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Dynamics and local policy in labour commuting

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Abstract

Background: In the paper, the influence of the selected parameters, which are population, travel time to work by car, employment rate and average gross earnings, to labour commuting flows in Slovenia is analysed for the period 2000 – 2009. Furthermore, the dynamics of the analysed parameters have been studied to be implemented in the local policy application. **Objectives:** The main goal of this research has been to study the stickiness and attractiveness of Slovenian municipalities regarding the analysed parameters to support local labour commuting policy. **Methods/Approach:** The influence of the analysed parameters to the labour commuting flows has been studied in the extended gravity model. The change of the influence of parameters on commuting flows has been studied separately for each year in the analysed period. Additionally, the calculation of the extended gravity model has been performed for the whole analysed period. **Results:** The results show that the analysed parameters more attracted than dispatched the inter-municipal labour commuting flows in Slovenia in the study period. The results of the study of the dynamics of the analysed parameters have been implemented in the case study at the local level. **Conclusions:** The results provide the important empirical contribution to physical planners at the state, regional and/or local level for creating development policies. The results show that some factors in the gravity model can be compensated with the change of the others and vice-versa.

Keywords: commuting, attractiveness, stickiness, dynamics, decision-making, municipalities, Slovenia.
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Introduction

The separation of residential location and location of working places has led to complex commuting patterns, which have been extended in geographical scale over the past decades. Consequently, home-job-home trips have adopted multi-regional network configurations and have led to complex interactive networks. Commuting has become an important study field in geography, transportation science and regional science (Rouwendal and Nijkamp, 2004), and nowadays, it is an important source of information for physical planners.

Models of commuting flows have become an important topic within regional science (Gorman et al., 2007; Rouwendal and Nijkamp, 2004). The importance of such models is among the others in making predictions about how changes in the spatial distribution of jobs and workers, or the infrastructure connecting the residential location and location of working places, might affect the region's economy. A variety of models have been developed with the aim of modelling and analysing commuting flows. One of the popular classes of models, which is the subject of this paper, is the class of gravity models (Haynes and Fotheringham, 1984). According to Sen and Smith (1998), the analogy of gravity forces in social sciences can be dated back to Carey and his studies, published in 1858, on the sociological phenomena of group behaviour. In modern times, the gravity model has many applications. It is mostly used in areas of transportation, physical planning, environmental studies, regional economics and geographical analysis (Taylor, 1975; Rich, 1980; Gitlesen and Jörnsten, 2000). This paper focuses on its use in the local policy implementation.

Labour commuting in Slovenia has been analysed by several authors in the last fifteen years: Bogataj and Drobne (1997, 2005) analysed inter-regional labour commuting flows and migration flows in Slovenia; Pelc (1988) and Dolenc (2000) presented »daily migration« in Slovenia in an empiric manner, Pavlin and Sluga (2000) studied the employment power of Ljubljana; Bole (2004) analysed labour commuting in Slovenia using Census 2002 data; Drobne and Bogataj (2005) analysed inter-municipal labour commuting flows using gravity approach; Drobne and others (2011a) analysed spatial interactions influenced by European corridors and the shift of the Schengen border regime in 2004; Bole (2011) analysed changes in labour commuting to major Slovenian employment centres from 2000 to 2009 – the results showed that both, the scope of labour commuting and number of routes, had been significantly increased; Drobne and Bogataj (2011) made comparative analysis of migration flows and labour commuting flows between statistical regions as well as between municipalities in Slovenia in 2000 – 2009 having analysed the endowment factors which influence attractiveness and stickiness of the analysed areas.

The main goal of this research is to study the stickiness and the attractiveness of Slovenian municipalities for labour commuters regarding the selected analysed parameters, which are population of the municipality, travel time by car between municipalities' centres, employment rate in the municipality, and average gross earnings in the municipality. The influence of the analysed parameters to the labour commuting flows is studied in the extended gravity model, separately for each year and in general for the whole analysed period between 2000 and 2009. The results of the study of the dynamics of the analysed parameters are implemented in the case study at the local level.

The introduction is followed by description of the methodology and used data. In the third part of the paper the results of modelling labour commuting flows in the extended gravity model as well as their application to the local policy are presented and evaluated for the case of Slovenia. The conclusion is earmarked for some suggestion for state, regional and/or local development policies using the results of our research.

Methodology and data

In this paper, the dynamics of parameters in the gravity model of inter-municipal labour commuters in Slovenia for the period 2000 – 2009 is analysed. For this purpose, the extended gravity model was calculated for each year. The change of the impacts of parameters on commuting flows were studied separately for each year and in general for the whole analysed period.

Parameters, that have been included in our study, are: population of the municipality, travel time by car between municipalities' centres, employment rate in the municipality and average gross earnings in the municipality. Data on labour commuting flows among municipalities, population, employment rate and workforce population, average gross earnings in the municipality and in the state were collected by the Statistical Office of the Republic of Slovenia (SORS) and published at SI-STAT Data Portal (SORS, 2011a) and/or in the Statistical Yearbook (SORS, 2011b). Geographic data on municipalities and municipalities' centres are maintained by The Surveying and Mapping Authority of the Republic of Slovenia (SMA, 2011). Data on the state road network for each year of the study period were acquired from The Slovenian Road Agency (SRA, 2010), which is responsible for collecting and maintaining data on state roads.

Using data on state roads, we developed GIS-network models, which were the basis for calculation of optimal (shortest) time-spending distances between the municipal centres of Slovenia (travelling by car). Ten origin-destination matrices were calculated considering conditions on state roads, separately for each year from the study period (construction of new highways per year, toll stations on highways and abolition of the toll system in 2008). It has to be mentioned, that in the analysed period 2000 – 2009, the number of Slovenian municipalities, as the territorial units of our study, was changed from 192 in 2000 to 193 in 2002 and to 210 municipalities in 2009. The change was reflected in the statistical research next year (one year after introduction of new municipalities).

The stickiness and attractiveness for the labour commuters' flows between Slovenian municipalities for the period 2000 – 2009 have been studied using gravity modelling approach. The basic concept of using the gravity model in social sciences suggests that two separate groups of people, say in two cities or regions, generate a mutual interaction in proportion to the product of the sizes of the cities or regions, and that this interaction is impeded by the frictional effect of the intervening distance over which it must take place. In other words, the volume of interaction between the two cities or regions is a positive function of their population sizes and an inverse function of the distance between them. Use of the gravity models in social sciences had different forms; for examples see (Haynes, Fotheringham, 1984). In our research, we use the extended gravity model where basic model is extended by two economic variables, employment and gross earnings in the municipalities of origin and destination. Model (1) defines the gravity model for labour commuters, which was calculated separately for each of ten analysed years and the same model was used for calculating the average powers for the whole analysed period:

$$DC_{ij} = \alpha \cdot P_i^{\beta_1} \cdot P_j^{\beta_2} \cdot d(t)_{ij}^{\gamma} \cdot K_{EMP,i}^{\delta_1} \cdot K_{EMP,j}^{\delta_2} \cdot K_{GEAR,i}^{\varepsilon_1} \cdot K_{GEAR,j}^{\varepsilon_2} \qquad (1)$$

where we denote with i the municipality of origin and with j the municipality of destination DC_{ij}, is the number of inter-municipal labour commuters, P_i and P_j are the populations in the municipality of origin respectively destination, $d(t)_{ij}$ is travel time by car between the municipality of origin and municipality of destination, $K_{EMP,i}$ and $K_{EMP,j}$ are the coefficients of employment in the municipality of origin respectively destination, $K_{GEAR,i}$ and $K_{GEAR,j}$ are the coefficients of gross salary in the municipality of origin respectively destination. α, which is the constant, and $\beta_1, \beta_2, \gamma, \delta_1, \delta_2, \varepsilon_1, \varepsilon_2$, which are the powers, are estimated in the regression analysis. Coefficients of the extended gravity model for commuting were calculated as follows:

$$K_{EMP} = \frac{EMP_{mun} / WFP_{mun}}{EMP_{SI} / WFP_{SI}} \qquad (2)$$

$$K_{GEAR} = \frac{GEAR_{mun}}{GEAR_{SI}} \qquad (3)$$

where EMP_{mun} is the number of employed persons in the municipality, EMP_{SI} is the number of employed persons in Slovenia, WFP_{mun} is the number of workforce population in the municipality, WFP_{SI} is the number of workforce population in Slovenia, $GEAR_{mun}$ is the average gross earnings in the municipality, and $GEAR_{SI}$ is the average gross earning in Slovenia.

In the model (1), powers $\beta_1, \delta_1, \varepsilon_1$ measure stickiness of the municipality, $\beta_2, \delta_2, \varepsilon_2$ measure attractiveness of the municipality, and accessibility is measured by γ. Coefficients $K_{\bullet,\bullet}$ are relative indicators for municipalities of origin and/or destination (Drobne, Bogataj, 2011).

When measures for stickiness and attractiveness (powers) in model (1) are estimated in the regression analysis, their dynamics can be studied. The results of the study of their dynamics were basis for a case study at the local level. In an application for the case study at local level, we show that some factors in the gravity model can be compensated with the change of the others and vice-versa.

Results

In the analysed period 2000 – 2009, there were 348,339 labour commuters between the Slovenian municipalities on average. Labour commuter is person in employment whose territorial unit of workplace is not the same as that one of residence. The source of data was the Statistical Register of Employment (SRDAP), which was kept by the Statistical Office of the Republic of Slovenia (SORS). SRDAP covers persons in paid employment and self-employed persons who are at least 15 years old and who have on the basis of the employment contract compulsory social insurance or are employed on the territory of the Republic of Slovenia. Employment can be permanent or temporary, full time or part time (SORS, 2011a). The territorial unit in our study is the municipality.

Table 1 shows that the number of labour commuters was increased from 299,188 in 2000 to 390,500 in 2009 (the average increase per year was 10,146 for 2000 – 2009 and 13,263 inter-municipal labour commuters for the period 2000 – 2008). Until the end of 2008 only permanent residence was taken into account for citizens of the Republic of Slovenia and only temporary residence for foreigners. In 2009 the methodology changed. If a person in employment has a registered temporary residence, this residence is taken into account firstly and only later his or her permanent residence. The mentioned methodological change has a certain impact on data dissemination; at the end of 2009 8.6% (slightly fewer than 70,000) persons in employment (excluding farmers) had only temporary or both temporary and permanent residence (SORS, 2011a).

From Table 1 it can be seen that the numbers of inter-municipal labour commuters in 2000 – 2009 was increasing for the travel time intervals of 0 – 150 minutes, but it was decreasing for the travel time intervals higher than 150 minutes; see also Table 2, where linear trend coefficients of labour inter-municipal commuters by travel time interval are given.

Table 1
Number of labour commuters between the Slovenian municipalities by travel time intervals and by the year in the period 2000 – 2009

Travel time (min)	Year									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
[0-15)	116,116	117,047	117,425	117,959	118,086	118,441	120,803	130,243	135,905	127,374
[15-30)	115,058	119,197	122,953	126,535	131,871	136,433	141,973	150,024	152,615	151,006
[30-45)	31,114	31,097	33,235	34,658	35,805	39,624	41,345	44,380	46,514	46,693
[45-60)	12,159	13,805	16,167	17,598	17,936	19,497	21,547	24,229	26,489	25,972
[60-75)	8362	9213	9447	10,839	13,947	14,002	16,342	18,407	18,029	16,455
[75-90)	6028	5614	7629	8134	7662	8796	9824	10,867	11,685	10,422
[90-105)	3804	4590	3222	3515	4030	3887	4342	5041	5155	4766
[105-120)	2461	2105	1812	2050	2312	2392	2627	3267	5238	4581
[120-135)	1230	1195	1175	1285	1306	1966	2251	2525	1917	1331
[135-150)	905	1216	1345	1682	1841	1511	1685	1901	1066	1189
[150-165)	1109	1020	1081	892	834	754	830	922	325	444
[165-180)	571	454	192	203	210	174	161	194	276	220
[180-195)	125	116	115	118	130	127	129	179	61	43
[195-210)	69	62	59	84	81	85	90	104	12	3
[210-225)	46	48	29	40	30	23	25	25	2	1
[225-240)	23	18	18	12	9	2	3	2	0	0
> 240	8	9	3	1	1	1	1	1	0	0
Slovenia	299,188	306,806	315,907	325,605	336,091	347,715	363,978	392,311	405,289	390,500

Source: (SORS, 2011a) and own calculation

Table 2
Linear trend coefficients of labour inter-municipal commuters by travel time intervals in Slovenian in the period 2000 – 2009

Travel time (min)	<15	[15-30)	[30-45)	[45-60)	[60-75)	[75-90)	[90-105)	[105-120)	[120-135)
Linear trend coefficients	1856.4	4507.2	1986.3	1617.1	1187.4	633.0	145.7	303.6	98.6
Travel time (min)	[135-150)	[150-165)	[165-180)	[180-195)	[195-210)	[210-225)	[225-240)	>240	
Linear trend coefficients	24.0	-72.2	-27.6	-4.7	-4.2	-4.8	-2.7	-0.9	

Source: (SORS, 2011a) and own calculation

Table 3 shows the share of labour commuters between the Slovenian municipalities by travel time intervals for each year in the study period 2000 – 2009.

Table 3
The percentage of labour commuters between the Slovenian municipalities by travel time intervals in the period 2000 – 2009

Travel time (min)	**Year**									
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
[0-15)	38.8%	38.2%	37.2%	36.2%	35.1%	34.1%	33.2%	33.2%	33.5%	32.6%
[15-30)	38.5%	38.9%	38.9%	38.9%	39.2%	39.2%	39.0%	38.2%	37.7%	38.7%
[30-45)	10.4%	10.1%	10.5%	10.6%	10.7%	11.4%	11.4%	11.3%	11.5%	12.0%
[45-60)	4.1%	4.5%	5.1%	5.4%	5.3%	5.6%	5.9%	6.2%	6.5%	6.7%
[60-75)	2.8%	3.0%	3.0%	3.3%	4.1%	4.0%	4.5%	4.7%	4.4%	4.2%
[75-90)	2.0%	1.8%	2.4%	2.5%	2.3%	2.5%	2.7%	2.8%	2.9%	2.7%
[90-105)	1.3%	1.5%	1.0%	1.1%	1.2%	1.1%	1.2%	1.3%	1.3%	1.2%
[105-120)	0.8%	0.7%	0.6%	0.6%	0.7%	0.7%	0.7%	0.8%	1.3%	1.2%
[120-135)	0.4%	0.4%	0.4%	0.4%	0.4%	0.6%	0.6%	0.6%	0.5%	0.3%
[135-150)	0.3%	0.4%	0.4%	0.5%	0.5%	0.4%	0.5%	0.5%	0.3%	0.3%
[150-165)	0.4%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
[165-180)	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	<0.0%	<0.0%	0.1%	0.1%
[180-195)	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%
[195-210)	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%
[210-225)	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%
[225-240)	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	0.0%	0.0%
> 240	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	<0.0%	0.0%	0.0%
Slovenia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: (SORS, 2011a) and own calculation

Comparing Table 3 and linear trend coefficients of share of labour inter-municipal commuters by travel time intervals in Table 4, one can notice that the percentage of labour commuters was slightly decreasing for travel times of less than 15 and more than 135 minutes. It is also evident that the percentage of labour commuters for the time-spending distances between 30 and 90 minutes was generally increasing in the study period. The percentage of labour commuters in the intervals between 30 to 75 minutes increased the most.

Table 4
Linear trend coefficients of percentage of labour inter-municipal commuters by travel time intervals in Slovenia in the period 2000 – 2009

Travel time (min)	**<15**	**[15-30)**	**[30-45)**	**[45-60)**	**[60-75)**	**[75-90)**	**[90-105)**	**[105-120)**	**[120-135)**
Linear trend coefficients	$-7*10^{-03}$	$-6*10^{-04}$	$2*10^{-03}$	$3*10^{-03}$	$2*10^{-03}$	$1*10^{-03}$	$-3*10^{-05}$	$5*10^{-04}$	$1*10^{-04}$
Travel time (min)	**[135-150)**	**[150-165)**	**[165-180)**	**[180-195)**	**[195-210)**	**[210-225)**	**[225-240)**	**>240**	
Linear trend coefficients	$-5*10^{-05}$	$-3*10^{-04}$	$-1*10^{-04}$	$-2*10^{-05}$	$-2*10^{-05}$	$-2*10^{-05}$	$-9*10^{-06}$	$-3*10^{-06}$	

The dynamics of construction of new highways in Slovenia and abolition of toll system in the analysed period are the main reasons for reduction of travel costs of inter-municipal labour commuters. Consequently, this could influence the number and the structure of inter-municipal labour commuters when analysing them by travel time. Table 5 shows the cumulative length of new highways ($CLNH$) and the mean travel time between the municipalities' centres (MTT) in Slovenia in the study period.

Table 5
The cumulative length of new highways (CLNH) and the mean travel time between the municipalities' centres (MTT) in Slovenia in the period 2000 – 2009

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
CLNH (km)	28.8	36.9	66.2	95.9	132.3	158.1	165.9	168.3	256.8
MTT (min)	103	102	99	99	98	96	96	96	91

The regression model of the cumulative length of new highways ($CLNH$) and mean travel time between the municipalities' centres (MTT) in Slovenia in the study period is:

$$MTT = 103.7\text{-}0.048 \cdot CLNH \quad R^2 = 96.5\% \tag{5}$$

It follows that construction of new highways had substantial reduced the travel times between the municipal centres.

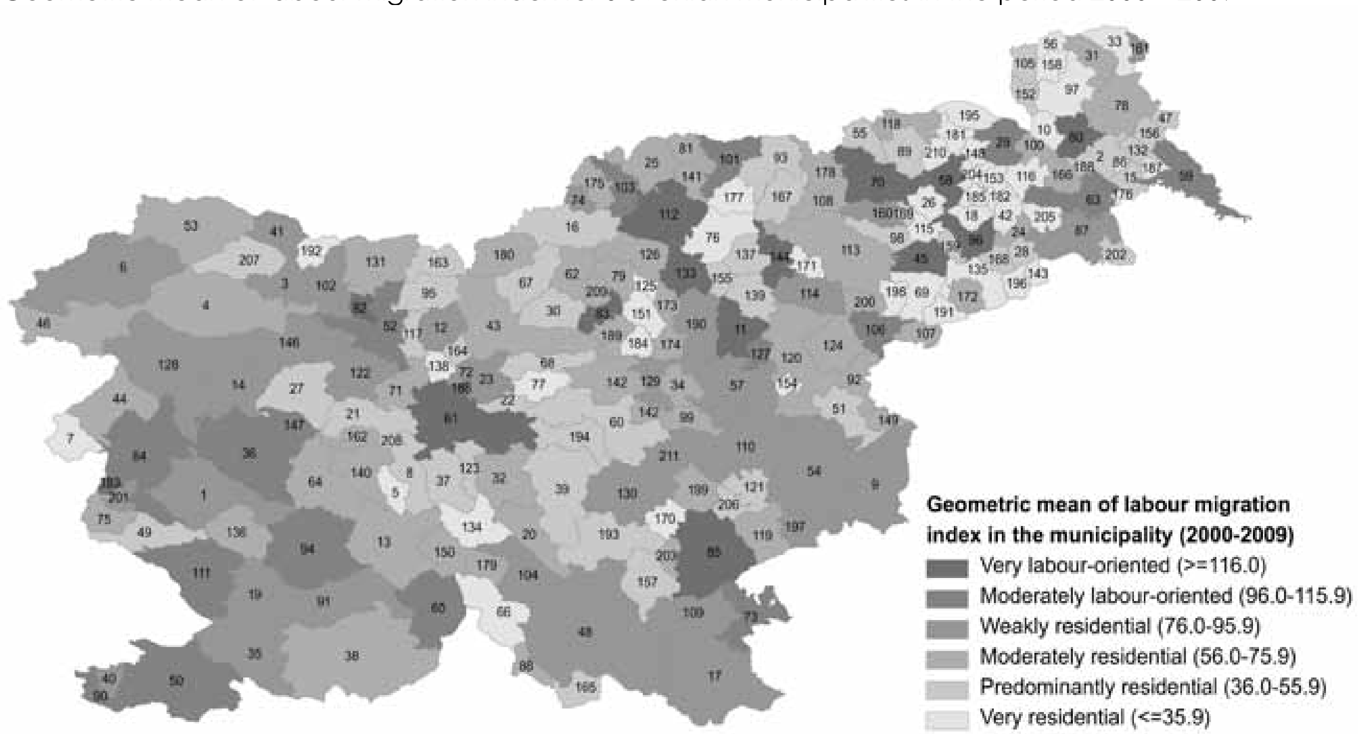
In the continuation, the impact of parameters of stickiness and attractiveness as well as time-spending distance on inter-municipal labour commuting flows in Slovenia was analysed. The attraction and/or stickiness of local territorial units, in our case the municipalities, can be measured by the labour migration index. The labour migration index (LMI) is the ratio between the number of employed persons (excluding farmers) in a certain territorial unit (municipality) by workplace and the number of employed persons (excluding farmers) in the same territorial unit (municipality) by residence multiplied by 100 (SORS, 2011a):

$$LMI = \frac{persons\ in\ employment\ by\ municipality\ of\ workplace}{persons\ in\ employment\ by\ municipality\ of\ residence} \cdot 100$$

$$LMI_i = 100 \cdot \frac{\sum_{j \neq i} DC_{ji}}{\sum_{j \neq i} DC_{ij}} \tag{6}$$

LMI is the indicator, which, for a specific territorial unit, links the number or workplaces with the number of employed persons (according to residence). It only measures the relationship within a specific territorial unit and does not consider the internal labour migration within the observed territorial unit. Territorial units, of which LMI is more than 96.0, are labour-oriented, and others are residential-oriented (SORS, 2011a). Figure 1 shows geometric mean of labour migration index for Slovenian municipalities in 2009 for the period 2000 – 2009 (there are codes of the municipalities on the map; the names could be found in (SORS, 2011c).

Figure 1
Geometric mean of labour migration index for Slovenian municipalities in the period 2000 – 2009



Source: (SORS, 2011a) and own calculation

Using the gravity model (1) and data explained in the chapter of methodology, we calculated extended gravity model for labour commuters among Slovenian municipalities for each year in 2000-2009 and the general gravity model for the whole period of ten years. Table 6 shows the results of power trends for the Slovenian municipalities in the study period 2000 – 2009. Detail results for each year are in (Zupan, 2010).

Table 6
Powers (exponents) of the extended gravity model (2) between the Slovenian municipalities by the year and in average for the period 2000 – 2009

Parameter	**Symbol of regression coefficient in the model (1)**	**Year**										**Period**
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2000-2009**
N		36,672	36,672	36,672	37,056	37,056	37,056	37,056	43,890	43,890	43,890	389,910
R^2 (%)		63.8	64.2	64.8	65.3	65.7	66.5	66.8	66.6	67.2	67.1	65.8
Adjusted R^2 (%)		40.7	41.2	42.0	42.6	43.1	44.2	44.7	44.3	45.1	45.0	43.3
constant	**α**	1.79	1.64	1.74	1.69	1.32	1.60	1.37	(1.02)	0.83	(1.07)	1.373
P_i	**β_1**	0.15	0.15	0.16	0.16	0.17	0.17	0.18	0.19	0.21	0.20	0.175
P_j	**β_2**	0.26	0.26	0.27	0.28	0.30	0.30	0.31	0.32	0.34	0.32	0.296
$d(t)_{ij}$	**γ**	-0.83	-0.85	-0.88	-0.90	-0.91	-0.93	-0.95	-0.92	-0.96	-0.96	-0.909
$K_{EMP,i}$	**δ_1**	-0.05	-0.05	-0.07	-0.06	-0.08	-0.05	-0.06	-0.08	-0.10	-0.08	-0.065
$K_{EMP,j}$	**δ_2**	-0.08	0.07	0.05	0.09	(0.02)	0.08	0.07	0.08	0.04	0.06	0.065
$K_{GEAR,i}$	**ε_1**	0.12	(0.04)	0.05	(0.02)	(0.04)	0.16	(0.06)	-0.10	-0.11	(-0.03)	0.033
$K_{GEAR,j}$	**ε_2**	0.46	0.37	0.45	0.44	0.44	0.82	0.69	0.41	0.36	0.32	0.464

Note: Parentheses denote exponents which significance is bad (P-value is greater than 0.1); in the most of other cases the significance is very good (P-value is much lower than 0.0001)

A general (average) inter-municipal gravity model of labour commuting in Slovenia in the period 2000 – 2009 is:

$$DC_{ij}^{(2000\text{-}2009)} = 1.373 \cdot P_i^{0.175} \cdot P_j^{0.296} \cdot d(t)_{ij}^{-0.909} \cdot K_{EMP,i}^{-0.065} \cdot K_{EMP,j}^{0.065} \cdot K_{GEAR,i}^{0.033} \cdot K_{GEAR,j}^{0.464} \qquad (7)$$

The model (7) shows that the power of the population in the municipality of destination is 1.7-times greater than of the population in the municipality of origin, the power of the coefficient of employment is equal for the municipalities of origin and destination, and the power of the coefficient of average gross earnings in the municipality of destination is 14-times greater than equal coefficient in the municipality of origin. The results show that the analysed parameters more attracted than dispatched the inter-municipal labour commuting flows in Slovenia in the period between 2000 and 2009.

From Table 6, we can see that the influences of the analysed parameters (exponents) have been changing over time. Figures 2 and 3 show the dynamics of exponents γ and ε_2, which denote the importance of travel time, respectively relative gross earnings in the municipality of destination, on commuting flows.

Figure 2
Dynamics of exponent in the model (1) in the period 2000 – 2009

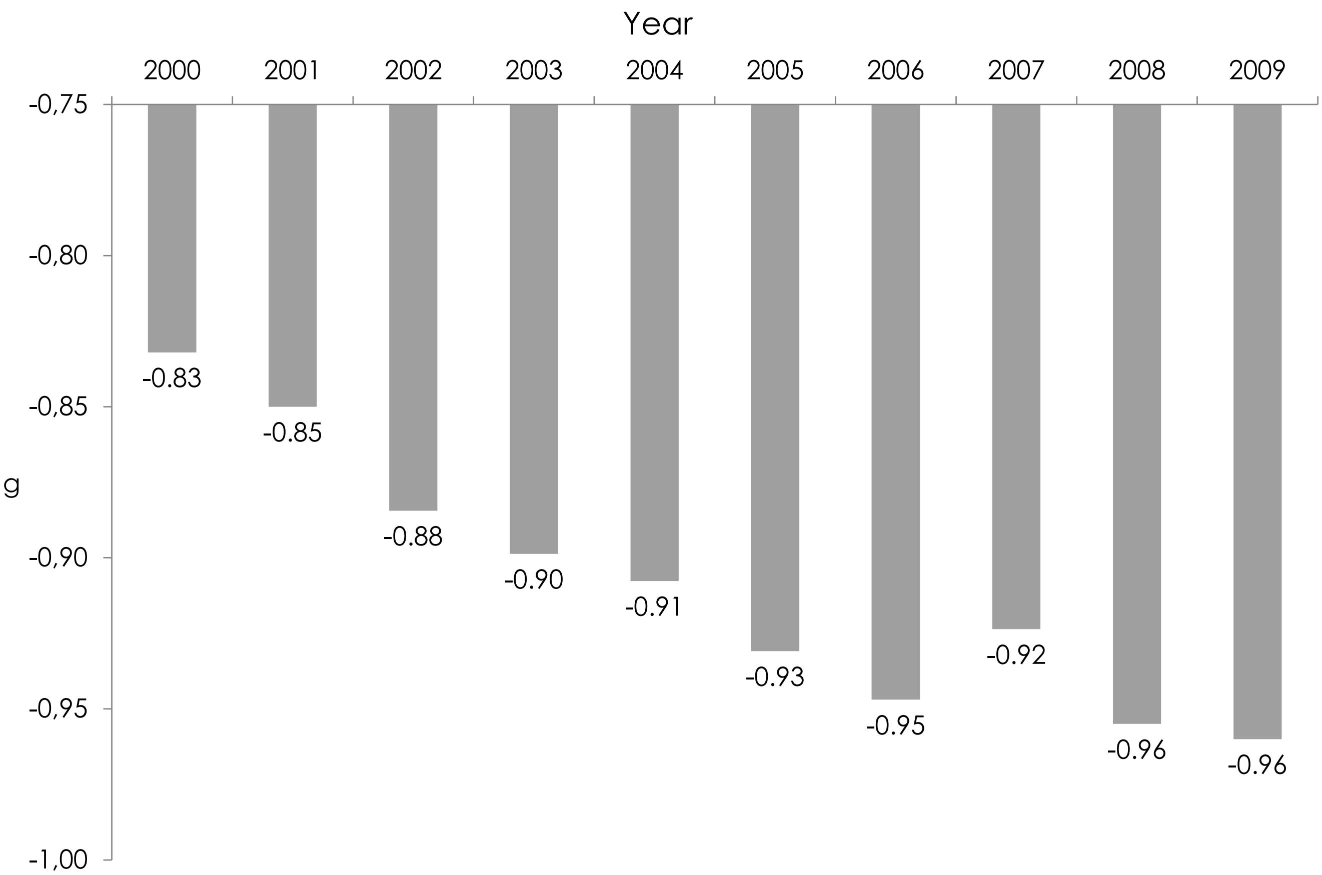
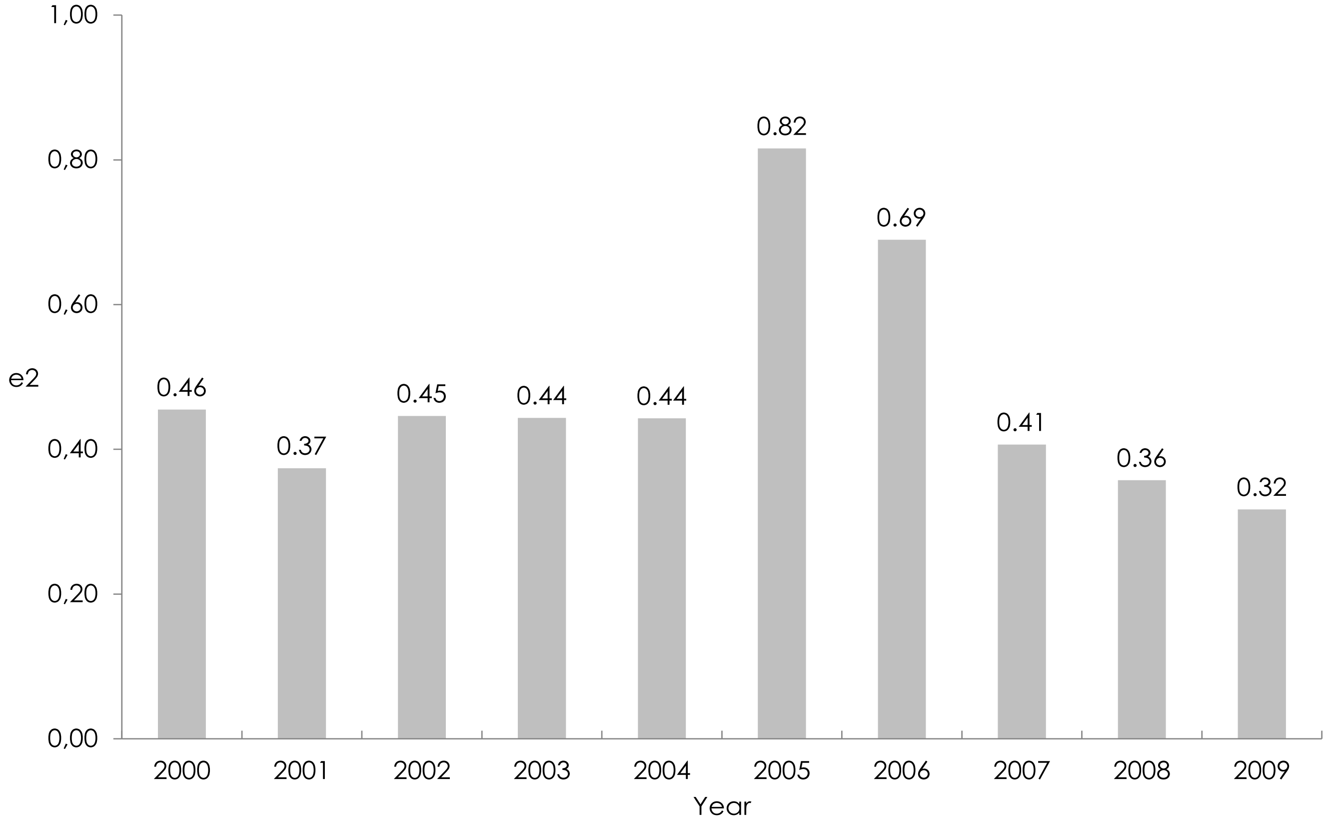


Figure 3
Dynamics of exponent in the model (1) in the period 2000 – 2009



Let us introduce technical time $k = y - 2000$, where y is a year. The trend analysis of γ gives

$$\gamma(k) = -0.848 - 0.014 \cdot k \tag{8}$$

and trend analysis of ε_2 gives

$$\varepsilon_2(k) = 0.487 - 0.003 \cdot k \tag{9}$$

The power of travel distance in the equation of labour commuting flows decreases in time. It means that the labour commuters are less and less willing to commute in general. Let us suppose (a) that this is more the result of the reluctance to labour commuting (and less because of the improved road conditions) and (b) that γ is constant for all distances as it is supposed in the model (1). In this case more distanced commuters influenced such results comparing to those, who are very close. If this is the case, the question appears: "How the other parameters of gravity model (1) should change to keep the intensity of flow at the same level?"

For the municipality of destination (j), the decision variable, which can compensate a lower willingness to commute, is gross- or net-earnings or their relative change p. The general formula considering this condition follows from (7):

$$DC_{ij}^{(2000-2009)} \doteq a^{(2000-2009)} \cdot K_{GEAR,j}^{\varepsilon_2^0} \cdot d(t)_{ij}^{-\gamma^0} \tag{10}$$

where ε_2^0 and γ^0 denote the exponents for total time period (2000 – 2009). To keep the intensity of in-flows on the same level, the following has to be obeyed:

$$DC_{ij} = a(k) \cdot \left[K_{GEAR,j}(1 + p(k))\right]^{\varepsilon_2(k)} \cdot d(t)_{ij}^{\gamma(k)} = const \tag{11}$$

In case that $a(k)$ is constant, from (9) it follows:

$$\left[K_{GEAR,j}(1 + p(k)\ \right]^{\varepsilon_2(k)} \cdot d(t)_{\boldsymbol{j}}^{\gamma(k)} = K_{GEAR,j}^{\varepsilon_2^0} \cdot d(t)_{\boldsymbol{j}}^{-\gamma^0}$$

$$(1 + p(k)\ ^{\varepsilon_2(k)} = \frac{d(t)_j^{-\gamma(k)}}{K_{GEAR,j}^{\varepsilon_2(k)}} \cdot \frac{K_{GEAR,j}^{\varepsilon_2^0}}{d(t)_{\boldsymbol{j}}^{\gamma^0}}$$

$$(1 + p(k)\ ^{\varepsilon_2(k)} = \frac{d(t)_j^{-\gamma(k)-\gamma^0}}{K_{GEAR,j}^{\varepsilon_2(k)-\varepsilon_2^0}} \tag{12}$$

from where we get

$$p(k) = \left(\frac{d(t)_{ij}^{-\gamma(k)-\gamma^0}}{K_{GEAR,j}^{\varepsilon_2(k)-\varepsilon_2^0}} \right)^{\frac{1}{\varepsilon_2(k)}} - 1 \tag{13}$$

where $p(k)$ is the dynamic decision variable (depends on time k).

Numerical example in local policy

For the case study we selected the municipality of Ljubljana, for which the geometric mean of for the period 2000 – 2009 equals to 167.51. It follows that Ljubljana is very labour oriented municipality (the average number of labour commuters who commuted to Ljubljana in the period 2000 – 2009 was 88,358). 54.2% (47,884) of them came from the municipalities, for which the travel time to Ljubljana was 30 minutes or less, 26.7% (23,619) came from the municipalities in the radius between 30 and 60 minutes of travel time to Ljubljana, and 19.1 % (16,855) of others came from the municipalities which were farther than 60 minutes.

Let us suppose that the Ljubljana municipality wish to keep the intensity of commuting flows which originate from the travel distance of d minutes at least at the same level as it was in the average in the study period 2000 – 2009. Ljubljana wishes to realize this policy in 2012 ($k = 12$).

From Table 7 it follows that the geometric mean of K_{GEAR} of Ljubljana in the period 2000 – 2009 equals $K_{GEAR,\text{Ljubljana}}^{(2000\text{-}2009)} = 1.23$ and $K_{GEAR,\text{Ljubljana}}$ in 2012 can be estimated using linear trend:

$$K_{GEAR,\text{Ljubljana}}(k) = 1.265 - 0.008 \cdot k \tag{14}$$

therefore $K_{GEAR,\text{Ljubljana}}(12) = 1.17$.

Table 7
$K_{GEAR,\text{Ljubljana}}$ in the period 2000 – 2009

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Geometric mean 2000-2009
$K_{GEAR,\text{Ljubljana}}$	1.26	1.25	1.25	1.26	1.22	1.21	1.21	1.21	1.20	1.19	1.23

From Table 1 and equations (8) and (9) we calculate $\gamma(12) = -1.011$ and $\varepsilon_2(12) = 0.455$. Table 4 shows that the intensity of commuting flows in the interval of 0 – 30 min was decreased in the study period. To keep the intensity of flows on the distance of 0 – 30 minutes of travel time (from neighbour municipalities) on the same level as it was in the average in 2000 – 2009, equation (13) requires

$$p(12) = \left(\frac{d(t)_{ij}^{-\gamma(12)-0.909}}{K_{GEAR,j}^{\varepsilon_2(12)-0.464}} \right)^{\frac{1}{\varepsilon_2(12)}} - 1 = \left(\frac{15^{1.011-0.909}}{1.23^{0.455-0.464}} \right)^{\frac{1}{0.455}} - 1 = 0.85 \tag{15}$$

From (14), it follows that the expected $K_{GEAR,\text{Ljubljana}}(12) = 1.17$, if the existing policy would not change. It means that the expected percentage of change in Ljubljana for 2012 is

$$\hat{p}_{\text{Ljubljana}}(12) = \frac{K_{GEAR,\text{Ljubljana}}(12)}{K_{GEAR,\text{Ljubljana}}^{(2000-2009)}} - 1 = \frac{1.17}{1.23} - 1 = -0.05 \tag{16}$$

From (16) we can conclude that we cannot stop the decrease of labour commuting flows from the nearest municipalities $(d \dot{<} 30 \text{ minutes})$ to Ljubljana $(-0.05 < 0.85)$ **(a)** if there is not introduced any new policy which would increase the gross earnings in Ljubljana relatively to other municipalities in Slovenia, or **(b)** if the investments to improve the accessibility to Ljubljana are not realized. We have to note here that γ is constant and does not depend on distance, which should be additionally consider; see e.g. (Bogataj, Drobne, Tuljak Suban, 2011).

Discussion and Conclusions

In the paper, we presented the results of the analyses of the municipalities' stickiness and the attractiveness for labour commuters in Slovenia in the period of ten years. Using the extended gravity model approach, we studied the influence of population of the municipality, travel time by car between municipalities' centres, employment rate in the municipality and average gross earnings in the municipality on the labour commuting flows. The powers of the influence of the analysed parameters were estimated in the regression analysis for each year of ten years period 2000 – 2009, and for the whole analysed period. It has been found out that the stickiness of origin and attractiveness of the destination for labour commuting flows are changing over the time. The results of the study of the dynamics of the analysed parameters were implemented in the case study at the local level. The results provide an important empirical contribution to physical planners at the state, regional and/or local level to create development policies. The results show that some factors in the gravity model can be compensated with the change of the others and vice-versa.

Among others, two important empirical results of our research to the planners and developers should be stressed out: first considers the change of the influence of size of the municipalities, and second considers the change of the friction distance in labour commuting. More precisely: (a) the stickiness of population size in the municipality of origin and attractiveness of the population in the municipality of destination were increasing in the analysed period, having power of stickiness and power of attractiveness in 2009; (b) the influence of distance on commuting increased in the analysed period from in 2000 to in 2009. From here it follows that the accessibility between the Slovenian municipalities should increase, or some other (economic) parameters should be changed, to keep the flows at the same level, as presented in the numerical example.

In our study, the logit model with the constant exponentials was analysed. According to (Drobne, Bogataj, 2011; Bogataj, Drobne, Tuljak Suban, 2011; Drobne, et al., 2011b) the distance power could be stepwise constant. In this case more accurate results might be achieved, and this could be one of the challenges for further research.

References

1. Bogataj, M, Drobne, S. (1997), "The Influence of Investments in Highways on Gravity and Interaction in Slovenia", in Rupnik, V, Zadnik Stirn, L, Drobne, S. (Eds.), Proceedings of the 4th International Symposium on Operational Research SOR'97, Slovenian Society Informatika, Preddvor, pp. 55-60.
2. Bogataj, M, Drobne, S. (2005), "Does the Improvement of Roads Increase the Daily Commuting?: Numerical Analysis of Slovenian Interregional Flows", in Zadnik Stirn, L, Indihar Štemberger, M., Ferbar, L, Drobne, S. (Eds.), Selected Decision Support Models for Production and Public Policy Problems, Slovenian Society Informatika, Ljubljana, pp. 185-206.
3. Bogataj, M, Tuljak Suban, D, Drobne, S. (2011), "Regression-Fuzzy Approach to Land Valuation", Central European. Journal of Operation Research, Vol. 19, No. 3, pp. 253-265.
4. Bole, D. (2004), "Daily Mobility of Workers in Slovenia", Acta geographica Slovenica, Vol. 44, No. 1, pp. 25-45.
5. Bole, D. (2011), "Changes in Employee Commuting: A Comparative Analysis of Employee Commuting to Major Slovenian Employment Centers from 2000 to 2009", Acta geographica Slovenica, Vol. 51, No. 1, pp. 93-108.
6. Dolenc, D. (2000), "Delovne migracije v Sloveniji" ("Labour commuting in Slovenia"), Statistical days "Radenci 2000", Statistical Society of Slovenia, Radenci.
7. Drobne, S, Bogataj, M. (2005), "Intermunicipal Gravity Model of Slovenia", in Zadnik Stirn, L, Drobne, S. (Eds.), Proceedings of the 8th International Symposium on Operational Research in Slovenia SOR'05, Slovenian Society Informatika, Ljubljana, pp. 207-212.
8. Drobne, S, Bogataj, M. (2011), "Accessibility and Flow of Human Resources between Slovenian Regions", Faculty of Civil and Geodetic Engineering, Ljubljana, Mediterranean Institute for Advanced Studies, Šempeter pri Gorici.
9. Drobne, S, et al. (2011a), "Dynamics and Local Policy in Commuting: Attractiveness and Stickiness of Slovenian Municipalities", in Zadnik Stirn, L, Žerovnik, J, Povh, J, Drobne, S, Lisec, A. (Eds.), Proceedings of the 11th International Symposium on Operational Research SOR'11, Slovenian Society Informatika, Ljubljana, pp. 323-328.
10. Drobne, S, et al. (2011b), "Regression-Neuro-Fuzzy Approach to Analyse Distance Function in Internal Inter-Regional Migrations in EU Countries", in Zadnik Stirn, L, Žerovnik, J, Povh, J, Drobne, S, Lisec, A. (Eds.), Proceedings of the 11th International Symposium on Operational Research SOR'11, Slovenian Society Informatika, Ljubljana, 171-176.
11. Gitlesen, J. P, Jörnsten, K. (2000), "A Disaggregated Gravity Model", available at: http://www.nhh.no/Admin/Public/DWSDownload.aspx?File=%2FFiles%2FFiler%2Finstitutter%2Ffor%2Fdp%2F2000%2F2800.pdf (31 March 2011).
12. Gorman, S. P., et al. (2007), "An Application of Complex Network Theory to German Commuting Patterns", in Friesz, T. L. (Ed.), Network Science, Nonlinear Science and Infrastructure Systems, Vol. 102, Springer, New York, pp. 167-185.
13. Haynes, K. E, Fotheringham, A. S. (1984), "Gravity and Spatial Interaction Models", Sage Publications, Beverly Hills.
14. Pavlin, B, Sluga, G. (2000), "Ljubljana kot zaposlitveno središče", ("Ljubljana as employment centre"), Ljubljana: geography of city, Ljubljana.
15. Pelc, S. (1988), "Prometna dostopnost do delovnih mest in njen pomen pri urejanju prostora" ("Traffic accessibility to working places and its role in spatial development"), master thesis, Faculty of Arts, University of Ljubljana.
16. Rich, D. C. (1980), "Potential Models in Human Geography", available at: http://www.qmrg.org.uk/files/2008/12/26-potential-models-in-geography.pdf (31 March 2011).
17. Rouwendal, J, Nijkamp, P. (2004), "Living in Two Worlds: A Review of Home-to-Work Decisions", Growth and Change, Vol. 35, No. 3, pp. 287-303.
18. Sen, A, Smith, T. E. (1998), "Gravity Models of Spatial Interaction Behaviour", Springer-Verlag, Heidelberg.
19. SMA (2011), Free Access Database, Municipalities, The Surveying and Mapping Authority of the Republic of Slovenia, Ljubljana, available at: http://www.gu.gov.si/en/services/free_access_database/municipalities/ (31 January 2011).
20. SORS (2011a), SI-STAT Data Portal, Statistical Office of the Republic of Slovenia, Ljubljana, available at:

http://pxweb.stat.si/pxweb/Dialog/statfile1.asp (31 March 2011).
21. SORS (2011b), Statistical yearbook of the Republic of Slovenia, Statistical Office of the Republic of Slovenia, Ljubljana, available at: http://www.stat.si/eng/pub_letopis_prva.asp (31 March 2011).
22. SORS (2011c). Administrative territorial structure, Maps and code lists of basic spatial units, Statistical Office of the Republic of Slovenia, Ljubljana, available at: http://www.stat.si/eng/tema_splosno_upravno_karte.asp (31 March 2011).
23. SRA (2010), Data on State Roads of the Republic of Slovenia, Slovenian Road Agency, Slovenia, Ljubljana.
24. Taylor, P. J. (1975), "Distance Decay in Spatial Interactions", available at: http://qmrg.org.uk/files/2008/11/2-distance-decay-in-spatial-interactions.pdf (31 March 2011).
25. Zupan, M. (2010), "Gravitacijski modeli delavcev vozačev med občinami Slovenije v obdobju 2000-2009" ("Gravity models of commuters among Slovene municipalities between 2000 and 2009"), graduation thesis, University of Ljubljana, Faculty of Civil and Geodetic Engineering, Ljubljana.

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