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The German Dimension of the Socio-Economic Gravity Systems of Europe

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Abstract

This paper analyzes the geo-economic dimension of the concept of regional efficiency and the role of social, economic and industrial gravity centers in the context of European geo-economic dynamics. In the above framework we evaluate and analyze the socio-economic gravity systems of Germany in the context of Europe as a tool for the exploration of the geo-economic efficiency of the German regions.

Keywords: Geo-economy, Germany, Europe, Gravity Centers

1. Theoretical Background

1.1 Geo-economic gravity system analysis

1.1.1 The notion of regional efficiency

One of the basic aims of regional analysis is the introduction and promotion of policies enhancing the ability of administrative units (provinces, regions or states) to better exploit the capabilities of their infrastructure as well as of their human and natural resources so as to attain sustainable growth both in the social and in the economic sphere. In the above context, the concept of efficient regions plays a critical role. The term "efficient regions" refers to administrative units or areas possessing (hidden or partially exploited) comparative geo-economic advantages. Modelling the above problem is a very difficult process and relevant attempts were not always fully convincing. The cost approach will be applied in this paper in order to model the concept of regional efficiency. In the cost approach the key concept of regional efficiency is expressed as the geo-economic ability of an area to act as a distribution supply center under cost criteria. The notion of the supply center is expressed by a system of facilities with the necessary infrastructure supplying surrounding areas with services or products at low cost. The notion of cost covers both the cost of establishing and operating the facilities as well as the associated transport cost. The demand of the surrounding areas on services or products in general is usually expressed by regional summary measures such as population GDP, Manufacturing Value Added (MVA) imports etc.

In the next section the general geo-economic gravity model is presented and analysed. This model regards the optimal location of a system of supply centers in the nodes (regional capital cities) of a transportation network connecting the regions of a geographical area.

1.1.2 The General Geo-economic Gravity (GGG) model

The "n-Facilities Location Problem" (which represented the original basis on which GGG model was developed) regards the location of n non-competing supply facilities in a geographical area which will fully cover the demand for services (public sector or social type facilities) or commodities (private sector or economic type facilities) of a system of demand poles at a minimum fixed and transport cost. The term “fixed cost” refers to the facility establishment and operations cost. The notion of the “demand pole” plays a crucial role in the modeling process varying widely as its spatial size is concerned. It can represent a small size “point-type demand pole” which may coincide, for example, with an industrial plant or warehouse or a market complex (mall or supermarket) or even with an industrial zone demanding raw materials, intermediate products or services for its activities. On the other hand, it can represent an "area-type demand pole" which is a larger spatial conglomeration of demand points such as an urban area or even an administrative unit (province region or a state). The notion of the "supply facilities", which is mainly determined by the characteristics of the relevant demand poles, can vary widely from "point-type supply facilities" coinciding with industrial plants warehouses industrial zones etc (which act this time as supply sources for a system of demand poles) to "area-type supply facilities" which represent a system of social or/and economic activities covering an urban area or even an administrative unit. For example, a point-type supply facility may represent a plant or warehouse that a firm plans to establish in an area so as to cover the demand of a system of demand poles in it at a minimum fixed and transport cost (the case of private sector supply centers) or it may represent a public facility e.g. a health or athletic center or school that a local authority plans to establish in an administrative area which will cover the associated demand of it with the minimum social cost (the case of a public sector supply facility). Note that, in the context of the modelling process, area-type demand poles are spatially represented by a "central" point inside them, usually the location of the corresponding administrative center (as an example the capital of the province, region or state). Note also that, in the context of regional development approaches the demand of large geographical areas (cities or administrative units) can be represented by summary measures such as their population, their GDP, their MVA or their imports.

Karkazis and Boffey (1981 and 1981a) and Boffey and Karkazis (1984) introduced efficient optimal algorithms for the n-facilities location problem on a transport network.

The GGG model represents a structural and conceptual generalization of the n-facilities location model. In the context of this model we consider a transportation network connecting the set of nodes **P**=(P1, P2,…, Pm) of it which coincide with the capital cities of a set of regions **R**=(R1, R2,..., Rm) of a given geographical area **A**. d(Pi, Pj) expresses the length (distance in km) of the shortest path connecting nodes Pi and Pj. The GGG problem regards the optimal location, in this network, of n (non competing) supply centers Sj j=1..n (to be established at the nodes of the network) which will fully cover a general/summary measure of demand Di for all regions of **A**. Note that the demand Di of a region Ri is considered to be spatially concentrated in its capital city. The above problem is expressed by the following model:

Min C(S1, S2,..., Sn) over all combinations of Sj (j=1,2,...,n) in **P** (1)

where C(S1, S2,..., Sn) is the supply system's total cost which consists of two sets of costs, the operational costs OC(Si) and the transport costs TC(Si) i=1,..,.n corresponding to the n supply centers. For the purpose of the present analysis and in view of the limited number of available regional statistics for the 301 European regions under consideration (population GDP and GDP per capita) we tried to introduce a simple multiplicative model which is capable of representing the impact of economies of scale (with respect to distance) on the transport cost and the impact of GDP per capita on the operational cost. We have also tested this model for a wide range of values regarding the tuning parameters controlling the above two factors with the purpose of: (i) offering to relevant research a wide range of numeric relationships to be tested in the context of specialized econometric models and (ii) theoretically analysing the behaviour of the supply system (and its regional characteristics) with respect to a number of key decision variables. The multiplicative model employed in this analysis is:

C(S1, S2,…, Sn) = OC(S1)*TC(S1) + OC(S2)*TC(S2) + …+ OC(Sn)*TC(Sn) (2)

The operational cost or *GDP pc factor* OC(Si) is expressed by the following function of normalized GDP per capita (NormGDPpc) of the region Ri accommodating supply center Si:

OC(Si) = NormGDPpc(i)^F (3)

where NormGDPpc(i) = GDPpc(i) / max GDPpc(j) over all j and F is a tuning exponent.

If F=0 then the operational cost is independent of the site of supply center (equal to 1 for every node). Increasing values of F (up to value 1) create increasing differentiations of GDP per capita impact (up to the distribution of NormGDPpc(i)s).

The total transport cost TC(Si) associated with supply center Si is given by the following function:

TC(Si) = Dj1*UTC(d[Si, Pj1], K) + Dj2*UTC(d[Si, Pj2], K) + .. .+ Dji*UTC(d[Si, Pji], K) (4) where UTC(d[Si,Pjk], K) represents the unit transport cost (that is the cost of transporting a unit of demand from supply center Si to node Pjk) which is a non-linear function of transport distance. Pj1 Pj2..Pji are the nodes of the network (regional capitals) that are closer to supply center Si than to the other supply centers (and hence they are served by Si). Dj1, Dj2,..., Dji are corresponding summary measures of demand and d[Si, Pjk] k=1,2,...,ji is the shortest path distance between supply center Si and node Pjk and K is the (transport cost) economies of scale modulator (see section 1.2.3).

The solution of the general geo-economic gravity model, that is the system of the n supply center locations minimizing corresponding cost function, will be called thereon “Geo-Economic Gravity System”. If the demand summary measure is regional population then the corresponding Geo-Economic Gravity System will be called “Social Gravity System”. This system of supply centers is associated with public sector facilities offering social services. On the other hand, if the demand summary measure is regional GDP, regional MVA or regional imports then the corresponding Geo-Economic Gravity System will be called "Economic Industrial or Trade Gravity System" respectively.

In order to distinguish between the various values n is taking in the applications analysed in this paper the Geo-Economic Gravity Systems corresponding to the values n=1,2 and 3 will be thereon called "Single, Dual and Triple Geo-Economic Gravity Systems" respectively.

1.1.3 The transport cost function

The non-linear transport cost function employed here is the simplest non-linear function allowing for economies/dis-economies of scale. Actually, the transport cost UTC(d, K), for transporting a unit of demand to a distance d, is a quadratic function of d containing a tuning parameter K determining the intensity of economies or dis-economies of scale:

$$UTC(d, K) = (K-1)*[d*d/dmax] + d \quad (5)$$

where dmax is the maximum distance recorded in the network

To clarify the role of the parameter K we consider the following cases:

- If K<1 then the per km unit transport cost is a decreasing function of distance and hence we get economies of scale
- If K>1 then the per km unit transport cost is an increasing function of distance and hence we get dis-economies of scale.
- If K=1 then the unit transport cost is linear with respect to distance: UTC(d, 1)= d.

In general the unit transport cost function is such that:

$$UTC(dmax, K) = K*UTC(dmax, 1) \quad (6)$$

Consequently the unit transport cost with a tuning parameter K corresponding to the maximum distance is K times the corresponding linear transport cost (K times smaller for economies of scale and K times larger for dis-economies of scale).

1.2 Regional discrimination cost analysis

<u>Single geo-economic gravity systems</u>

In the case of a single geo-economic gravity system, supply center's total cost is minimized at the location of the gravity center. As we deviate from the gravity center the corresponding transportation cost is increased (as a rule) in a non-linear and rather complex way. The main factors differentiating transportation cost from its minimum level at the gravity center is of course the distance from this location but also the distribution of demand points (sites of regional or state capitals in our case) in the area under consideration. In order to express the spatial differentiation of supply system's cost in a way amenable to regional planning considerations we introduce the notion of Regional Discrimination Cost (RDC) at a site (regional capital) P of an area **A**, RDC1(P), as follows:

$$RDC1(P) = C(P) / C(G) \quad (7)$$

where C(P) expresses the supply system's total cost at location P and C(G) the corresponding cost at the gravity center G. Hence

$$RDC1(P)>=1 \text{ and } RDC1(G)=1. \quad (8)$$

It is evident from the above that the higher the regional discrimination cost of a region R is the lower the relative attractivity of R with respect to investment considerations is expected to be. The above underlines an 'in-built' weakness of the region which is very difficult to remove in a short or medium term horizon. In such cases regional incentives are possibly the only means of encountering the problem by counter-balancing high transportation costs.

Multiple gravity systems

In the case of a n supply centers (dual, triple etc gravity systems) the regional discrimination cost at a site (regional capital) P of an area **A**, RDCn(P), is defined as follows:

$$RDCn(P) = Ci(P) / Ci(Gi) \quad (9)$$

where Gi is the gravity center of the system which is closest to site P, Ci(Gi) is the portion of system's total cost corresponding to Gi and Ci(P) is the total cost of supplying from site P all the nodes assigned to gravity center Gi. Hence

$$RDCn(P)>=1 \text{ and } RDCn(Gi)=1 \quad (10)$$

1.2.1 Characterization of network nodes

For the purpose of easing the drawing of practical conclusions (in the context of numerical analysis performed) we introduce the following characterizations for the network nodes.

Single Gravity Systems (n=1)

A node MG is characterized as "Main Gravity Center" if RDC1(MG)=1. A node G is characterized as "Gravity Center" if RDC1(G)<=1.01.

Dual Gravity Systems (n=2)

The nodes of the dual gravity system (that is the pair of nodes minimizing total supply cost) are characterized as "Main Gravity Centers". A pair of nodes (G1, G2) is characterized as "Gravity Center pair" if total supply cost of it, C(G1, G2), deviates no more than 1% from total supply cost of the dual gravity system.

Triple Gravity Systems (n=3)

The nodes of the triple gravity system (that is the triplet of nodes minimizing total supply cost) are characterized as "Main Gravity Centers". A set (G1, G2, G3) of nodes is characterized as "Gravity Centers triplet" if total supply cost of it, C(G1, G2, G3), deviates no more than 0.1% from total supply cost of the triple gravity system.

1.2.2 Literature review

Karkazis (2000) applied the planar (euclidean distances) and linear version of GGG model to evaluate the social, economic and industrial gravity centers of the Balkans.

Karkazis (2005a) applied the planar and linear version of GGG model to evaluate the social, economic and industrial (single, dual and triple) gravity systems of Turkey at a provincial level and their intra-time relocations whereas Karkazis and Isen (2005) applied the above model to assess the impact of Southeastern Anatolia Project on the geo-economic gravity systems of Turkey. Also, Karkazis (2005b) applied a multi-criteria approach (including among other criteria the notion of geo-economic gravity systems) to analyse the dynamic behaviour of the regional (provincial) manufacturing industry profiles of Turkey.

Furthermore, Karkazis (2005c) applied the linear version of GGG model to make a dynamic comparative analysis of the geo-economic gravity systems of Europe and Turkey, performing sensitivity analysis tests on key parameters of the model.

Finally Karkazis (2008) applied the GGG model on the network (true km distances) to evaluate optimal locations for supply centers on the main road network of Turkey and to analyse the impact of transport cost economies of scale on their spatial characteristics.

Karkazis and Doumi (2007) applied the linear GGG model on the network to evaluate the geo-economic gravity centers of Greece and the regional discrimination costs of the provinces (nomoi) of the country.

Karkazis (2007) analyzed the impact of transportation cost on the geo-economic dynamics of Europe.

Karkazis (2008a) performed a comparative analysis of the regional socio-economic profiles of France in the context of E.U. employing a specialized GGG model focusing on a regional discrimination cost (RDC) analysis assisted by RDC iso-curves.

Karkazis, Angelis Mavri and Chalimourda (2009) analysed the issue of the optimal development of supply centers in Germany and their regional geo-economic impact.

Finally, Karkazis (2011) performed a comparative analysis of the geo-economic profiles of the German regions in the context of Europe.

1.3 The role of GIS in regional and transport analysis

The development of special purpose GIS's is of outmost importance for regional and especially for strategic transport analysis.

EUROSTAT has developed a major GIS for the regions of Europe, the Geographic Information System for the Commission (GISCO). The GISCO database contains core geographical data for all of Europe such as administrative boundaries, but also thematic geospatial information, for instance population grid data.
[https://ec.europa.eu/eurostat/statisticsexplained/index.php/Geographical_information_system_of_the_Commission_(GISCO)]

The geo-economic analysis presented in this paper was assisted by three specialized GIS performing advanced regional and transport analysis for Europe, Germany and the
Balkans:

- The GIS "Ptolemeos - Regional Analysis – E. U. 15 and the Balkans" (Karkazis, 2008b),
- The GIS "Regional Europe" (Karkazis, 2012a) and
- The GIS "Regional Germany" (Karkazis, 2012b)

The nodes of corresponding road network coincide with the 252 regional capitals of inland NUTS 2 regions of E.U. countries, Turkey and Northern Macedonia. For the evaluation of shortest path distances an appropriately modified version of the branch- bound method was employed described in 1.4.3.

2. The Socio-Economic Gravity Centers of Germany in The Context Of Europe

2.1 Social gravity centers of Europe during the period 2000-2014

For linear transport costs, the main social gravity center of Europe in 2000 was Karlsruhe (table 1) a regional capital belonging to the state of Baden-Wurttemberg in Southwest Germany. All social gravity centers of Europe in 2000 were also located in Germany. Specifically, except Karlsruhe Stuttgart is the regional capital of the region of Stuttgart belonging to the federal state of Baden-Wurttemberg, Ansbach is the capital of the region of Mittelfranken (Middle Franconia), Wurzburg is the capital of the region of Unterfranken (Franconia) and Augsburg is the capital of the region of Swaben (Swabia). The last three regions belong to the federal state of Bavaria.

TABLE 1. Social gravity centers of Europe. Linear transport costs.
Summary measure of demand: population 2000 & 2014.

Main gravity center (RDC=1.0)		Gravity centers (RDCs <= 1.01)	
2000	2014	2000	2014
Karlsruhe	Karlsruhe	Karlsruhe	Karlsruhe
		Stuttgart	Stuttgart
		Ansbach	
		Wurzburg	
		Augsburg	

Fourteen years later, in 2014, Karlsruhe remained the main social gravity center of Europe, whereas the gravity centers of it reduced from five to two, Karlsruhe and Stuttgart, both of them belonging to the federal state of Baden-Wurttemberg.

The socio-economic profile of the regions accommodating the main social gravity centers of Europe
(in parentheses the ranking among the 41 German regions).

Karlsruhe. The area of the region of Karlsruhe is 6919 sq.km and its population in 2014 was 2.70 mil.inh. During the period 1996-2014 its population increased by 1.96% (16th). In 2014 its GDP was 72.6 bil.euros (8th). During the period 1996-2014 its GDP increased by 50.3% (16th). In 2013 its Industrial GVA was 27.5 bil.euros (6th). During the period 1996-2013 the Industrial GVA of Karlsruhe increased by 17.4% (8th). Finally, the GDP p.c. of the region of Karlsruhe in 2014 was 40383 euros (6th) (Karkazis 2011a).

Stuttgart. The area of the region of Stuttgart is 10558 sq.km and its population in 2014 was 3.97 mil.inh. During the period 1996-2014 its population increased by 2.61% (11th). In 2014 its GDP was 184.8 bil.euros (8th). During the period 1996-2014 its GDP increased by 68.5% (3d). In 2013 its Industrial GVA was 60 bil.euros(1st). During the period 1996-2013 the Industrial GVA of Stuttgart increased by 50.7% (4th). Finally the GDP p.c. of the region of Stuttgart in 2014 was 46517 euros (4th) (Karkazis 2011b).

The impact of scale economies and diseconomies on the location of gravity centers

The introduction of strong diseconomies of scale in the transport cost function with respect both to distance and quantity transported (economies of scale modulator K= 1.50) has no impact on the location of the main social gravity center for 2014 (which remains located in Karlsruhe) and a minor impact on the synthesis of gravity centers for the same year which are now Karlsruhe, Stuttgart, Wurzburg and Neustadt in Rhineland-Palatinate.

The introduction of strong economies of scale in the transport cost function with respect both to distance and quantity transported (economies of scale modulator K= 0.50) has no impact on the location of the main social gravity center for 2014 (which remains located in Karlsruhe) and a minor impact on the synthesis of gravity centers for the same year which are now Karlsruhe, Stuttgart and Augsburg.

2.2 Economic gravity centers of Europe during the period 2000-2014

For linear transport costs, the main social gravity center of Europe in 2000 was Metz in France (table 2). Among the three gravity centers of Europe in 2000 (Metz, Arlon and Saar) one, Saar, was located in Germany. Note that Saarbrucken is the capital of the federal state of Saarland.

TABLE 2. Economic gravity centers of Europe. Linear transport costs.
Summary measure of demand: GDP 2000 & 2014.

Main gravity center (RDC=1.0)		Gravity centers (RDCs <= 1.01)	
2000	2014	2000	2014
Metz (France)	Metz	Metz	Metz
		Arlon (Belgium)	Saarbrucken
		Saarbrucken (Germany)	

Fourteen years later, in 2014, Metz remained the main social gravity center of Europe, whereas the gravity centers of it reduced from three to two, Metz and Saar.

The socio-economic profile of the region of Saarland
(in parentheses the ranking among the 41 German regions).

The area of the region of Saarland is 2569 sq.km and its population in 2014 was 0.99 mil.inh. During the period 1996-2014 its population declined by 8.6% (9th). In 2014 its GDP was 33.7 bil.euros (33d). During the period 1996-2014 its GDP increased by 44.5% (28th). In 2013 its Industrial GVA was 9 bil.euros (28th). During the period 1996-2013 the Industrial GVA of Saarland increased by 33.7% (9th). Finally the GDP p.c. of the region of Saarland in 2014 was 34000 euros (21st) (Karkazis 2011c).

The impact of scale economies and diseconomies on the location of gravity centers

The introduction of strong diseconomies of scale in the transport cost function with respect both to distance and quantity transported (economies of scale modulator K= 1.50) has no impact both on the location of the main social gravity center for 2014 (which remains located Metz) and on the gravity centers of Europe.

The introduction of strong economies of scale in the transport cost function with respect both to distance and quantity transported (economies of scale modulator K= 0.50) has no impact on the location of the main social gravity center for 2014 (which remains located in Metz) but increases considerably the number of gravity centers from two to the following five: Metz, Strasburg, Karlsruhe, Neustadt and Saarbrucken.

2.3 Dual social gravity system of Europe during the period 2000-2014

For linear transport costs, the main pair of the dual social gravity system of Europe in 2000 as well as in 2014 was Metz and Istanbul (table 3). Among the western gravity centers of the above system three are located in western Germany (Karlsruhe, Trier and Saarbrucken), two in eastern France (Metz and Strasburg). one in Belgium (Arlon) and finally one in Luxemburg. Note that Trier is the capital of the nuts 2 region of Trier which belongs to the federal state of Rheinland-Palatinate.

TABLE 3. Dual social gravity system of Europe. Linear transport costs.
Summary measure of demand: population 2000 & 2014.

Main dual gravity system 2000 & 2014	Dual gravity system 2000 & 2014	
(Metz, Istanbul)	Western group	Eastern group
	Metz, Strasburg, Luxemburg, Arlon, Karlsruhe, Trier, Saarbrucken	Istanbul, Tekirdag, Izmit

The introduction of strong economies or diseconomies of scale has no impact on the main dual social gravity center locations and only a minor impact on dual social gravity center locations.

The socio-economic profile of the region of Trier
(in parentheses the ranking among the 41 German regions).

The area of the region of Trier is 4923 sq.km and its population in 2014 was 0.52 mil.inh. During the period 1996-2014 its population increased by2.6% (12th). In 2014 its GDP was 14.8 bil.euros (40th). During the period 1996-2014 its GDP increased by 47% (22nd). In 2013 its Industrial GVA was 3.4 bil.euros (40th). During the period 1996-2013 the Industrial GVA of Trier increased by 29.7% (12th). Finally the GDP p.c. of the region of Trier in 2014 was 28488 euros (31st) (Karkazis 2011d).

2.4 Dual economic gravity system of Europe during the period 2000-2014

For linear transport costs, the main pair of the dual economic gravity system of Europe in 2000 as well as in 2014 was Lille (France) and Munchen (table 4). Note that Munchen is the capital of the region of Upper Bavaria (Oberbayern). The 'western' regional capitals of the gravity system pairs are both located in northern France (Lille and Amien) whereas the 'eastern' ones in Munchen, Milan and Bolzano. Note that Munchen is the capital of the region of Upper Bavaria (Oberbayern) which belongs to the federal state of Bavaria.

TABLE 4. Dual economic gravity system of Europe. Linear transport costs.
Summary measure of demand: GDP 2000 & 2014.

Main dual gravity system 2000 & 2014	Dual gravity system 2000 & 2014	
[Lille, Munchen]	Northwestern group	Southeastern group
	Lille, Amien	Munchen, Milan, Bolzano

The introduction of strong economies of scale has an impact only on northern Italy where Bolzano ceases to be a gravity center whereas the introduction of strong diseconomies of scale leads to the substitution of Milan by Ljubljana (Slovenia).

The socio-economic profile of the region of Upper Bavaria
(in parentheses the ranking among the 41 German regions).

The area of the region of Upper Bavaria is 17530 sq.km and its population in 2014 was 4.47 mil.inh. During the period 1996-2014 its population increased by 12.2% (1st). In 2014 its GDP was 230 bil.euros (1st). During the period 1996-2014 its GDP increased by 81.5% (1st). In 2013 its Industrial GVA was 51.9 bil.euros (2nd). During the period 1996-2013 the Industrial GVA of Upper Bavaria increased by 65.9% (2nd). Finally the GDP p.c. of the region of Upper Bavaria in 2014 was 51446 euros (2nd) (Karkazis 2011e).

2.5 Triple social gravity system of Europe during the period 2000-2014

For linear transport costs, the main triple social gravity system of Europe in 2000 as well as in 2014 was [Paris, Regensburg, Izmit] (table 5). Note that Regensburg is the capital of the region of Upper Palatinate belonging to the federal state of Bavaria. We can distinguish the gravity centers of this system into three groups: the western group consisting of Paris, Lille and Amien in northern France, the central group consisting of Regensburg, Munchen, Bayreuth, Linz, Prague, Pilsen, Dresden, Chemnitz and Bratislava and the eastern group consisting of Istanbul and Izmit in western Turkey

TABLE 5. Triple social gravity system of Europe. Linear transport costs.
Summary measure of demand: population 2000 & 2014.

Main triple gravity system 2000 & 2014	Triple gravity system 2000 & 2014		
[Paris, Regensburg, Izmit]	Western centers	Central centers	Eastern centers
	Paris, Lille, Amien	Regensburg, Munchen,Linz, Bayreuth,Prague, Pilsen, Dresden, Chemnitz,Bratislava	Izmit, Istanbul

The introduction of strong economies of scale leads to the substitution of Paris by Lille in the main triple gravity system whereas the introduction of strong diseconomies of scale has no impact on it.

The socio-economic profile of the region of Upper Palatinate
(in parentheses the ranking among the 41 German regions).

The area of the region of Upper Palatinate is 9691 sq.km and its population in 2014 was 1.08 mil.inh. During the period 1996-2014 its population increased by 2% (15th). In 2014 its GDP was 39.7 bil.euros (28th). During the period 1996-2014 its GDP increased by 62.6% (5th). In 2013 its Industrial GVA was 11.8 bil.euros (24th). During the period 1996-2013 the Industrial GVA of Upper Palatinate increased by 47.7% (6th). Finally the GDP p.c. of the region of Upper Palatinate in 2014 was 36815 euros (12th) (Karkazis 2011f).

2.6 Triple economic gravity system of Europe during the period 2000-2014

For linear transport costs, the main triple economic gravity system of Europe in 2000 as well as in 2014 was [Lille, Munchen, Istanbul] (table 6). We can distinguish the gravity centers of this system into three groups: the western group consisting of Lille and Amien in northern France, the central group consisting of Munchen and Augsburg in southern Germany and the eastern group consisting of Istanbul, Izmit, Tekirdag and Bursa in western Turkey

TABLE 6. Triple economic gravity system of Europe. Linear transport costs.
Summary measure of demand: GDP 2014.

Main triple gravity system	Triple gravity system		
[Lille, Munchen, Istanbul]	Western centers	Central centers	Eastern centers
	Lille, Amien	Munchen, Augsburg	Izmit, Istanbul Tekirdag, Bursa

The introduction of strong economies or diseconomies of scale has no impact on the triple economic gravity system.

3. Conclusions

3.1 The geo-economic profile of Germany during the period 1996-2006

Angelis et al (2009) analyzed the geo-economic dynamics of Germany during the period 1996-2006 and made the following conclusions.

Notes.
1. A region R is characterized by a ranking efficiency N with respect to a number of criteria (statistical indices) if it ranks between 1 and N with respect to all criteria.
2. The higher the Regional Discrimination Cost (RDC) of a region is, the less efficient this region is in geo-economic terms.

The regional profile of Germany
On the basis of 3 criteria (population, GDP and industrial GVA growth during the period 1996-20060) expressing regional efficiency sustainability characteristics, the regions of Oberbayern and Schwaben, in the southern part of Germany, are characterized by high efficiency (ranking efficiency at level 6) and the regions of Mecklenburg-Vorpommern and Leipzig, in the eastern part of the country, by low efficiency (ranking efficiency at level 10). Note that

The geo-economic gravity centers of Germany
During the period 1996-2006, all three geo-economic gravity centers of Germany (social, economic and industrial) were located in the northern part of the state of Hessen. During the period 1996-2006 the geoeconomic gravity centers of the country exhibited a small relocation towards a south direction not exceeding 20 km.

Regional discrimination cost (RDC) of Germany
The social, economic and industrial RDCs of Germany exhibited strong spatial variations: from the minimum value 1 corresponding to the area of the gravity centers (in the central part of Germany: triangle Kassel-Giessen-Darmstadt) to a maximum value ranging between 1.74 and 1.94 (corresponding to the regional capital Frankfurt (O)). For all types of RDCs (social, economic and industrial) the northeastern part of Germany (Brandenburg-Nordost, Schleswig-Holstein and Mecklenburg-Vorpommern regions) exhibited consistently the highest values among all regions of the country.

3.2 The geo-economic profile of Germany during the period 2006-2014 in the context of Europe

With respect to the social gravity centers of Europe of the period 2000-2014 Germany is the single dominant geo-economic power of it with the federal states of Bavaria and Baden-Wurttemberg accommodating all gravity centers.

With respect to the economic gravity centers during the above period the dominant geo-economic powers of Europe are France and Germany with the federal state of Saarland accommodating one of the two gravity centers of Europe.

With respect to the dual social gravity system, during the same period, the dominant powers of Europe are France and Turkey with Germany accommodating three out of seven gravity centers of Western Europe, located in the federal states of Baden-Wurttemberg, Saarland and Rheinland-Palatinate.

With respect to the dual economic gravity system during 2000-2014 the dominant powers of Europe are again France and Germany with Bavaria (Munchen) accommodating the leading gravity center in central Europe.

With respect to the triple social gravity system during 2000-2014 Germany, France and Turkey are the leading geo-economic powers of Europe with Germany (Bavaria and Saxony) accommodating five out of the nine gravity centers of central Europe.

Finally, with respect to the triple economic gravity system, during the above period, Germany, France and Turkey are again the leading geo-economic powers of Europe with the federal state of Bavaria in Germany accommodating the central gravity center of the triple.

Conclusively, the federal states of Bavaria and Baden-Wurrtemberg in southern Germany accommodated the majority of the gravity centers of Europe under examination. It is not coincidental that these two federal states exhibited a very attractive socio-economic profile both within Germany and in the context of Europe. In particular, Bavaria and Baden-Wurttemberg exhibited the two highest increases of population and GDP during the period 1996-2014.

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