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## Gravity model as the tool for internal migration analysis in Poland in 2004-2010

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**Gravity model as the tool for internal migration  
analysis in Poland in 2004-2010**

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## **Gravity model as the tool for internal migration analysis in Poland in 2004-2010**

**JEL Classification:** *J11, O11, R11, R23*

**Keywords:** *gravity model, internal migration, economic determinants of migration*

**Abstract:** Population migration is a long-lasting process affected by many factors. The analysis of its effects is a typical research approach to its interpretation. The object of the paper is to investigate migration phenomenon by means of gravity model application. It helps to explain variations in the level of migration flows between and within regions, to determine its effects and reasons including geographical factor. The analysis covers internal migration in Poland in the period of 2004-2010. Inter- and intraregional flows at NTS-2 level were considered. Two periods of time regarding economic situation in Poland were specified: 2004-2007, 2008-2010. Key economic factors (GDP, capital expenditures, unemployment, wages and salaries) were used as explanatory variables. Distances between regions were determined on their centroids. The research results confirmed that regional economic indicators are the determinants of internal migration directions in Poland whilst overall economic situation affects its intensity. The regions featuring

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relatively good economic situation are the centres of population inflow (particularly from neighbouring locations) whereas the other perform the role of “demographic resources” for better developed voivodships.

## Introduction

Migration flow represents the physical movement of humans from one area to another in order to change the place of residence due to environmental, financial, cultural reasons etc. Theoretical foundations of migration phenomena were presented by Ravenstein (1885); Tobler (1995); Arango (2000); Janicki (2007).

Human migration is not only a demographical phenomenon but also has its social and economic consequences for labour market, regional development, social and technical infrastructure etc. In connection with these reasons migration phenomenon is examined in many empirical studies. Research approaches frequently presented in the literature consider only the effects of population migration, e.g. migration inflow, outflow and net migration value, without the reasons underlying this phenomenon (see e.g. Long-term migration... 2004; Matusik 2005; Janicki 2006).

The objective of the paper is to investigate migration phenomenon by means of gravity models application. This approach helps to explain the level of migration flow variations between and within regions, to determine migration effects as well as its determinants having included the geographical factor.

Gravity models were discussed by Chojnicki (1966); Anderson (1979); Thomas and Huggett (1980); Mazurkiewicz (1986); Grabiński et al. (1988); Fotheringham and O’Kelly (1989); Zeliaś (1991), pp. 172-175; Sen and Smith (1995); Roy (2004); Suchecki et al. (2010), pp. 226-230. Applications of the econometric models for internal migration research were presented by Dańska-Borsiak (2007, 2008); LeSage and Pace (2009), Matusik, Pietrzak, Wilk (2012), Pietrzak, Drzewoszewska, Wilk (2012), Pietrzak et al. (2012), Wilk, Pietrzak, Matusik (2013), Pietrzak, Wilk, Matusik (2013a, 2013b), Pietrzak, Wilk (2013), Wilk, Pietrzak (2013).

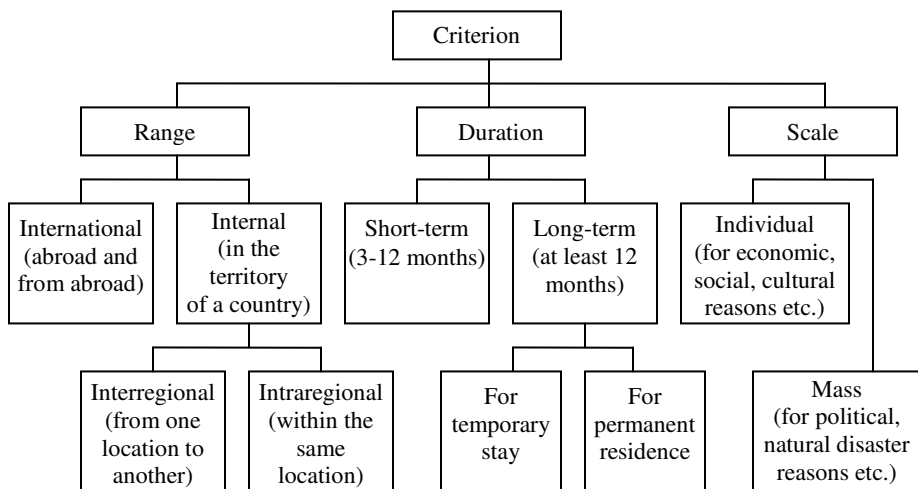
The paper discusses an impact direction and intensity of selected economic factors such as GDP, capital expenditures, unemployment rate, wages and salaries, as well as influence of overall economic trends on migration phenomenon including the role of geographical factor. The following theses were presented:

- regional economic indicators determinate internal migration directions in Poland whilst overall economic situation affects its intensity,
- voivodships characterized by a relatively good economic situation are the centres of population inflow (particularly from neighbouring locations) and their net migration is positive,
- voivodships featuring worse economic situation perform the role of “demographic resources” for better developed regions.

### Human migration phenomenon

Migration flows can be classified by range, duration and scale (see Figure 1). Departures abroad (emigration) and arrivals from abroad (immigration) are defined as international (external) migration. Changing the place of residence in the territory of a country is referred to as internal migration. Arrivals are called migration inflow, whilst departures – migration outflow. There are internal movements from one location to another or within the same location.

**Figure 1.** Category criteria of migration phenomenon



Source: Authors' compilation based on *Methodological documentation of Local Data Bank...* Gawryszewski (2005), Holzer (2003).

The reasons underlying the discussed phenomena are both economic (financial, occupational etc.) factors and non-economic (social, political, environmental, geographical etc.) ones (see Woods 1982; Arango 2000; Janicki 2007). Consequences of particular circumstances such as political conflicts (e.g. political unrest, outbreak of a war) and the occurrence of natural disasters (e.g. flood, earthquake) can become the reason of mass migration.

More frequently the migration phenomenon has an individual character due to economic (e.g. a change of job, reduction of maintenance costs), social (e.g. starting a family), cultural (e.g. nomadic existence, cultural assimilation) and geographical (e.g. suburbanization process) factors. Such migration flows present a considerable scale but are spread in time.

### **Methodology of the research**

Gravity models were used to explain variations in the level of flows that arise between two locations – origin region and destination region – in the fields such as international and regional trade, population migration and tourism research, transportation economics etc. (see Suchecki 2010, p. 226). In regional studies gravity models were labeled as spatial econometric interaction models.

Gravity models are loosely derived from Newton's law of universal gravitation (1687) which states that the attractive force between two bodies is directly related to their size and inversely related to the distance between them<sup>2</sup>. It is assumed that the interaction between two geographic entities, through trade or migration etc., is subject to forces that are inversely proportional to the distance (or income differential) between them and based on some relevant measure of their “masses”, including population, area, income etc. (Letouzé et al. 2009, p. 13).

In contrast to typical spatial econometric models where the sample involves  $n$  regions, with each region being an observation, these models involve  $n^2 = N$  origin-destination pairs with each origin-destination pair representing an observation. The models rely on the function of explanatory variables pertaining to characteristics (e.g. economic indicators) of both origin and destination regions, as well as the distance<sup>3</sup> between them.

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<sup>2</sup> Newton's law was applied to migration research by e.g. [Lee 1966, pp. 47-57].

<sup>3</sup> Several types of distance measures can be considered such as physical, time, economic distance etc. [see e.g. Zeliaś 1991].

Standard gravity model can take the form of (see LeSage, Pace 2009, p. 214)

$$Y^* = \beta_0^* + X_o \beta_o + X_d \beta_d + \gamma d + \varepsilon, \quad (1)$$

where:  $Y^* = \ln(Y)$ ,  $Y$  – vector of flow values from  $n$  origin regions to  $n$  destination regions,  $X_o, X_d$  – matrices of explanatory variables values respectively for origin regions (i.e. push factors<sup>4</sup>) and destination regions (i.e. pull factors<sup>5</sup>),  $d$  – vector of distances between regions,  $\beta_o, \beta_d, \gamma$  – structural parameter vectors,  $\beta_0^*$  – constant,  $\varepsilon$  – spatial noise.

When considering interregional flows, as well as intraregional flows the gravity model can be presented as (see LeSage, Pace 2008, p. 945)<sup>6</sup>

$$Y = \alpha_1 X_1 + \alpha_2 X_2 + \beta_1 X_o^* + \beta_2 X_d^* + \beta_3 X_i + \gamma d + \varepsilon, \quad (2)$$

where:  $X_1$  – vector of interregional flows, 1 representing the pair of different regions and 0 the pair of the same regions,  $X_2$  – vector of intraregional flows (inversely to  $X_1$ ),  $X_o^*, X_d^*$  – matrices of explanatory variables values representing respectively origin regions and destination regions, with 0 standing the pair of the same regions,  $X_i$  – matrix of explanatory variables values for the pair of the same regions and 0 otherwise,  $\alpha_1, \alpha_2, \beta_1, \beta_2, \beta_3$  – structural parameter vectors.

## Gravity models for internal migration in Poland

The conducted investigation covers internal migration for permanent residence in Poland in the period of 2004-2010 at voivodship level of Polish administrative division (NTS-2). Both inter- and intraregional migration flows are analyzed. Two periods of time regarding

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<sup>4</sup> Push factors are these characteristics of origin region which encourage (discourage) out-migration (in-migration), such as low incomes, high unemployment, high prices, in general few opportunities for development.

<sup>5</sup> Pull factors are the destination place characteristics which encourage (discourage) in-migration (out-migration).

<sup>6</sup> For detailed instructions related to model components construction (see LeSage, Pace 2009; Sen, Smith 1995).

economic situation in Poland were specified, i.e. 2004-2007 and 2008-2010.

The first period corresponds to Polish economy prosperity of following Poland's accession to the European Union. The second one refers to world financial and economic crisis which slowed down economic growth and development in Poland. Key social and economic indicators were used as explanatory variables (see Table 1).

**Table 1.** The set of explanatory variables

Abbreviation	Explanatory variable	Unit
GDP	Gross Domestic Product <i>per capita</i>	Thousands of PLN
Investments	Investment outlays in enterprises <i>per capita</i>	Thousands of PLN
Wages&Salaries	Average monthly gross wages and salaries in national economy	Hundreds of PLN
Unemployment	Registered unemployment rate	%

Source: Authors' compilation.

Population migration phenomenon is a long-lasting process. For that reason two vectors of migration flows from  $n$  origin regions to  $n$  destination regions defined as aggregated values, for the periods 2004-2007 and 2008-2010 respectively, were specified. Migration directions and its intensity are the consequence of previous economic considerations.

Migration is likely to lag behind the changed circumstances (see Greenwood 1985, p. 535). Therefore all explanatory variables are lagged by a period of time in order to avoid endogeneity problems or simultaneity bias<sup>7</sup>. They correspond to the year, 2003 and 2007 respectively.

For each period of time four separated gravity models shown in (2) were specified due to high statistical correlation of explanatory variables values<sup>8</sup>. Physical distances between voivodships, determined on the basis of their centroids, were used as distance measures. The least squares method was applied to determine the estimates of model structural parameters.

<sup>7</sup> Similar approach is suggested by LeSage and Pace (2009); Dańska-Borsiak (2008); Bunea (2012).

<sup>8</sup> The application of ridge regression did not provide satisfactory results. The determined estimates reflect the impact of explanatory variables as well as the variables correlated with each of them. For that reason the role played by variables may be underestimated.



## The influence of regional economic factors on migration flows

The results of parameters estimation for the periods 2004-2007 and 2008-2010 are shown in Table 2 and Table 3 respectively (see also Figure 2). Intraregional migration flows are determined by the explanatory variables for which the estimates of parameter  $\beta_3$  are statistically significant (p-value below 0,05), i.e. GDP, Investments and Wages&Salaries. Unemployment rate does not affect intraregional migration during the period of economic prosperity in Poland, as well as during the period of world financial crisis.

**Table 2.** Gravity models estimates for 2004-2007

GDP			Investments		
Parameter	Estimate	<i>p</i> -value	Parameter	Estimate	<i>p</i> -value
$\alpha_1$	1,71	0,11	$\alpha_1$	14,13	0,00
$\alpha_2$	6,60	0,00	$\alpha_2$	12,32	0,00
$\beta_1$	1,50	0,00	$\beta_1$	0,76	0,00
$\beta_2$	2,88	0,00	$\beta_2$	1,52	0,00
$\beta_3$	2,02	0,00	$\beta_3$	1,12	0,00
$\gamma$	-1,41	0,00	$\gamma$	-1,41	0,00
<i>R-squared</i>		0,99	<i>R-squared</i>		0,99
Wages&Salaries			Unemployment		
Parameter	Estimate	<i>p</i> -value	Parameter	Estimate	<i>p</i> -value
$\alpha_1$	-46,29	0,00	$\alpha_1$	19,84	0,00
$\alpha_2$	-13,44	0,22	$\alpha_2$	16,58	0,00
$\beta_1$	2,89	0,00	$\beta_1$	-0,39	0,12
$\beta_2$	5,15	0,00	$\beta_2$	-0,94	0,00
$\beta_3$	3,41	0,02	$\beta_3$	-1,23	0,21
$\gamma$	-1,49	0,00	$\gamma$	-1,58	0,00
<i>R-squared</i>		0,99	<i>R-squared</i>		0,99

Source: Authors' estimations in R environment (5% of significance level) based on data from Local Data Bank of Central Statistical Office of Poland.

**Table 3.** Gravity models estimates for 2008-2010

<b>GDP</b>			<b>Investments</b>		
Parameter	Estimate	<i>p</i> -value	Parameter	Estimate	<i>p</i> -value
$\alpha_1$	1,99	0,09	$\alpha_1$	12,99	0,00
$\alpha_2$	5,99	0,02	$\alpha_2$	11,50	0,00
$\beta_1$	1,22	0,00	$\beta_1$	0,72	0,00
$\beta_2$	2,51	0,00	$\beta_2$	1,51	0,00
$\beta_3$	1,88	0,02	$\beta_3$	1,14	0,02
$\gamma$	-1,40	0,00	$\gamma$	-1,43	0,00
<i>R-squared</i>		0,99	<i>R-squared</i>		0,99
<b>Wages&amp;Salaries</b>			<b>Unemployment</b>		
Parameter	Estimate	<i>p</i> -value	Parameter	Estimate	<i>p</i> -value
$\alpha_1$	-45,63	0,00	$\alpha_1$	19,33	0,00
$\alpha_2$	-14,86	0,17	$\alpha_2$	15,64	0,00
$\beta_1$	2,72	0,00	$\beta_1$	-0,42	0,05
$\beta_2$	4,97	0,00	$\beta_2$	-1,29	0,00
$\beta_3$	3,45	0,02	$\beta_3$	-1,32	0,09
$\gamma$	-1,51	0,00	$\gamma$	-1,53	0,00
<i>R-squared</i>		0,99	<i>R-squared</i>		0,99

Source: Authors' estimations in R environment (5% of significance level) based on data from Local Data Bank of Central Statistical Office of Poland.

An estimate value corresponds to the intensity (importance) of an explanatory variable with reference to migration phenomenon. In both considered periods of time the highest estimate corresponds to Wages&Salaries and the lowest to Investments.

Signs of the estimates provide information regarding impact direction of an explanatory variable on population migration. Its positive (negative) value means that explanatory variable values increase results in intraregional migration flows up (down). It should be noted that growth in GDP, Investments and Wages&Salaries values results in better economic

situation of a region which stimulates intraregional migration flows. This may also suggest that in voivodships featuring worse economic situation intraregional migration flows are lower than in others.

The interpretation of interregional migration flows is more complicated and difficult than intraregional migration flows due to the need for considering push factors for origin regions ( $\beta_1$ ) and pull factors for destination regions ( $\beta_2$ ). Estimates of both parameters are statistically significant for all explanatory variables in the second studied period of time. In 2004-2007  $\beta_1$  estimate for Unemployment is statistically insignificant.

Positive (negative) value of  $\beta_1$  estimate means that the growing (dropping) explanatory variable value in origin regions results in migration outflows from these regions. Positive (negative) value of  $\beta_2$  estimate means that the upturn (downturn) of explanatory variable value in destination regions results in migration inflows to these regions.  $\beta_1$  as well as  $\beta_2$  estimates are positive for GDP, Investments and Wages&Salaries regardless of economic trend.

The higher level of GDP, Investments and Wages&Salaries in destination (origin) regions the higher pull effect to the regions (push effect from the regions). This means that migration inflows, as well as migration outflows, are higher for the regions characterized by a relatively good economic situation, but the pull effect is stronger than the push effect (in each case  $\beta_2$  estimates exceed almost twice  $\beta_1$  estimates).

Statistically significant and negative sign of  $\beta_2$  estimate (in both periods of time) for Unemployment means that unemployment rate declines in destination regions results in the growth of migration inflow to the regions. During the second analyzed period of time  $\beta_1$  estimate turns out to be statistically significant with negative sign and relatively low impact as compared to  $\beta_2$ . Unemployment rate growth in origin regions – during the period of financial crisis – results in the decreasing migration outflow from these regions.

In the analyzed periods of time for all explanatory variables  $\square$  estimates – related to the influence of geographical factor on migration phenomenon – are statistically significant and present similar values. Distance elasticity is negative which means a longer distance between origin and destination regions results in lower migration flows. Distance affects migration decisions by costs of moving which increases with physical distance. This suggests the presence of higher migration flows between neighbouring locations.

The analysis results provide the following conclusions. Regional economic factors have significant impact on human migration decisions. Voivodships enjoying the relatively good economic situation become the centres of population inflow (particularly from neighbouring locations), additionally migration flows within these locations are more intense than in others.

### **The influence of economic trend on migration determinants**

There are two-way flows between regions with each of them playing the role of both origin region and destination region at the same time. From this point of view it is necessary to investigate the difference and the sum of  $\beta_1$  and  $\beta_2$  estimates (see Table 4).

Positive difference between  $\beta_2$  and  $\beta_1$  means greater migration inflows to the region with higher values of an explanatory variable, negative difference – quite the contrary<sup>9</sup>. Positive difference for GDP, Investments and Wages&Salaries means that economic notions have stronger impact on migration in destination regions rather than origin regions and for that reason positive net migration for better developed regions. Negative difference for Unemployment means higher migration inflows and positive net migration in the voivodships characterized by lower level of unemployment rate.

Considering the sum of  $\beta_1$  and  $\beta_2$  estimates it can be observed that Wages&Salaries has the strongest effect on migration flows whilst Unemployment the weakest<sup>10</sup>. Total intensity of GDP, Investments and Wages&Salaries presents lower values in the period of financial crisis than in the previous period.

Additional information regarding an overall economic trend can be achieved on the basis of difference between estimates in 2008-2010 and 2004-2007 (see Table 5 and also Figure 2).

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<sup>9</sup> Gravity models applied in the analysis do not consider spatial dependence – the influence of economic and social processes on neighbouring regions of an origin and destination region.

<sup>10</sup> Note that the units of explanatory variables may affect the interpretation of the results as regards the comparability of determined units (e.g. considering whether decreasing of unemployment rate by 1 percentage point is associated with average monthly gross wages and salaries increase by 100 PLN).

**Table 4.** The difference and the sum of  $\beta_1$  and  $\beta_2$  estimates

Explanatory variable	$\beta_2 - \beta_1$		$\beta_2 + \beta_1$	
	2004-2007	2008-2010	2004-2007	2008-2010
GDP	1,38	1,29	4,38	3,73
Investments	0,76	0,79	2,28	2,23
Wages&Salaries	2,26	2,25	8,04	7,69
Unemployment	x	-0,87	x	-1,71

Source: Autors' estimations based on Table 2 and Table 3.

**Table 5.** Difference between  $\beta_{2008-2010}$  and  $\beta_{2004-2007}$  estimates

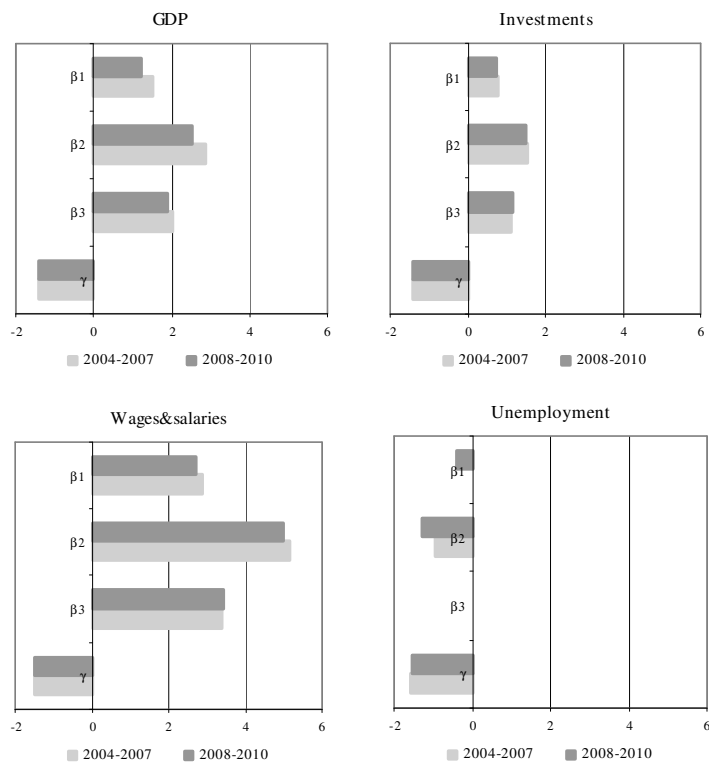
Explanatory variable	$\beta_1$	$\beta_2$	$\beta_3$
GDP	-0,28	-0,37	-0,14
Investments	-0,04	-0,01	0,02
Wages&Salaries	-0,17	-0,18	0,04
Unemployment	x	-0,35	x

Source: Autors' estimations based on Table 2 and Table 3.

The estimate of  $\beta_3$  parameter for GDP has changed more than in case of other parameters. Positive influence of GDP on intraregional migration flows is lower during the period of financial crisis as compared to the times of economic prosperity. The influence of Investments and Wages&Salaries on the phenomenon is not affected by any fluctuations in economic trends.

The estimates of  $\beta_1$  and  $\beta_3$  parameters for Investments only have not changed significantly. Positive influence of GDP and Wages&Salaries on interregional migration flows is lower during financial crisis than in the period of economic prosperity. On the other hand, negative influence of Unemployment on interregional migration flows is higher in times of financial crisis than during economic prosperity. Interregional migration flows are declining when Unemployment is increasing.

Investigation results confirm the overall conclusion following which an economic boom favours interregional migration flows but does not affect intraregional movements.

**Figure 2.** Estimates of gravity models for 2004-2007 and 2008-2010

Source: Autors' estimations based on Table 2 and Table 3.

## Conclusions

Internal migration is the key mechanism for adjustment to regional economic shocks, especially when other tools prove useless. Research approaches frequently presented in literature take into account only the effects of migration flows, e.g. the value of migration inflow, outflow and net migration which does not provide an in-depth analysis of the problem.

The objective of the conducted research was to study internal migration in Poland in 2004-2010 using gravity models. The application of certain econometric models helped to consider variations in the level of migration flows between and within regions, migration effects, as well as its reasons considering the role of geographical factor.

Investigation results do confirm the theses presented in the introduction of the paper. Regional economic indicators determine internal migration directions in Poland whilst an overall economic situation affects its intensity.

Voivodships characterized by a relatively good economic situation are the centres of population inflow (particularly from neighbouring locations) and their net migration is positive. Therefore higher migration outflow is typical for the voivodships featuring worse economic situation and thus performing the role of “demographic resources” for better developed regions. It can be concluded that it this could result in growing divergence between social and economic development of regions in Poland.

It should be noted that the higher the level of territorial units the lower the precision of investigation results due to an extensive degree of data aggregation, high variables correlation and considering spatial dependences, becomes unfounded.

Future research should focus on lower level of territorial units (e.g. NTS-3), consider other social and economic factors (e.g. education level, economic profile, crime rate), determine spatial dependences, analyze international migration flows and pay special attention to the role of urban agglomerations.

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