the whole country. Increasing the penalty for illegal waste dumping would be a possibility to raise the costs of illegal waste dumping, though the effectiveness of penalty applications strongly depends on the environmental law enforcement. As already mentioned earlier in this article, environmental criminality is not sufficiently monitored and in criminal practice only little importance is devoted to environmental crimes. This suggests that the environmental law enforcement and so the detection probability are insufficient. In order to raise the costs of illegal waste dumping, it is therefore crucial to improve the environmental law enforcement. A good example that the public authorities and society ascribe low importance to the environmental topics are the results of the TrashOut project. Thanks to the TrashOut application, out of 2018 localized dumps, only 133 have been cleared, leaving 1885 uncleaned illegal dump sites in Slovakia (at the time the dataset was obtained). For the cleaning of the reported dumps, local public authorities (municipalities) should be in charge and take action. However, they do not seem to adopt appropriate measures. In order to deal with the illegal dumping problem, it is essential to improve the level of information of the public authorities on TrashOut and to remove the administrative and legal barriers that hinder the application of the appropriate measures. In this manner a platform for the cooperation and communication of (especially local) public authorities and TrashOut should be created.

According to the empirical evidence, the costs of legal ways of waste disposal are positively related to the volumes of dumped waste. The significance of this relation is demonstrated in three, out of five model specifications. Landfilling as an official way of waste management has significant negative impacts on the environment. Though, it is still a widely used official waste disposal method in Slovakia. In order to treat waste properly, it is necessary to lower the costs of proper waste management and simultaneously shift to the environmentally friendlier ways of waste treatment, making these more accessible and attractive than landfilling. The EU Landfill Directive issued in 1999 was the impulse to the formation of EU's new approach to the waste management, which builds upon three main principles: (1) in the first place, it should be attempted to prevent waste emergence, if this is not possible (2) waste should be recycled or reused (3) at the very last instance, final waste disposal measures can be applied (waste incineration in the first place, if even this is not possible, the very last possibility is landfilling) (European Commission cited August 2013). The directive has set goals for reducing the amount

of biodegradable municipal waste landfilled (EEA 2009, 7). In this context, Slovakia needs to reduce the amount of landfilled biodegradable municipal waste to 50% of the quantity generated in 1995 (when Slovakia generated 695 000 tons of biodegradable municipal waste and landfilled more than 80% of it) (Aleksic 2013, 9). EEA (2009) indicates several measures, which could be taken in order to meet the set goals. These are, for instance, closing landfills and installing incineration capacities, strengthening the separate collection of biodegradable municipal waste fractions, raising the costs of landfilling, creating markets for compost and other recycled materials, increasing the composting capacity, introducing producer responsibility for packaging, improving the quality of data on biodegradable municipal waste and waste in general and further more (EEA 2009, 7-10). It remains essential to apply these measures in practice.

Considering the results on the expected volume of waste production, all the estimates (*NOMWAGEln*, *POVERTY*, *EDUCT*, *UNEMPL*) have proven that the higher is the volume of produced waste, the higher is the rate of illegal dumping. Again, also in this case the results were not significant in all the model specifications. The most reliable information provides the estimate on *NOMWAGEln*. It was shown that even when having financial resources or being highly educated, people do not generally tend to demonstrate environmentally friendly behavior and environmental responsibility. As a response to this status quo, it is necessary to implement measures in order to decrease the amount of produced waste and simultaneously to implement measures to increase the attractiveness and motivation to treat the waste responsibly. Waste prevention can be addressed by numerous policies and policy actions. These policies fall into three different categories. Firstly, information policies that try to change behavior and help to make informed decisions (e.g. awareness campaigns, information on waste prevention techniques, training programs for competent authorities or eco-labelling). Secondly, promotion policies, which incentivize behavioral change and provide financial and logistical support for beneficial initiatives (e.g. promotion of environmental management systems, clean consumption incentives, promotion of research and development and support for voluntary agreements and promotion of reuse and repair). Thirdly, regulation policies attempting to enforce limits on waste generation, expand environmental obligations and impose environmental criteria on public contracts (e.g. planning measures, taxes and incentives, such as pay as you throw schemes, extended producer responsibility policies, green public procurement policies). The waste prevention depends on the behavior of many different stakeholders, such as national and local authorities, households as well as businesses and furthermore and hence the measures need to target all these groups (BioIntelligence Service S.A.S. et al. 2012, 4-11). In this context, Slovak Republic introduced national waste prevention program via the Government Resolution No. 729 from 18 December 2013.

Lastly, it is essential to mention that improving the availability and quality of data related to the environmental issues (as these are specifically of a poor

quality in Slovakia) is crucial in order to understand, assess and mange environmental problems, such as illegal waste dumping. Data should be more detailed, accurate and consistent. Since environmental problems can be very area-specific, understanding its specific nature would enable to perform higher quality analysis, obtain better results and consequently introduce more appropriate, fitting political measures (Department of Environment and Climate Change NSW 2008, 31).

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Appendix 1

This section describes the method that has been applied in order to deal with the imprecision issue resulting from difficulties to measure the volume of a certain illegal dump by a person reporting it. The resulting information should provide an estimation on the average amount of waste volumes in Slovakia in some more detail.

TrashOut divides the dumps according to their size into three categories, namely: "fits truck" (t), "fits wheelbarrow" (wb) and "fits bag" (b). No detailed indications on the exact size of these measures have been provided. Moreover, an accurate estimation of an average person is thus questionable. It also remains unclear whether the detected size describes, for instance, a full truck or a half full truck, and what every single person perceives as a truck, a wheelbarrow or a bag. Therefore, in order to assess these problems and to estimate the total volume of the illegally dumped waste, the average volumes of a waste bag, a wheelbarrow and a truck are considered. The values were obtained by averaging several types of such means of disposal provided in the market. The chosen average volumes of a truck, wheelbarrow and a bag are as follows:

- Truck: 6.5 cubic meters (m^3) [10].

- Wheelbarrow: 0.08 m^3 [11].

- Bag: 0.04 m^3 [12].

Since it is not clear, whether an illegal dump of e.g. a wheelbarrow size completely fills in the volume of a wheelbarrow or whether it is just barely bigger than a bag, the middle value between a completely filled bag and between a completely filled wheelbarrow is taken. Generally speaking, for each of the three sizes the middle value is the value between the full capacity of the particular volume and the full capacity of the volume that is by one instance (out of the three considered volume categories) lower than the considered volume. Taking these measures and applying the previously described method, following are the average bag, wheelbarrow and truck dump volumes used for the analysis, if we take into account the fact that their filling capacity might vary between their lower border and their completely filled capacity:

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[10]The average volume of a truck is chosen based on the comparison of products sold by three big truck selling companies in Slovakia.

[11]The average volume of a wheelbarrow is chosen based on the information of one of the biggest companies selling home improving and do-it-yourself goods in Slovakia. Moreover, the average volume of a wheelbarrow also corresponds to the size of a standard wheelbarrow usually used at construction sites in Slovakia, fitting the typical concept of a wheelbarrow in Slovakia.

[12]The average volume of a bag is chosen based on the waste bag sizes, that are typically accessible on the market in Slovakia.

- Truck: 3.29 m^3

- Wheelbarrow: 0.06 m^3

- Bag: 0.025 m^3 [13].

TrashOut also succeeds in providing a description of the dumped trash composition. The categories of waste that can be found on the dumps are as follows: electronic (e), household (h), construction (c), metal (m), liquid (q), automotive (a), plastic (p) and dangerous (n) waste. Since there are no indications considering the proportions of different waste types on the single dumps, it is assumed that the proportion of all types included on the dump is the same $(1/\sum j_d)$, where j describes the waste category $(j = \{e, h, c, m, q, a, p, n\})$ and d stands for the specific dumping. Hence, the volume of a specific waste type on a specific dump would be calculated as follows:

$$1/\sum j_d * y_{di} = y_{dij} \tag{2}$$

and the aggregate volume of a specific waste type on all 2018 dumps is just the sum of the results from the previous formula:

$$\sum_{d=1}^{2018} y_{dij} = y_j \tag{3}$$

, where i describes the dumping volume $(i = \{t, wb, b\})$ and y stands for the waste volume in cubic meters.

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[13]The lower limit for a bag is considered to be a completely filled small shopping bag (0.01 m^3), which tends to be the smallest size of a kitchen litter bag tendentially used in an average household in Slovakia. Volume of 0 m^3 cannot be considered as a lower limit, because by definition the illegal dumps tend to have volumes larger than litter.

Appendix 2

///Include Figure 3 around here ///

List of tables

Table 1. Dumped waste in (%) according to category

Waste Type	(%)
Glass	8.68%
Electronic	4.30%
Household	22.39%
Construction	28.72%
Metal	5.76%
Liquid	1.13%
Automotive	11.85%
Plastic	15.06%
Dangerous	2.11%

Table 2. Absolute volumes of reported dumped waste (m^3) at NUTS 3

Region	(m^3)
Bratislava	893.56
Nitra	380.85
Trnava	333.04
Žilina	310.25
Košice	237.22
BanskáBystrica	214.63
Trenčín	208.93
Prešov	128.45

Table 3. Per person volumes of reported dumped waste (l) at NUTS 3

Region	(l) per person
Bratislava	1.47
Trnava	0.66
Nitra	0.55
Žilina	0.45
Trenčín	0.35
BanskáBystrica	0.33
Košice	0.30
Prešov	0.16

Table 4. Descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max.
DUMPSNR	26.2078	31.0735	1	139
Wpp	0.4956	0.5140	0.0004	2.0580
POPDENS	257.5325	541.8575	39	4045
ACR	0.4680	0.1651	0.1759	0.8302
EFFORT	5.4038	6.9030	-23.6638	18.9225
NOMWAGE	770.3896	138.2301	580	1224
POVERTY	0.0710	0.0526	0.0057	0.2377
UNEMPL	14.4397	6.8725	3.53	34.59
EDUCT	0.1472	0.0595	0.0811	0.3766
N		77		

Table 5. Truncated regression models: Determinants of illegal waste dumping in Slovakia at LAU 1 level.

	(1) WPPln	(2) WPPln	(3) DUMPSNR
ACR	1.563*	1.358	107.6***
	(0.876)	(0.900)	(33.47)
POPDENS	−0.000574**	−0.000644**	−0.0553*
	(0.000261)	(0.000258)	(0.0313)
EFFORT	0.0625**	0.0626**	1.393
	(0.0247)	(0.0248)	(0.991)
NOMWAGEln	2.636*	2.398	226.6***
	(1.511)	(1.588)	(71.75)
POVERTY	−10.38**		−513.3**
	(4.916)		(231.9)
EDUCT	10.02**	9.407**	389.5***
	(4.517)	(4.429)	(133.5)
UNEMPL		−0.0889**	
		(0.0393)	
Constant	−20.75**	−18.43*	−1586.1***
	(9.976)	(10.55)	(478.4)
σ	1.526***	1.522***	27.08***
	(0.168)	(0.158)	(4.790)
N	77	77	77

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6. Truncated regression models: Determinants of illegal waste dumping in Slovakia at LAU 2 level

	(4) WPPln	(5) WPPln
ACR	0.967***	1.188*
	(0.275)	(0.616)
POPDENS	−0.000110**	−0.000427***
	(0.0000499)	(0.000102)
EFFORT	0.0260**	0.0365
	(0.0122)	(0.0249)
NOMWAGEln	1.245***	1.858*
	(0.478)	(0.974)
UNEMPL	0.0968	−6.472
	(3.446)	(8.345)
EDUCT	0.707	−3.059
	(1.173)	(2.265)
Constant	−9.388***	−11.67*
	(3.177)	(6.639)
σ	1.098***	1.375***
	(0.0373)	(0.110)
N	332	122

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

List of figures

Figure 1. Number of illegal dumps in Slovakia at LAU1

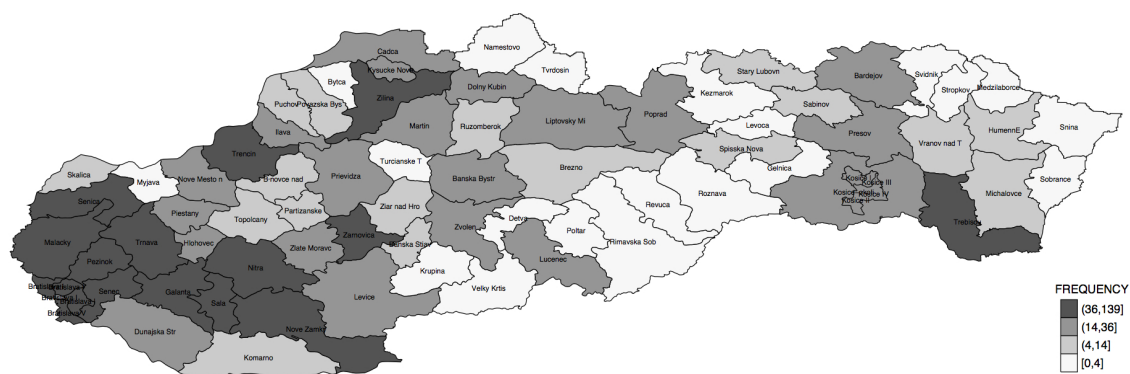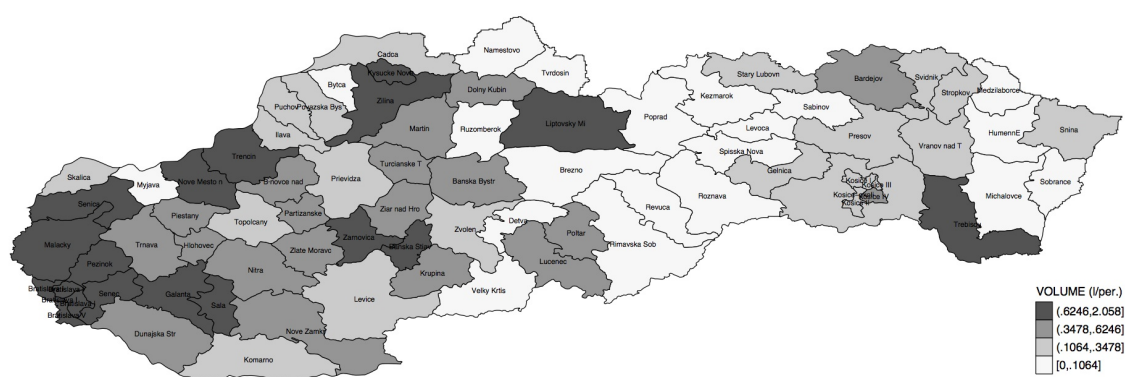Figure 2. Volume of illegally dumped waste per person in (l) in Slovakia at LAU1

Figure 3. Correlation between county-specic volume of produced municipal waste per person (WASTEm) and variables on expected volume of waste production (NOMWAGEln, POVERTY, EDUCT, UNEMPL)