Migration Flows and Municipal Waste Analysis Using the Spatial Panel Durbin Model - The Case of Poland

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The European Conference on Sustainability, Energy & the Environment 2016
Official Conference Proceedings

Abstract
The aim of the paper is to examine the impact of migration processes (mainly the emigration and immigration) and economic prosperity on the quantity of municipal waste. The data used in this research concerned the quantity of collected mixed municipal wastes during the year (an endogenous variable), the number of registrations and de-registrations (to and from rural, urban areas), expenditures on waste management, population density and revenue of NUTS-4 budget (exogenous variables). The analysis covered 379 Polish NUTS-4 (poviats) and the time span from 2005 to 2014. Assuming that, migration processes, quantity of collected wastes and socio - economic development are characterised by spatial heterogeneity and spatial autocorrelation, there were used spatial econometric methods, such as: ESDA (Exploratory Spatial Data Analysis) and spatial panel Durbin model based on Environmental Kuznets Curve.

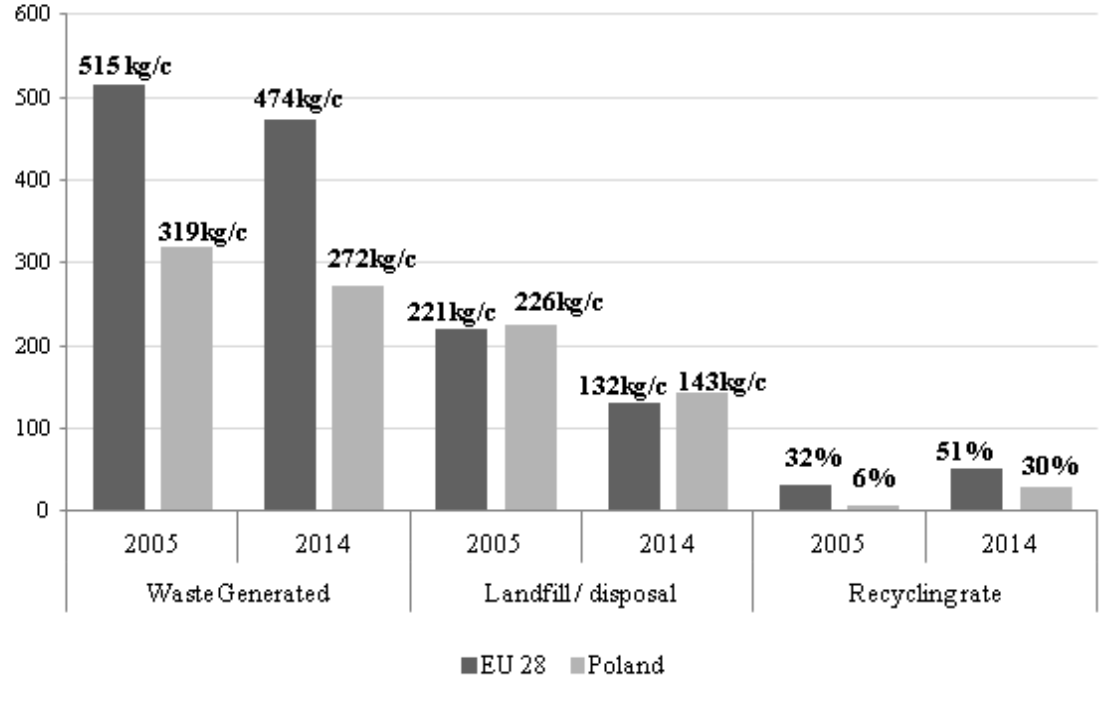
Keywords: municipal wastes, migration processes, ESDA, EKC, spatial panel Durbin model

1. Introduction

Both the Polish[1] and European Union[2] laws define municipal waste as waste mainly generated by households (although it also includes, to a much smaller extent, waste from sources such as shops, enterprises, office buildings and educational, healthcare and public administration institutions). The National Waste Management Plan revision puts a particular emphasis on carrying out tasks in the municipal sector, including intensifying undertakings connected with recycling and disposal of municipal waste (ME, 2015). The principal objective of the tasks is to minimise the quantity of landfilled waste.

Poland is a country situated in Central Europe, of the surface area of over 312 square kilometers (which makes it the 70th and 9th biggest country in the world and Europe respectively), with the population of about 40 million (CSO, 2015). In the 1990s, Poland underwent economic transformation and since 2004 the country has been a member of the European Union. Nonetheless, Poles still struggle with increasing environmental degradation, including huge quantities of generated waste and problems with its recycling. Over 272 kg of unsorted municipal waste was collected *per capita* in Poland in 2014 (only 17% less than in 2005). As much as 168 kg of waste *per capita* came from households. In turn, the ratio of landfilled waste to collected unsorted waste reached as much as 53% with the 30% recycling rate (only 28% of waste was landfilled with the recycling rate at 51% in the European Union-28 in the same year) [3], Figure 1.

Figure 1. Municipal waste (generated, landfilled/disposed, recycling rate) in Poland and EU-28 in selected years



[1] The Act of 14 of December 2012 on waste, http://dziennikustaw.gov.pl/du/2013/21/1, accessed on: 2.05.2016.
[2] Framework Directive 2008/98 / EC on waste from 19 November 2008.
[3] Eurostat data: Municipal waste generation and treatment, by type of treatment method, accessed: 2.05.2016.

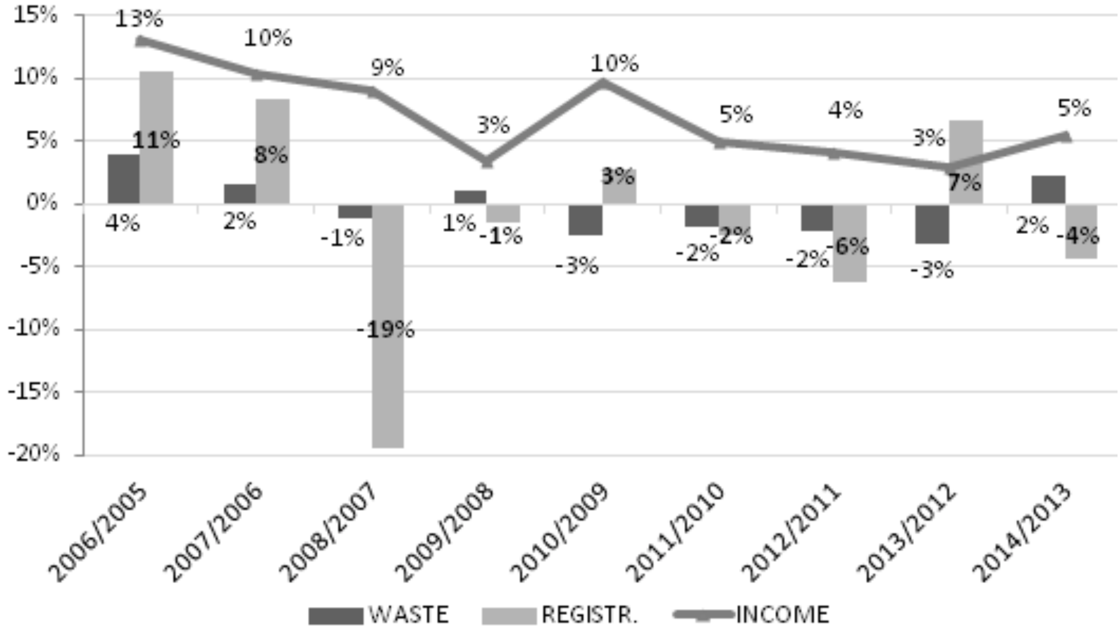
Note: kg/c - kilograms per capita.
Source: own elaboration based on Eurostat.

Main factors determining the quantity and quality of generated municipal waste include, among others: the place of waste generation, wealth of the society, level of the consumption of products, season of the year, ecological awareness and educational level, "type of the area (urban, rural) where it is generated, population density, type of housing (detached, multi-family), presence of public facilities as well as presence, type, size and number of commercial, small industry or service-providing facilities" (ME, 2014). The specialist literature also offers a theory explaining the relationship between migration of people and natural environment (the so-called ecological theory of migration).[4] This article attempts to verify assumptions of the above-mentioned theory at the level of Polish poviats (NUTS-4). The main assumption coincides that the migration processes (internal migration as well as by type and direction) and economic prosperity determine the quantity of municipal waste. The data used in this research concerned the volume of collected mixed municipal wastes during the year (an endogenous variable), the number of registrations and de-registrations, expenditures on waste management, population density and revenue of NUTS-4 budget (exogenous variables). The analysis covered the time span from 2005 to 2014.

As already mentioned, the quantity of municipal waste collected in Poland in 2014 fell by 2% compared to 2005; the number of registrations for residence dropped by 9%, too (including from urban and rural areas by 12% and 3% respectively). On the other hand, budget incomes of poviats *per capita*, investment expenditures on waste management and numbers of registrations for residence from abroad increased. Figure 2 indicates trends in the analysed phenomena. Provisionally, it confirms the legitimacy of the formulated research assumption. It can be observed that the falling number of registrations for residence was accompanied by a decrease in the quantity of collected municipal waste in the studied period. In turn, a fast rise in poviats' budget incomes *per capita* was accompanied by a growth in the number of registrations for residence, whereas a decelerated increase in incomes entailed the slower dynamics of changes in the number of registrations for residence. Such a relationship seems correct. From the economic point of view, a rise in budget incomes (the unit's wealth) is favoured by an increase in the local economic base possible to be achieved through, among others, carrying out investments aimed at the location of new and further development of existing business activity as well as development of housing, which results in a potential population growth in a given unit (Dańska-Borsiak, 2013). That, however, whether changes in the quantity of collected municipal waste were directly associated with changes in the described demographic and economic variables will be explained by results of the carried out econometric analysis (see: *Results of analysis and discussion*).

[4]This theory assumes that the environmental factors are the determinants of migration processes, but on the other hand, population movements cause changes in the natural environment, too, more eg. in: (Sobczak 2012; Janicki 2014; Bremner i Hunter, 2014).

Figure 2. The dynamic of the level of municipal waste, the number of registrations and the revenue budgets of poviats in Poland in the years 2005-2014 (indexes in %)



Note: REGISTR. - the number of internal registrations per 10 thousand of people.
Source: own elaboration.

Assuming that, migration processes, quantity of collected wastes and socio-economic development are characterised by spatial heterogeneity and spatial autocorrelation, there were used spatial econometric methods, such as: ESDA and Durbin spatial model based on Environmental Kuznets Curve (EKC). The EKC assumes a relationship between various indicators of environmental degradation and income per capita.[5]

1. Spatial Panel Durbin Model - research method and applications

The spatial panel Durbin model (SPDM) is a tool simultaneously taking into account spatial autoregression and cross regression, *i.e.* the impact of spatially non-lagged and lagged exogenous variables, drawing at the same time on the panel data (Anselin *et al.*, 2008; Elhorst, 2003).

This study uses a spatial panel Durbin model with specified fixed effects and autoregression of the endogenous variable:

$$y_{it} = \alpha_i + \rho \mathbf{W} y_{it} + \mathbf{x}_{it}^T \boldsymbol{\beta} + \mathbf{W}\mathbf{x}_{it}^T \boldsymbol{\gamma} + \varepsilon_{it},\ \varepsilon_{it} \sim N(0, \sigma_u^2) \qquad (1),$$

where: i = 1,2, ..., N, t = 1,2, ..., T, α_i – individual specific fixed effects, constant in time and different for different cross-sectional categories, y_{it} – vector of observations

[5] In the early stages of economic growth degradation and pollution increase. Beyond some level of income per capita the trend reverses, so that at high-income levels economic growth leads to environmental improvement. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita. Typically the logarithm of the indicator is modeled as a quadratic function of the logarithm of income (Stern, 2003). About the empirical spatiotemporal research on different types of Environmental Kuznets Curve in EU (e.g.: Antczak 2012);

on the endogenous variable, $\mathbf{x}_{it}^T = [x_{1it}, x_{2it}, ..., x_{Kit}]$– vector of observations on K explanatory variables for the i cross-sectional unit in the t period, ε_{it} – pure random error, $\boldsymbol{\beta} = [\beta_1, ..., \beta_K]^T$– vector of parameters at explanatory variables, ρ – spatial autoregression parameter, $\mathbf{W}$ – spatial weights matrix of NxN dimensions and zero diagonal elements, standardised in rows, $\boldsymbol{\gamma}$ – vector of spatial parameters of selected spatially lagged independent variables.

The group of commonly applied spatial panel Durbin models also includes models with specified fixed effects or random effects and spatial autocorrelation of the random element, random effects and autoregression of the dependent variable, as well as mixed models (Suchecki *et al.*, 2012).

Spatial panel Durbin models enjoy an established position in the specialist literature (especially international one), although results of research on migration of people and the impact of its processes on the environmental quality (particularly the quantity of generated waste) have not been popularised. The described models were applied, among others, in analyses of the impact of socio-economic processes (including migration flows) on the quantity of municipal waste generated in Turkey (Keser, 2010) and a well-known city in China (Lin, 2015). In turn, Cox *et al.* (2013) applied the spatial panel Durbin model in looking for factors affecting the volume of solid waste generated in Ecuador. For that purpose, they also used GIS tools. An interesting publication is an article by Yang *et al.* (2016) where the Durbin model was applied to evaluate the impact of migration flows, ecological factors (including the quantity of generated waste) and adjacency of regions on population mortality rates in US poviats. So far, no scientific article has been published in Poland describing the research issue raised in this paper.

2. Database

The research hypothesis put forward at the beginning of this article has been verified based on statistical data concerning:

- quantity of mixed municipal waste collected in kg *per capita*, WASTE, (endogenous variable),
- and a set of exogenous variables:
  - ✓ number of de-registrations for residence to rural areas from other poviats per 10 thousand of the population, DC;
  - ✓ number of registrations for residence from urban areas to other poviats per 10 thousand of the population, RC;
  - ✓ budget incomes in PLN *per capita*, I;
  - ✓ investment expenditures of poviats in the Municipal Services Management and Environmental Protection section in PLN *per capita*, EX;
  - ✓ number of de-registrations for permanent residence abroad per 10 thousand of the population, FD;
  - ✓ population density, D;
  - ✓ and spatially lagged selected variables.

The said socio-economic factors determining the quantity of annually collected municipal solid waste were chosen based on the formal criterion (correlation coefficients) and in accordance with the above-mentioned ecological theory of migration. Data were collected for poviats (NUTS-4) from the CSO of Poland. Table 1 displays the summary statistics of the data.

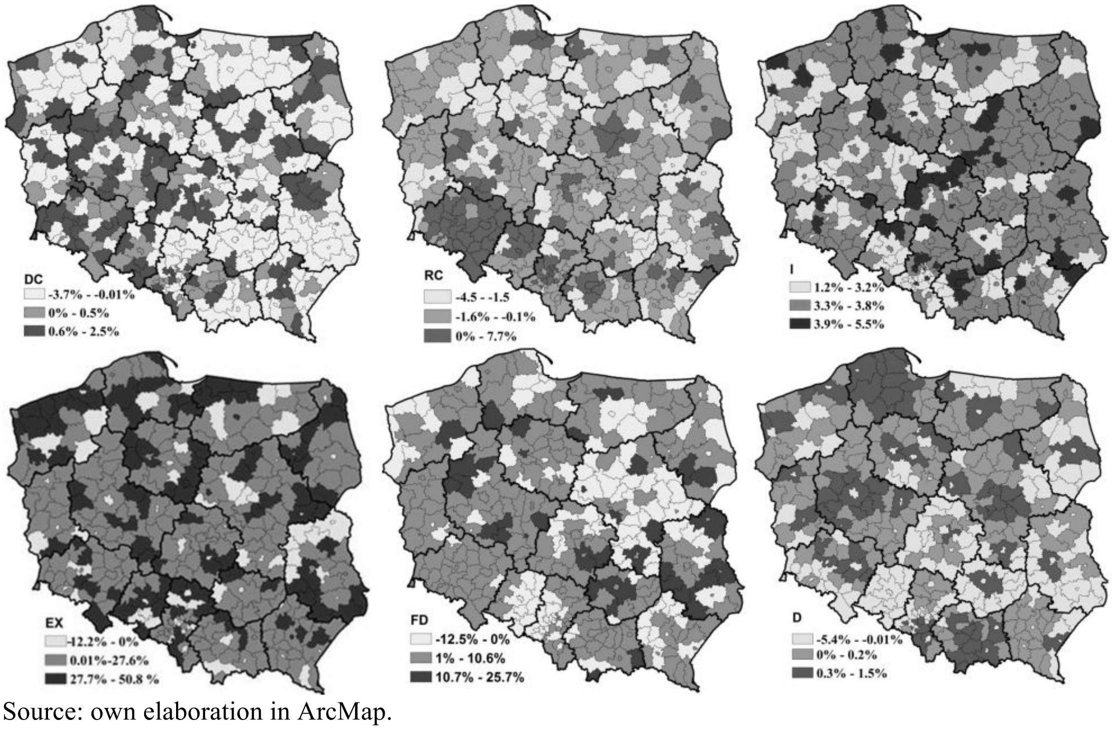
Table 1. Summary statistics of the collected data

Variable	Mean	Max	Min	Median	Stand. Dev.	CV
WASTE	203.9	971	30	197	91	45%
DC	30	120	9	25	16	53%
RC	48	305	12	35	38	79%
I	2836.7	8506	1415	2755.5	805.7	28%
EX	20.5	799.8	0	4.2	40.5	198%
FD	67	755	0	44	78	116%
D	2837	8506	1415	2756	806	28%

Source: own elaboration.

In the years 2005-2014, there were changes in the volumes of the analysed variables. The studied phenomena were also characterised by significant spatial diversification (high values of coefficients of variation). Undoubtedly, the above-described processes determined the specificity of a given region and influenced the development of a unit and annual volume of collected waste. Maps in Graphs 1 and 2 show the mean rates of changes in the studied variables and evaluate those changes.

Graph 1. Average pace of change of the exogenous variables and time span: 2005-2014 on NUTS-4 level

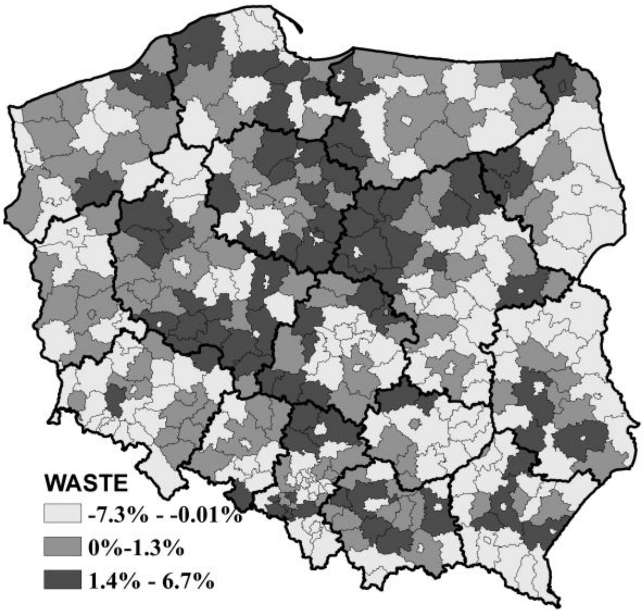


Source: own elaboration in ArcMap.

In the studied period, all poviats of Poland experienced an annual rise in incomes *per capita*, which may indicate a rise in wealth, improved financial situation of the population and economic development of the country. In the years 2005-2014, the highest mean rate of increase was observed in units of the Łódzkie and Mazowieckie regions – central Poland (denoting of voivodships, see App. 1). The mean rate of changes in the number of de-registrations for residence to rural areas was negative in a large proportion of analysed poviats. In turn, the rates of registrations for residence from urban areas and de-registrations for residence abroad were positive in a majority of units. That may be connected with, among others, a better situation on the labour market of both urban areas and other developed countries as well as des-urbanisation trends. In the case of both the variables, the highest rate of changes was reported in the Dolnośląskie (and selected poviats of the Łódzkie, Świętokrzyskie and Lubelskie voivodships). On the other hand, a negative rate of changes (fall) in the number of de-registrations for residence abroad was observed in the Mazowieckie and poviats of the Łódzkie, Kujawsko-Pomorskie and Warmińsko-Mazurskie voivodships adjacent to its borders (which confirms the strong economic position and attractiveness of the Mazowieckie voivodship, and Warsaw in particular, which encourages Poles to stay in that area). The rate of changes in investment expenditures on waste management was positive in a majority of analysed poviats. In turn, the rate of increase in population density in urban areas was negative in the years 2005-2014, which confirms the common European trend of the so-called urban depopulation.

A significant improvement in the situation associated with the quantity of annually collected municipal waste occurred mainly in urban areas. The rate of changes in the phenomenon was negative in those units, *i.e.* there was a fall in the quantity of waste in the years 2005-2014. A similar trend was also observed in poviats situated in Eastern, South-Eastern and South-Western Poland, Graph 2.

Graph 2. Average pace of change of the endogenous variable and time span: 2005-2014 on NUTS-4 level



Source: own elaboration in ArcMap.

The application of the spatial panel model will allow considering those diversification of objects and dynamics of phenomena in the estimation process. However, an integral part of the applicability of panel models is examining the stationarity of its variables. That characteristic was verified using the Levin-Lin-Chu panel test of the following set of hypotheses: H_0: panels contain unit roots and H_1: panels are stationary. Table 2 presents the results of the Levin-Lin-Chu test.

Table 2. Levin-Lin-Chu unit-root test for variables

Adjusted t*	*WASTE*	*DC*	*RC*	*I*	*EX*	*FD*	*D*
Without trend	-24.8***	-29.5***	-24.2***	-28.2***	-32.4***	-44.4***	-4.8***
With trend	-41.3***	-69.9***	-65.6***	-37.4***	-32.3***	-10.7***	-17.6***

Note: significance levels: α = 0.10*, 0.05 **, 0.01 ***.
Source: own elaboration in STATA 11.

Based on information contained in Table 2, it can be stated that both the waste quantity determinants and endogenous variable were stationary. Hence, some long-term stability of processes and elimination of spurious regression were observed.

An important stage in creating spatial models is examination of the spatial autocorrelation. In order to identify that, global Moran's *I* statistic was applied.[6] The intensity of spatial interactions were displayed in the matrix **W** of the first order of contiguity using queen criteria (row standardised, the elements of the matrix take values between zero and one and the sum of the row values is always one). The choice of this type of matrixes was determined by shipment of waste to the landfill and the relevant companies as well as by population flows within the districts.[7] The Moran's *I* statistics was significant for the selected years. Most of the autocorrelation coefficients were positive, but some were negative therefore the adjacent poviats tended to cluster according to the all variables, but the polarisation could have occurred in terms of the de-registrations on rural areas, DC. Certain values fluctuated over time, and the changes had no clear pattern, Table 3.

Table 3. Values of global Moran's *I* statistics for outflows, inflows and other variables using the W matrix

Year/Variable	*WASTE*	*DC*	*RC*	*I*	*EX*	*FD*	*D*
2005	0.33***	-0.05	0.19***	0.16***	0.02	0.69***	0.22***
2006	0.32***	-0.06*	0.21***	0.17***	-0.002	0.59***	0.23***
2007	0.35***	-0.05*	0.16***	0.22***	0.07**	0.69***	0.23***
2008	0.35***	-0.01	0.18***	0.19***	0.15***	0.63***	0.23***
2009	0.40***	-0.05*	0.17***	0.15***	0.11***	0.60***	0.23***
2010	0.39***	-0.06*	0.20***	0.18***	0.09***	0.57***	0.23***
2011	0.37***	-0.07**	0.20***	0.13***	0.05**	0.59***	0.23***
2012	0.41***	-0.08***	0.19***	0.15***	0.001	0.59***	0.23***
2013	0.48***	-0.07***	0.21***	0.14***	0.15***	0.61***	0.23***
2014	0.50***	-0.06***	0.21***	0.13***	0.14***	0.57***	0.23***

Note: significance levels: α = 0.10*, 0.05 **, 0.01 ***.
Source: own elaboration in OpenGeoDa.

3. Results of analysis and discussion

[6]more see, e.g.: LeSage (2008).
[7]CSO provides that most of the flows of individuals who were commuting from their place of residence to a workplace were very close to the border of a given unit (e.g., 20% to 50% of the intensity of the work-related population flows to voivodship capitals, subregions, and counties were very close to the border), CSO, 2014. On the other hand, in Poland, due to lower costs of waste shipment, the short-distance transport still dominates, http://ekotechnologie.org/download/3_Rozdzial.pdf, accessed: 3.05.2016.

Statistically significant spatial interactions, stationarity of series forming the panel and confirmed correlation of variables are conditions for creating a spatial panel Durbin model. Out of many possible variants of spatial models, the spatial panel model with specified fixed effects and autocorrelation of the error term described by formula (1) was chosen to be analysed.[8] The estimation results of the presented model allowed indicating characteristics determining the quantity of municipal waste annually collected in poviats from 2005 to 2014 (Table 4). Moreover, the strength and direction of the impact of those factors on the studied variable were estimated and direct and indirect effects for particular variables were also added. The mean *direct effect* captures the effect of a unit change in an explanatory variable in a focal county on the dependent variable in this county. This measure includes also the feedback effect. The feedback effect arises when the impact of an increase in an explanatory variable in a focal unit affects the neighbouring states, passes through them and returns to this initial focal unit. The average *indirect* (*spillover*) *effect* is the effect of a unit change in an explanatory variable in a focal county on the dependent variable in the neighbouring poviats[9]. The total effect of an explanatory variable consists of the *direct effect* of the increase in the explanatory variable on the dependent variable in the focal unit and the *indirect effect* of the increase in the explanatory variable (spillover effect) on the dependent variable in the contiguous units (LeSage and Pace 2009).

Table 4. Results of the estimation of the non-spatial and spatial SAR-FEM Durbin model of the collected municipal waste in Polish NUTS-4

$$lWASTE_{it} = \alpha_i + \alpha_1 lDC_{it} + \alpha_2 lRC_{it} + \alpha_3 lI_{it} + \alpha_4 (lI_{it})^2 + \alpha_5 lD_{it} + \alpha_6 lEX_{it} + \alpha_7 lFD_{it} + e_{it}$$

parametr	*value*	*t-Student*	*Std.error*	*direct*	*indirect*
α_0	-12.3***	-5.8	2.1	-	-
α_1	0.03	1.6	0.2	-	-
α_2	0.05**	3.4	0.02	-	-
α_3	3.9***	7.2	0.5	-	-
α_4	-0.3***	-7.2	0.03	-	-
α_5	0.4***	4.2	0.09	-	-
α_6	-0.05**	-2.4	0.002	-	-
α_7	0.002	0.44	0.004	-	-

pseudo R^2=0.31; Chow's test of fixed effects, F=42.42 ***, residuals normality: Shapiro-Wilk, W = 0.88***, Levin-Lin-Chu, without trend: t^* = -38.9***, with trend: t^* = -57.1 ***;

$$lWASTE_{it} = \beta_i + \beta_1 lDC_{it} + \beta_2 lRC_{it} + \beta_3 lI_{it} + \beta_4 (lI_{it})^2 + \beta_5 lD_{it} + \beta_6 \mathbf{W} lEX_{it} + \beta_7 \mathbf{W} lFD_{it} + \rho \mathbf{W} lWASTE_{it} + e$$

parametr	*value*	*t-Student*	*Std.error*	*direct*	*indirect*
β_0	-1.8***	-3.2	0.6	-	-
β_1	-0.03*	-1.7	0.02	-0.03*	-0.04*
β_2	0.06**	2.4	0.03	0.06**	0.07**
β_3	1.14***	3.7	0.3	1.2***	1.3***
β_4	-0.2***	-3.6	0.05	-0.17***	-0.19***
β_5	0.4***	4.2	0.09	0.37***	0.42***
β_6	-0.01***	-3.3	0.003	-0.01***	-0.01***
β_7	0.01**	2.5	0.005	0.01**	0.01**
$\boldsymbol{\rho}$	**0.5*** **	**13.5**	**0.04**	**-**	**-**

[8] The carried out tests verifying the quality and usefulness of spatial panel Durbin models showed the highest efficiency of models with fixed effects and autocorrelation of the random component. The properties of other spatial panel Durbin models are available via e-mail: wiszniewska@uni.lodz.pl.

[9] The second possible interpretation of the indirect effect reflects the change in the dependent variable in a focal unit as a result from an increase in the independent variable in the adjacent units (Seldadyo et al. 2010).

pseudo R^2=0.75; Chow's test of fixed effects, F=16.89 ***, residuals normality: Shapiro-Wilk, W = 0.84, Levin-Lin-Chu, without trend: t^* = -21.6***, with trend: t^* = -36.1 ***; Chow's test of spatial effects: $F_{SD\text{-}FEM}$=6,23 ***, SD-FEM better than FEM;

Note: significance levels: α = 0.10*, 0.05 **, 0.01 ***.
Source: own elaboration in RCran.

Based on the received results, it was confirmed that migration processes influenced the quantity of waste generated in poviats. A 1% rise in the number of registrations for residence from urban areas resulted in a 0.06% increase in the endogenous variable *ceteris paribus*. In turn, an average increase in the scale of de-registrations for residence to rural areas led to a 0.03% decrease in the annual volume of collected waste. Thus, in cities and towns, where service-providing and commercial facilities are located, the quantity of generated waste was larger than in rural areas and on the outskirts of urban areas. The quantity of municipal waste per one rural inhabitant was, on average, twice as small as that per one urban inhabitant. Rural houses are not infrequently equipped with individual hearths and part of waste is incinerated (Tyralska-Wojtycza, 2015). The immigrants from urban areas (urban population) usually has greater wealth, which results in an increase in the amount of waste generated, especially glass and plastic (Ibanez et al. 2011). A rise in the dependent variable was contributed to by an increase in population density (by 0.4% on average) and a rise in poviats' budget incomes *per capita* (by 1.14% on average). That was directly connected with wealth, a higher level of industrialisation and urbanisation as well as increased consumption by the population. It is, however, worth drawing attention to meeting the Kuznets curve assumptions in selected poviats of Poland. The value of the extremum of the cubic function (income *per capita*) was above PLN 3.2 thousand *per capita*, which means that an increase in income above that level did not cause an increase in municipal waste in a given administrative unit.[10] Therefore, in the analysed period, there were poviats in which the rate of an increase in income *per capita* was positive but generated a slower or even negative rate of increase in waste quantity (that group included most cities with poviats rights but also the Policki, Słupski or Wrocławski poviats). Higher budget incomes of poviats also resulted in higher investment expenditures, which is indicated by the significance of estimation of the parameter at the spatial image of the EX variable. A 0.01% fall in the quantity of waste in a given poviat was determined by an increase in the said expenditures in adjacent poviats (defined in the **W** matrix as units directly adjacent to a given poviat – having a common border with that). On the other hand, a 1% rise in the number of de-registrations for residence abroad from adjacent poviats resulted in an about 0.01% increase in the quantity of waste collected in a given poviat (*ceteris paribus*).

The direct and the indirect effects were consistent for certain variables. The indirect effects were generally stronger than direct ones. For example, a 1% increase of the deregistrations to rural areas in the given local unit decreased the volume of the collected municipal waste in this unit by 0.03%; and it decreased the endogenous variable in each poviats by 0.04% (excluding the focal one).

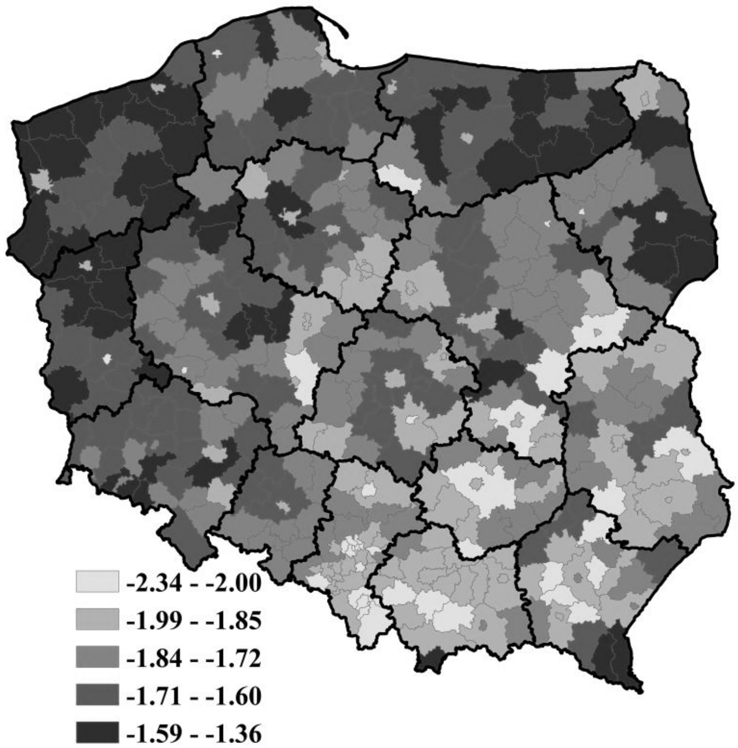
Statistics characterising the properties of the spatial Durbin model reflect the effectiveness of the applied instrument. The inclusion of spatial effects enhanced the quality of the model. The pseudo-determination coefficient for the Durbin model was higher than the goodness of fit to empirical data of the non-spatial model. What is

[10] more about several implementing EKCs in the continuation of research.

more, the Chow spatial effects test indicated the higher quality of the spatial model as well as its correctness and usefulness in application in that kind of analyses. Results in the spatial model were substantially correct. Results of modelling without spatial interactions indicated two variables which proved to be of no importance to the quantity of municipal waste, *i.e.* the numbers of de-registrations for residence to rural areas and de-registrations for residence abroad. Furthermore, in the classical model, the value of the absolute term was significantly higher than in the spatial model, whereas an increase in income *per capita* had a significantly stronger effect on the quantity of waste than other factors (Table 4). Thus, the consideration of spatial interactions in the form of the **W** matrix proved to have been justified. The significance of the spatial autocorrelation parameter estimation confirmed the impact of spatial relationships on the quantity of annually collected municipal waste in the analysed period. In turn, the positive ρ sign indicated the clustering of poviats with similar (low or high) values of the dependent variable in the geographical space. The value of ρ assessment means that an increase of 1% in the volume of waste generated in adjacent units resulted in an average increase of 0.5% in that phenomenon in a given poviat in the years 2005-2014.

The estimation of values of fixed effects for each analysed unit allowed obtaining additional information about the specificity of poviats. Thus, units were identified whose conditions to the largest and smallest extent affected changes in the mean quantity of waste collected in Poland in the studied period (Graph 3).

Graph 3. Fixed effects estimated from spatial panel Durbin model



Source: own elaboration in ArcMap.

The map in Graph 3 shows that, in the years 2005-2014, the greatest impact on the mean level of the dependent variable was exerted by poviats situated in the Northern and Eastern parts of the country. Nevertheless, in those parts of Poland, there were urban units which simultaneously showed noticeably lower significance for the quantity of annually collected municipal waste than their surrounding areas. The least impact on the level of the analysed phenomenon was exerted by poviats of Sothern and Eastern Poland.

4. Summary and directions of further research

This article attempted to verify relationships between population migration, economic development and quantity of municipal waste annually collected in Polish poviats in the years 2005-2014. The study applied the spatial panel Durbin model which proved to be an effective tool in that kind of analyses (which was indicated by the quality of the model, substantial accuracy of received results, extensiveness and thoroughness of information).

Results of the conducted analysis indicated that the quantity of waste was associated with the economic condition of poviats, wealth of the population and population density. Nevertheless, internal processes and foreign migrations (their intensity and direction) considerably influenced the value of the analysed endogenous variable. The application of an appropriate spatial model enabled verifying the occurrence and inclusion of inter-poviat relations in the analysis. As a result, it appeared that spatial autocorrelation also determined the volume of the studied phenomena not only in a given poviat but also in adjacent ones. Moreover, the carrying out of the Kuznets curve assumptions confirmed a strong non-linear correlation between the economic development of poviats and quantity of municipal waste. However, the form of the estimated function indicated that there were urban units in Poland whose faster economic growth led to a fall in the dependent variable value, *e.g.* through investment expenditure on waste management also in adjacent poviats.

Due to the generality of statistical information, the received results should be regarded as a starting point for further research. The next stage in the analyses will be an attempt at building models describing the impact of population flows on the quantity of produced waste divided into categories as well as searching for environmental factors determining migration processes (and then the analysis will look at how environmental degradation might stimulate or force migration). Moreover, a special emphasis will be placed on the evaluation of the phenomena in urban units. In turn, the models will be enriched with different kinds of spatial weights matrices (also asymmetrical, directional) and based on different environmental Kuznets curves. However, taking into account the diversification of occurring environmental and economic processes and local determinants of poviats, it is worth applying geographically weighted regression (GWR) in future, too.

Appendix 1.
Map of the NUTS-2 and NUTS-4 of Poland

Note: 0- warmińsko-mazurskie, 1 - pomorskie, 2 - zachodniopomorskie, 3- podlaskie, 4 - kujawsko-pomorskie, 5- wielkopolskie, 6 - lubuskie, 7 - lubelskie, 8 - łódzkie, 9 - mazowieckie, 10 - dolnośląskie, 11 - świętokrzyskie, 12 - śląskie, 13 - opolskie, 14 - podkarpackie, 15 - małopolskie.

References

Anselin L., Le Gallo J., Jayet H., (2008), *Spatial Panel Econometrics*, [w:] Matyas L., Sevestre P. (red.), *The Econometrics of Panel Data*, Fundamentals and Recent Developments in Theory and Practice, Berlin, Springer, pp. 625-660. Kluwer, Third Edition.

Antczak E., (2012), *Aplikacja przestrzennych modeli panelowych do weryfikacji hipotezy Środowiskowej Krzywej Kuznetsa na przykładzie Polski* (eng.*The application of spatial panel models to verify the Environmental Kuznets Curve hypothesis on the Polish example*), Roczniki Kolegium Analiz Ekonomicznych, Zeszyt 27/2012, Warsaw 2012, pp. 113-130.

Bremner J., Hunter L.M., (2014), *Population Reference Bureau Migration And The Environment*, Polpulation Bulletin, Population Reference Burea, VOL. 69, NO. 1.
Council of the European Union, (2006), *Review of the EU Sustainable Development Strategy (EU SDS)-Renewed Strategy*, nr 10117/06, Brussels.

CSO, (2014), *Territorial variation of commuting*, Central Statistical Office in Poland, Warsaw, online:
http://stat.gov.pl/spisy-powszechne/nsp-2011/nsp-2011-wyniki/dojazdy-do-pracy-nsp-2011,7,1.html, (accessed 30.06.2015).

Dańska-Borsiak, B., (2013), *Migracje do podregionów według typów; wpływ czynników ekonomicznych i gospodarki opartej na wiedzy* (eng. *Migrations Towards Subregions: The Influence Of Economics Factors And Knowledge-Based Economy*), Roczniki Kolegium Analiz Ekonomicznych nr 30/2013, Warsaw, pp. 27-41.

Elhorst J.P., (2003), *Specification and Estimation of Spatial Panel Data Models*, International Regional Science Review 26 (3), pp. 244-268.

Ibáñez et al., (2011), *Modelling municipal waste separation rates using generalized linear models and beta regression*, Resour. Conserv. Recycl., 55, pp. 1129–1138 http://dx.doi.org/10.1016/j.resconrec.2011.07.002.

IGSMiE, (2009), *Ewaluacja gospodarki odpadami komunalnymi w Polsce*, (eng. *Evaluation of waste management in Poland*), IGSMiE PAN, Krakow.

Janicki W., (2014), *Przegląd teorii migracji*, (eng. *Overview of migration theories),* http://phavi.umcs.pl/at/attachments/2014/0215/30630-19-przeglad-teorii-migracji-ludnosci.pdf (accessed: 19.03.2016).

Keser S., (2010), *Investigation Of The Spatial Relationship Of Municipal Solid Waste Generation In Turkey With Socio-Economic, Demographic And Climatic Factors,* https://etd.lib.metu.edu.tr/upload/3/12611575/index.pdf, accessed: 3.05.2016.

LeSage J., Pace R., (2009), *Introduction to Spatial Econometrics*. Chapman & Hall, Boca Raton.
LeSage J.P., (2008), *An Introduction To Spatial Econometrics*, Revue D'économie Industrielle, nr 123, http://rei.revues.org/3887?file=1, accessed: 3.05.2016.

Lin S., (2015), *New Wenzhou: Migration, Metropolitan Spatial Development and Modernity in a Third-tier Chinese Model City*, http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1535&context=dissertations_2, accessed: 3.05.2016.

MOS, (2015), *Aktualizacja Krajowego planu gospodarki odpadami 2014,*(eng. *The update of the National Waste Management Plan 2014*)*,* Warsaw, https://www.mos.gov.pl/g2/big/2015_09/8fc2497f345721fe22ca200b9ceac57.pdf, accessed: 2.05.2016.

Seldadyo, Harry, J. Paul Elhorst, De Haan J., (2010), *Geography and governance: Does space matter?* Papers in Regional Science 89(3), pp. 625–640.
Sobczak M., (2012), *Migracje ludności południowego Maroka a zmiany środowiska przyrodniczego*, (eng. *Migrations of the population of southern Morocco and changes in the natural environment*) https://depotuw.ceon.pl/bitstream/handle/item/104/Rozprawa.pdf?sequence=1,(accessed: 1.05.2016).

Stern D., J., (2003), *The Environmental Kuznets Curve*, http://isecoeco.org/pdf/stern.pdf, (acessed: 17.05.2016).

Suchecki B., et al. (2010), *Ekonometria przestrzenna. Metody i modele analizy danych przestrzennych*, (eng. *Spatial Econometrics. The methods and models of spatial data analysis*), BECK, Warsaw.

Suchecki B., et al., (2012), *Ekonometria przestrzenna II. Modele zaawansowane*, (eng. *Spatial Econometrics II. Advanced Models*) BECK, Warsaw.

Szpadt R., (2010), *Prognoza zmian w zakresie gospodarki odpadami*, (eng. *The forecast of changes in waste management*), National Fund for Environmental Protection and Water Management.

Tyralska-Wojtycza E., (2015), *Gospodarka odpadami – fakty i zamierzenia ze szczególnym uwzględnieniem elektroodpadów,* (eng. *Waste management - facts and intentions with particular emphasis on electro-waste*), http://www.ekoedu.uw.edu.pl/rep/pdf/36a8a0aecd8f327214d89b88fa93ad36.pdf, accessed: 4.05.2016.

Villa-Cox G., Villa-Cox R., Pindo J.C., Matamoros D., (2013), *Estimating The Relationship Between Socioeconomic Determinants And Solid Waste Production For The Simulation Of Waste Production Patterns: The Guayaquil, Ecuador Case Study*, Sardinia 2013, Fourteenth International Waste Management and Landfill Symposium.

Yang T. Ch., Noah J. A., Shoff C., (2016), *Revisiting the Rural Paradox in US Counties with Spatial Durbin Modeling*, Chapter Recapturing Space: New Middle-Range Theory in Spatial Demography Volume 1 of the series Spatial Demography Book Series, pp. 253-273.