Roads as Channel of Centrifugal Policy Transfer. Spatial Interactions Model Revised

Katarzyna Kopczewska

Faculty of Economic Sciences, University of Warsaw, ul.Dluga 44/50, 00-241 Warszawa, Poland, kkopczewska@wne.uw.edu.pl

Abstract. This paper proposes a methodology to measure spatial effects of roads and local authorities' seats in a diffusion of business activity, which usually follows the distance decay patterns, from core to periphery. Regional development policy, pursued by regional authorities, directed to local units and designed to support local economies is implemented as a centrifugal diffusion process. This invisible flow of policy will be modeled with one-way spatial interaction model represented by multinomial distance-decay function on the integrated spatial dataset.

Keywords: spatial spillover, policy transfer, range of local governments, distance-decay function

1 Introduction

An important aspect of the policy transfer is its spatial characteristics. The regional and local governments interact in setting and pursuing a policy. There are many spatial models of development: from core-periphery to polycentricity, which differ in the spatial distribution of the social and economic activity. Depending on the spatial model of development, core localizations have different role in creating stimuli for spatial processes. The more centralized region, the stronger centrifugal stimuli needed to evoke a spatial diffusion.

The unequal forces over whole administrative territory lead to geographical concentration of business in space. The attractive, centrally located core territories will catch major of the economic activity. The natural centrifugal diffusion, resulting from the agglomeration effects like searching for cheaper offices, avoiding over-congested roads etc. will strengthen the urban sprawl process. However, this concerns only a suburban area or first-row neighbours of the city. Further reaching interactions need usually some institutional support, what means that diffusion is a forced process then. There is an empirical evidence, that impact of core cities on surrounding areas (rural or nonmetropolitan) ranges no more than 25 miles (ca. 40 km), with the highways included [13], [3], [17].

Business initiative is usually attracted by public sector activities which are the implementation of development policy. Local interactions of business with public sector are targeted to operate on the administrative regional territory. The policy going beyond the boundaries would be then inefficient in the sense of regional costs and benefits, as the part of benefits would be consumed outside the region, with all the costs incurred in the region. This means that local authorities (NUTS 4 or NUTS5) cooperate mainly with their NUTS3 or NUTS2 authorities in order to keep policy effects inside the region. This sets the direction of policy flows, from core to periphery, inside the region only.

Distance is here a crucial issue. According to "immortal" Waldo Tobler's law [23] that "*everything is related to everything else, but near things are more related than distant things*", there exists a chance that local authorities located far from their regional authorities will be less efficient in policy implementation than the one located centrally. The first reason for this is perceiving a policy as a tacit knowledge, which needs short distance to flow completely. Policy transfer can be perceived as a flow of tacit knowledge between agents, which is dependent on the distance, both geographical, as well as cultural and social. Rising spatial separation of local and regional authorities weakens the policy flow and reduces the interactions between core-periphery[1] [6]. Spatial concentration is needed in order to co-operate in developing new approaches, building social networks etc. [18]. The second reason is the spatial accessibility of territory, which allows for easier flows to localizations which are well connected with the core city. Accessibility, understood as a facility of reaching destination point from given location by using a certain transport system, can determine the economic potential of regions. According to Keeble et al. [14], EU low potential regions generate low incomes. Standard spatial accessibility is often defined as road distance not longer than 60-90 minutes [4], [7] for access to palliative care or transportation to the airport in terms of the territorial cohesion etc. Unfortunately, there is still few empirical evidence on the relations between accessibility (also road network and infrastructure investment) and economic performance of regions and their business activity [2], [10].

However, distance and accessibility effects might be disturbed by the institutional effects. Having a seat of local self-government, what usually automatically converts a localization into a local center, might be a business attraction factor. There exists many surveys (ex. [12], [21]) on city-suburbans relations when neighbouring authorities' decision are not independent from each other.

This leads to main hypothesis that territories located on peripheries and not connected by high-speed roads may implement the policy weaker because of lower attractiveness. Roads access might cause facilitated diffusion of business impulses. This diffusion will be a natural process, emerging when agglomeration diseconomies will dominate. However accessibility effects might be balanced by institutional factor. The seats of authorities, regardless of road connections, can reveal higher business concentration that it would result from location factor only. An active policy of public sector can evoke driven diffusion, which appears when business opportunities are being noted. The first question is whether the roads are significant channel of speeding-up the diffusion process. The second question is about the role of the local

[1] Concept started by Tobler [23], developed in quantitative distance-decay models [8]. Currently socioeconomic patterns which are homogenous over space sometimes are rarely assumed in the literature.

authorities' seats in attracting a business activity. The overall question is about accumulation of business stimuli over space.

2 Spatial integrated dataset

An integrated spatial data allow for economic the analysis of spatial processes. Five kinds of the data were merged: the administrative division of the country, the localization of county authorities, the road network, distance and business indicators. All data were collected on NUTS5 level. This level of aggregation minimizes the risk that some spatial trends might be hidden and ensures that the edge effect will be as small as possible in spatial modeling.

Administrative division of the country – according to NUTS classification adopted in EU statistics all NUTS5 regions belong to higher NUTS levels. There are 2478 NUTS5 municipalities (*gmina*), 379 NUTS4 counties (*powiat*) and 16 NUTS2 regions (*województwo*) in Poland. In all mentioned units, local and regional self-governments have their seats. Regional development policy is designed on NUTS2 level and then implemented on NUTS5 and NUTS4 level. Also NUTS5 and NUTS4 units are responsible for undertaking local actions to support socio-economic development and growth. An average NUTS5 municipality has an area of 126 km^2 and 15,5 thousand of inhabitants, while at NUTS4 there are on average 100'000 inhabitants on 825 km^2 area. Territorial structure of the country must be taken into consideration when analysis concerns the public sector. Institutional help will be limited by territorial division and structural belonging of territories to higher class regions.

Institutional rent of NUTS4 powiat cities – intermediary government on NUTS4 level was designed to carry out routine activities on supra-municipal level. Also labour market institutions are located on this level. Powiat cities play a role of local centers, with local authorities, hospitals, secondary schools, geodesy specialists etc. Municipalities, which have a status of local core city are more important than similar other cities, mainly because of being closer to authorities and local decisions centers. This level existed in Poland prior to 1975 and was re-introduced in 1999.

Roads – existing international public roads were taken into account and included as a dummy variable on NUTS5 level (Fig.1). They have an open-access from all municipalities through which the roads run. Corridor express roads and highways with access on road junctions only were excluded, as there is an evidence that their impact might be inverse [20]. The length of main national public roads in Poland is 18 368 km, where 5500 km are international public roads, 916 km are highways, 364 km are an express dual-lane roads and 242 km are a single-lane roads. Main national roads are ca.5% of all public roads in a country[2]. Unequal spatial distribution of roads has its roots in historical division of the country. Density of roads (an area covered by infrastructure) measured on NUTS2 regions is from 4% (in the eastern and northern part) to more than 8% in the southern part. In ca.22% of municipalities inter-national roads are located.

[2] An area is 312 679 km^2 and there are 7730 km^2 roads in Poland.

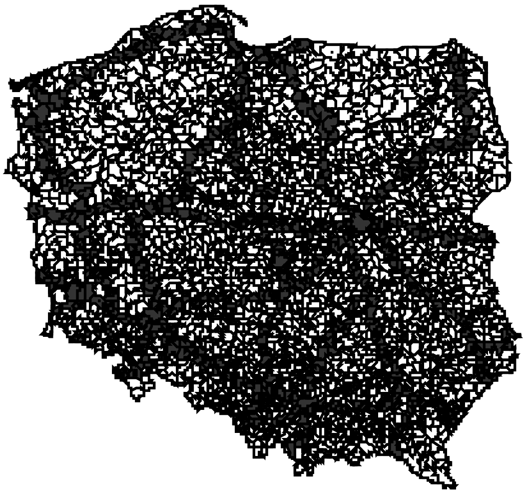

Fig. 1. International roads in Poland in NUTS5 municipalities

Distance – Euclidean distance between NUTS5 territories and their respective main regional city was calculated as a measure of spatial separation[3]. NUTS5 municipalities cooperate with their NUTS2 regional authorities in providing goods and services and implementing social, economic and environmental policy. After the territorial-administrative reform of 1999, when 49 regions were reduced to 16 NUTS2 units, there are municipalities which are located ca.180 km from the core city. High distance from core means usually worse accessibility (Fig.2). Travel time, based on Euclidean distance can be approximated. For Polish road network one can assume that 1 km Euclidean distance = 1.2 km road distance and the 1 km road distance = 1.06 minutes travel time[4]. Similar multipliers were found by Tobler [24].

[3] With this approach the problems of natural barriers, road network, travel time etc are being faced. For this reason, more sensitive studies use sophisticated measurement of distance, such as road distance in km, travel time and travel costs. However, this information is not commonly available for local units. There is thus a clear trade-off between price and quality of distance information.

[4] For a random sample of 100 municipalities within 50, 100 and 150 km from the central city a road distance and an estimated travel time were calculated. Web-map www.zumi.pl was used. Results are at regression coefficients with significance level less than 0.00001.

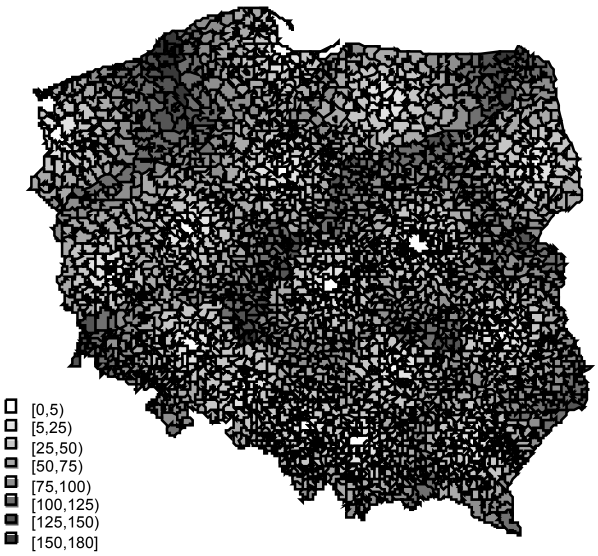

Fig. 2. Euclidean distance between NUTS5 municipalities and their regional core city

Business indicators – for every NUTS5 municipality a number of firms per 1000 inhabitants was calculated (for year 2009). In Polish economy there are 3,74 mln business units, where 95% are small size companies (employment less than 10) and ca.4,3% average size business units (employment less than 50). Spatial distribution is also unequal (Fig. 3) – from 65 units per 1000 people in PL09 Podkarpackie (east-southern part) to 122 units in PL0G Zachodniopomorskie (west-northern part). On regional level business stimuli and attitude is a consequence of the historical circumstances, culture, development level, endogenous resources etc. On local level, when all those factors are uniform inside a region, location and institutions does matter. Market forces tend to locate business units in most attractive places: local centers and / or the most accessible locations.

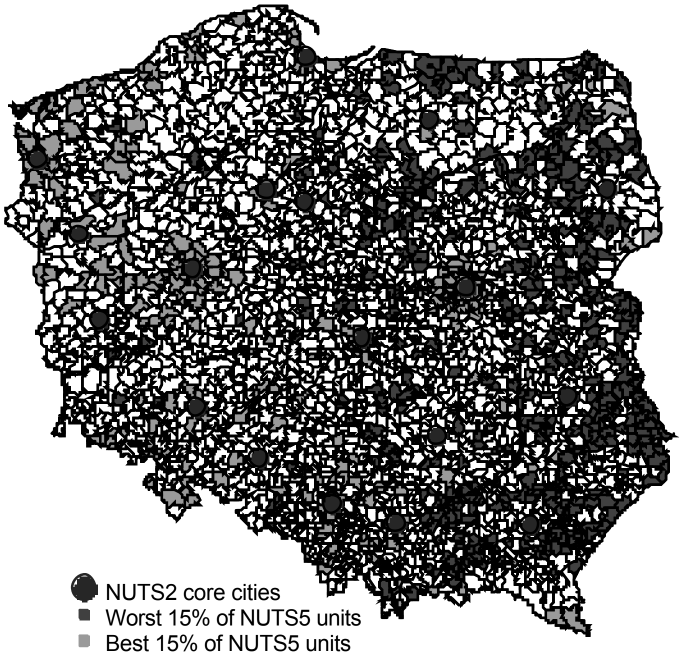

Fig. 3. Spatial distribution of business activity *per capita* (2009)

3 One-way spatial interactions model

Decreasing with the distance flows of goods and services between two destinations are usually analyzed with spatial interactions models, which are widely applied in transportation, migration, trade and also policy diffusion, research impact, knowledge flows, innovation implementation etc. [25], [22]. The basic model of spatial interactions assumes the existence of a T matrix of T_{ii} flows between locations from origin M to destination N (1), d matrix of the d_{ij} distances between locations (2), and T' matrix of T'_{ij} theoretical values of flows (3).

$$T = \{T_{ij}\}_{i,j=1}^{M.N} \tag{1}$$

$$d = \{d_{ij}\}_{i,j=1}^{M.N} \quad (2)$$

$$T' = \{T_{ij}^{'}\}_{i,j=1}^{M,N} \quad (3)$$

The assumption of the two-way flows in pairs is important in business models of trade, migration etc. In case of policy transfer, flows of development and innovation incentives or tacit knowledge, which are usually not observed it is required to adopt one-way flows, from the core to the periphery. This is consistent with institutional settings, in which core - regional authorities, set a roadmap of activities for periphery – local authorities. Assuming that one core gives an impulse to many peripheries and that the flows are centrifugal the *d* matrix and *T* matrix became a vector. In this kind of models the flows of policy are invisible as such, and only its results are measured. Unequal spatial distribution of examined process is then explained by localization, given as distance to core, high accessibility (ex. by high-speed road) and characteristics of neighbours.

As the distance-decay models are to present flows according to the distance, there are some possible, alternative functions, like exponential (4), power (5) or polynomial (6) to be applied:

$$\ln x_1 = \beta_0 + \beta_1 D \quad (4)$$

$$\ln x_1 = \beta_0 + \beta_1 \ln D \quad (5)$$

$$x_1 = \beta_0 + \beta_1 x_0 + \phi_1 D^1 + \phi_2 D^2 + \phi_3 D^3 + \phi_4 D^4 + \ldots + e \quad (6)$$

where x_1 is the level of proxy indicating policy flows result, and D is the distance between core and territory.

Problem of function selection was widely discussed in the literature. There are classifications like by Goux [11] or by Forteringham and O'Kelly [8] indicating a function relevance to the research problem and also advanced models of two-way flow like in LeSage and Pace [16]. There is also a long list of advantages and disadvantages pros and cons of the function selection, such as power function turns out to be better than the exponential when it is necessary to ensure comparability of parameters between the tests regardless of the measurement scale [8]. However, discussion is often far from polynomial functions, which are accused of changing the direction of interaction in $+\infty$ zone and also of ability to predict negative interactions, when the function falls below the *x* axis or ambiguous interpretation of the constant term [22]. On the other hand, polynomial functions are more flexible in adjusting to the data. This kind of models are often used in trend surface analysis [15].

For the model quality assessment several measures can be used. The basic R^2 is recommended for OLS calibration, the Information Gain I for the MLE calibration and finally SRMSE (*Standarized Root Mean Square Error*) is useful regardless of functional form and estimation method.

$$SRMSE = \frac{\sqrt{\frac{\sum_{i,j=1}^{M,N}(T_{ij} - T_{ij}^{'})^2}{M \cdot N}}}{\frac{\sum_{i.j=1}^{M,N} T_{ij}}{M \cdot N}} \tag{7}$$

The SRMSE interpretation uses a rule of thumb with the following thresholds: SRMSE between 0 and 0.5 means very good fit; SRMSE ~ 0.75 is for a moderate adjustment to observe major trends only; SRMSE between 1 and ∞ means a poor fit, often with off-scale observations [1].

Spatial interaction models, irrespectively of the functional form, usually are estimated with classical, a-spatial methods. For one-way invisible flows, the spatial structure and neighborhood matrix should be included in estimation. Assuming a relation as below (Fig.4), where B, C and G are neighbors in periphery, and A is distant core, spatial autocorrelation effects may occur for A-B, A-C and A-G pairs because of similarity of interaction. Also the diffusion of development stimuli from A will be stronger to D and E than to C, B and G. Better accessibility of E and C than D, B and G may also strengthen the invisible flow. However, stronger flow of intangible assets should be visible in proxy data for regions.

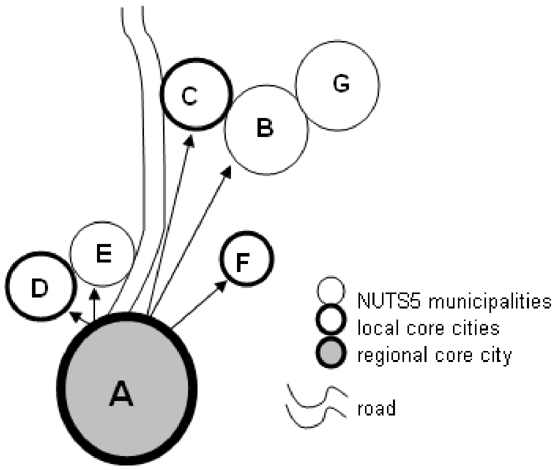

Fig. 4. Spatial interactions approach

Searching for a proxy for invisible flow requires good institutional orientation in the possible connections. If the business development stimuli are analyzed, a possible proxy will be number of companies *per capita* (or to working population) in given region. Also the ratio of insolvent and bankrupt companies to newly established firms might shed a light on the policy transmission process.

Incorporating spatial structure in the model is possible with spatial weights matrix. In the case of spatial one-way flow models an inverse distance matrix will duplicate an information of the covariates on the distance. The contiguity matrix, where only common border matters, fits the problem theoretically, as the local flows range at most closest neighbours. Also a matrix of higher than the first row can be applied. *Ex post* results will confirm a choice done *a priori*. Structural form of spatial model – spatial lag or spatial error – depend on spatial process characteristics and can be tested with LM models on the basis of OLS residuals. Spatial estimation details can be found in Cohen [5].

4 Estimation results

A model of policy diffusion was estimated on NUTS5 Polish data. Local development of business was found to be de strongly dependent on distance, but also on road network and institutional settings. Spatial effects are clearly visible, both in empirical statistics (Tab.1) and estimated theoretical values (Tab.2). There is a significant effect of business spatial concentration in a local core cities. Municipalities located on peripheries (far from core, poor accessibility because no international roads) without local authorities have on average less than half of business units located in regional core city. On the basis of empirical data, when a municipality runs a road then a number of business units per capita grows on average by ca. 15%. An effect of administrative decision on making a seat of authorities in local city increases the number of business units by ca. 60%. Both (roads and seats) effects joined improve municipality performance by ca. 75%. The effect of local governments seems to be on average four times stronger than roads impact, but the further located area the stronger spatial effects observed.

Table 1. Empirical statistics of business units per 1000 inhabitants depending on distance (km), road network and institutional settings

	0 km	**< 25 km**	**25-50 km**	**50-75 km**	**75-100 km**	**100-125 km**	**125-150 km**
General average	136	88,5	68,2	65,7	68,1	66,66	70,7
No road, no authorities' seat	NA	83,2	60,7	59,5	62,3	59,1	62,1
Roads included, no authorities' seat	NA	90,4	69,9	70,6	67,2	59,9	72,5
No roads. authorities' seat included	130,1	109,3	96,3	98,2	97,7	106,7	109,3
Both roads and authorities' seat included	137	100	105,2	108,4	115,1	107,9	134,0

Three model specifications were tested: multinomial, power and exponential, and each of those was estimated with use of a-spatial and spatial model. The form of spatial error model was chosen on a basis LM tests on OLS residuals. The first main point in this analysis is choosing a model. Standardized Root Mean Square Error (SRMSE) indicates that power and exponential specification do not fit the data well. Fourth-degree polynomial model is much better than the previous two (SRMSE=0,3-0,4) and is fitted well. Also the spatial models, justified with the significant lambda in the regression and significant positive Moran I for OLS residuals are much better fitted than a-spatial ones (better AIC and SRMSE). Misspecification of a-spatial models results in a bias, ie. over-estimated parameters are a consequence. Spatial error model has filtered out the spatial autocorrelation , caused by similarity of flows to locations equally distanced.

Table 2. Estimation results – number of usiness units per 1000 inhabitants was explained by distance, road network and NUTS4 authoroties' seats.

Model	**Polynomial y~f(x)**		**Power log(y)~f(x)**		**Exponential log(y)~f(x)**	
Covariates	**a-spatial**	**spatial**	**a-spatial**	**spatial**	**a-spatial**	**spatial**
Constant	103,5***	97,3***	4,47***	4,29***	4,16***	4,20***
Log(Dist)	---	---	-0,10***	-0,04**	---	---
Dist	-2,16***	-1,50***	---	---	-0,0015***	-0,0013***
Dist^2	3,8e-2***	2,3e-2***	---	---	---	---
Dist^3	-2,8e-4***	-1,4e-4*	---	---	---	---
Dist^4	7,4e-7***	3,06e-7*	---	---	---	---
Road	7,7***	4,51***	0,12***	0,06***	0,13***	0,067***
Seat of auth.	35,6***	34,0***	0,47***	0,44***	0,48***	0,45***
SRMSE	0,387	0,303	1,04	1,04	1,04	1,04
AIC	23 356	22 414	1623,6	403,31	1670	340
Moran's I	0,44***	-0,07	0,51***	-0,07	0,52***	-0,07
Lambda	---	0,68***	---	0,73***	---	0,73***

The second important point is the meaning of the distance from the core city. When no spatial effects, roads or authorities seats, appear, only ca. 25-30 km is enough to extinguish the core-periphery diffusion process (Fig.4). According to fitted curve, the value of business units per 1000 inhabitants falls then below national average. Most of the municipalities located further than 30 km from centre is weaker then the average units in terms of business saturation.

The third points is about the disturbances over space. The natural spatial diffusion and cumulating effects because of distance are changed by accessibility and institutional settings. International roads extend the range of the diffusion to ca. 45-50 km, making the diffusion reaching 20 km further. On average, number of business units per 1000 inhabitants is 5-7% higher then without the road. When NUTS5 municipality is a seat of NUTS4 authorities (no international roads included), then number of business units is 35%-55% higher then without it. Status of being the local core causes that business saturation almost never falls below 100 units per 1000 inhabitants, so is higher by 30 units then without having local authorities in a city.

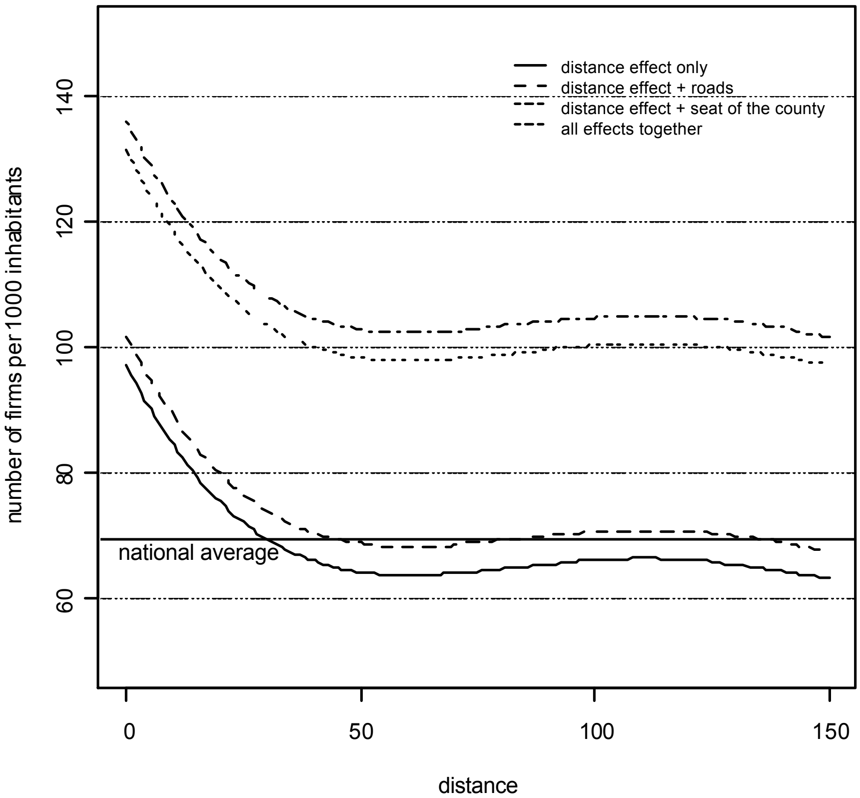

Fig. 5. Fitted values of polynomial model

5 Conclusions

This study of spatial diffusion of business activity in the core-periphery pattern was deigned to capture the effects of international roads and institutional settings on natural flows mechanisms. NUTS5 municipalities connected administratively with regional NUTS2 core cities present different business saturation, which was hypothesized to decrease with the distance. The one-way spatial interactions model, specified as fourth-degree polynomial functions and estimated as spatial error model proved that distance is indeed a significant factor of diffusion process. However, this might be disturbed by higher accessibility and by institutional rent.

According to the results, an economic development might be stimulated by expanding the roads network in order to facilitate business flows from core to periphery. Better two-way accessibility, from central to local units and *vice versa*, increases the business saturation by 5-7% and extends the core range by 20 km. Much stronger spatial effects are achieved with institutional settings. NUTS4 authorities are an assistant self-government in relation to NUTS5 authorities, which are responsible for local development. Duties of NUTS4 authorities are to join NUTS5 units and provide public goods and services on supra-local level. Their impact on business environment is much higher than roads influence and one should expect 35-55% increase in number of business units per 1000 inhabitants then in other locations. Those results are consistent with existing empirical evidence on weak impact of transportation infrastructure on regional production [9], [19].

Those results show that core-periphery spatial diffusion process is rather poor, although it was implemented in Polish regional policy for last 15 years. The economic development in local NUTS4 seats is rather a matter of local interactions than flows from the core. This means that implementation of endogenous development idea is having place here. This leads to conclusion that spatial cohesion policy should be implemented on local level. Local core cities and their accessibility are the most important element in developing business environment.

References

1. Andersson, J., Joernsten, K., Pettersen Strandenes, S.: Modeling Freight Markets for Coal. NHH Discussion Paper (2008)
2. Beuthe, M.: Transport evaluation methods: from cost-benefit analysis to multicriteria analysis and the decision framework. In: Giorgi, L., Pearman, A. (eds) Project and Policy evaluation in Transport. Ashgate, Aldershot (2002)
3. Briggs, R.: The impact of interstate highway system on non-metropolitan growth, US Department of Transportation, Office of University Research, Washington D.C. (1980)
4. Cinnamon, J., Schuurman, N., Crooks, V.: A method to determine spatial access to specialized palliative care services using GIS. BMC Health Services Research 8:140 (2008)
5. Cohen, J.P.: The broader effects of transportation infrastructure: Spatial econometrics and productivity approaches. Transportation Research Part E 46 317--326 (2010)
6. Dicken, P.: Global Shift. Mapping the Changing Contours of the World Economy, SAGE, Fifth edition, 100--105 (2007)
7. ESPON, Scenarios on the territorial future of Europe. ESPON Project 3.2 Final Report, Luxemburg (2007)
8. Fotheringham, A.S, O'Kelly, M.E.: Spatial Interaction Models: Formulations and Applications, Kluwer Academic Publishing (1989)
9. Garcia-Mila, T., McGuire, T.J.: The contribution of publicly provided inputs to states' economies. Regional Science and Urban Economics vol.22, no.2, 229--242 (1992)

10. Gutierrez, J., Condeco-Melhorado, A., Martin, J.C.: Using accessibility indicators and GIS to assess spatial spillovers of transport infrastructure investment, Journal of Transport Geography 18 141--152 (2010)
11. Goux, J.M.: Structure de l'espace et migration. In: Sutter, J., (eds). Human Displacements (Entretiens de Monaco en Sciences Humaines: Premiere Session) (1962)
12. Houghwout, A.F.: Regional Fiscal Cooperation in Metropolitan Areas: An Exploration. Journal of Policy Analysis and Management 18, 579--600 (1999)
13. Humphrey, C.R., Sell, R.R.: The impact of controlled access highways on population growth in Pennsylvania nonmetropolitan communities, 1940-1970, Rural Sociology, vol.42, 332--343 (1975)
14. Keeble, D., Offord, J., Walker, S.: Peripheral regions in a community of twelve. Office for Official Publications of the European Communities, Brussels / Luxemburg (1988)
15. Legendre, P., Legendre, L.: Numerical Ecology. Elsevier Science. 2 edition (1998)
16. LeSage, J., Pace, R.K.: Introduction to Spatial Econometrics. CRC Press Taylor & Francis Group (2009)
17. Lichter, D.T., Fuguitt, G.V.: Demographic response to transportation innovation: the case of the interstate highway. Social Forces, vol.59 492--511 (1980)
18. Lundvall, B., Johnson, B.: The learning economy. Journal of Industry Studies 1(2):23--42 (1994)
19. Munell, A.H.: How does public infrastructure affect regional economic performance, New England Economics Review September-October: 11--32 (1990)
20. Rephann, T., Isserman, A.: New highways as economic development tools: An evaluation using quasi –experimental matching methods. Regional Science and Urban Economics, vol.24 723--751 (1994)
21. Schaltegger, Ch.A., Zemp, S.: Spatial Spillovers in Metropolitan Areas: Evidence from Swiss Communes. CREMA, Basel, Working Paper No.2003-06 (2003)
22. Taylor, P.: Distance Decay Models in Spatial Interactions, CATMOG (Concepts and Techniques in Modern Geography) nr 2 (1975)
23. Tobler, W.: A computer movie simulating urban growth in the Detroit region. Economic Geography, 46(2): 234--240 (1970)
24. Tobler, W.: Speculations On The Geometry Of Geography. National Center For Geographic Information And Analysis, Technical Report 93-1 (1993)
25. Vries, J., Nijkamp, P., Rietveld, P.: Exponential or power distance-decay for commuting? An alternative specification. Paper presented at 45th Congress of the European Regional Science Association, Amsterdam (2005)