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ESTIMATING THE TERRITORIAL AUTOCORRELATION OF AIR PASSENGERS FLOWS IN EUROPE USING A MULTIVARIATE GRAVITY MODEL

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Abstract: Using a gravity model that includes the cost distances and the airports' mass at origin and destination, we have obtained a matrix of residuals for 21325 air links in Europe. These residuals served as the basis for calculating the coefficients of territorial autocorrelation in a multiple regional context. The coefficients we obtained were classified using an hierarchical clustering, at country level. This final typology shows that the national frontiers are more and more permeable to air traffic, having a limitated impact on the intensity of air links between the airports. Some spatial discontinuities are still at work in the European air space and they still have an influence on the amount of traffic, negatively (West-East opposition) or positively (the Scandinavian countries vs. the mainland). Mapping the residuals of the air flows gravity model indicate that these spatial discontinuities can occur also at regional scales of analysis, but they are fuelled by other logics: economic performance, tourism or workforce migration.

Keywords: territorial autocorrelation, gravity models, territorial belonging frame, air flows, ETIS PLUS database, OLS regression.

I. INTRODUCTION

The main intention of this paper is to propose a typology of the European countries based on the territorial autocorrelation of the air flows between 385 airports retained in our analysis. This effect of national territorial belonging was measured using the residuals of several gravity models applied to the spatial interactions between the European air nodes functioning in 2010. The models were implemented for all the air links with more than 500 flights (departures) by year, at origin and destination. In order to model these air connections we have used a database provided by ETIS PLUS, containing a matrix of 1.4 million air links world-wide. Using such a massive quantity of information is a methodological challenge, both for data management and models implementation. In the canonical gravity models proposed in the recent literature, the air flows are considered a variable depending on the distance between the airports and the economic potential at origin and destination (Dobruszkes et al., 2011; Grosche et al., 2007). That's the reason why we have also included in our data collection process indicators extracted from the ESPON Database II Project, more precisely the GDP for all the European functional urban areas (FUA). The gravity models were solved using a multiple regression technique (OLS) and standardized residuals were obtained for all the airport pairs in our database (Beguin, 1979). These residuals were declined using a territorial belonging frame that includes the national context of flights (domestic vs. European departures), the major EU geographical macro-regions and the political context (recently integrated states vs. the EU core). Weighting the residuals with this triple appurtenance frame eventually allowed us to elaborate coefficients of territorial autocorrelation that were interpreted using a hierarchical clustering tool (Decroly and Grasland, 1997). The typology we obtained, divided the EU space in four categories that suggest rather unorthodox conclusions regarding the functioning of the air flows European system. It seems that these links are less and less influenced by political or geographical discontinuities, becoming more and more dependent on the regional economic potential. As the gravity models and the final typology indicate, in some European geographical macro-regions almost autonomous flight systems emerge, such is the case for the Scandinavian countries (Halpern and Bråthen, 2011). This aspect might be of major interest for policy designers and decision makers, especially when one will have in mind the role played by the air traffic orientation in the regional and national competitiveness policies.

II. LITERATURE REVIEW

There is an extensive literature relating to the adoption of gravity models in order to analyse bilateral activities, such as passenger flows, cargo flows, tourism flows, trade, investment and other activities (Chang, 2012, 2014; Marrocu and Paci, 2012; Hazledine, 2009; Khadaroo and Seetanah, 2008; Groscheet al., 2007; Wei and Hansen, 2006; Doganis, 2004). Most of these studies used gravity models, including both parametric linear regression and non-parametric regression models to identify the determinants for bilateral air passenger flows. The results generally confirm the key role played by some variables, such as GDP, travel time, distance, travel cost, national per capita income, unemployment rate, buying power index, catchment area, population, with GDP being the most determinant (Chang, 2014; Redondi et al., 2013; Dobruszkes et al., 2011; Sellner and Nagl, 2010; Grosche et al., 2007; Spiekermann and Wegener, 2006.). Reviewing the recent literature, researchers take into considerations the GDP at the scale of municipalities, of NUTS 2 or NUTS 3 geographical aggregations, FUA's GDP, although more efficient, being omitted due to data unavailability at the FUA scale (Redondi et al., 2013; Maertens, 2012). Dobruszkes et al. (2011), in their paper linked to an analysis of the determinants of air traffic volume for Europe, worked on the basis of functional urban areas, all airports located within a single FUA being aggregated to a single value, the size of the FUAs being measured in terms of population and GDP.

In general, these determinants which influence air passenger traffic can be classified into geo-economic and service-related factors (Grosche et al., 2007; Jorge-Calderón, 1997; Rengaraju and Thamizh Arasan, 1992). In dealing with this issue, travel time and distance are frequent variables used to determine accessibility and air connectivity, while most of the researchers overlook airfare in their analyses because appropriate data is generally unavailable. Redondi et al. (2013) in their paper related to the role played by small airports examine the impact of the exclusion of small and very small airports on the travel costs, emphasizing the benefits of maintaining those. Literature on new economic geography investigated the relationship between accessibility and economic growth, in most cases improvements in accessibility leading to economic growth, because the reduction in transport costs allows a location to capitalize on production cost advantages (Krugman and Venables, 1995; Krugman, 1991). In relation to this topic, Papatheodorou and Arvantis examine the advantages and disadvantages in attracting low-cost carriers in Greece, in an attempt to improve the accessibility of Greek islands, the demand for air travel increasing with decreasing fares. Studies based on surveys of passengers showed that most of them would not have traveled at all if no low-cost airline flights had been available (Tacke and Schleusener, 2003). Other writers also emphasized the importance of low-cost airline companies, challenging the traditional view of airports (Maertens, 2012; Dobruszkes, 2006; Pantazis and Liefner, 2006; Reynolds- Feighan, 2001). Travel cost is often highly correlated with the distance and travel time, as well as it may be assumed an exogenous factor (Rengaraju and Thamizh Arasan, 1992; O'Connor, 1982).

The broader topic of the concentration of air service in Europe is widely debated in the literature, the general image of the European air traffic revealing a selective network. World territorial structures and those of the European Union have often been compressed into two conventional models: the core-periphery model and the hierarchical model of urban network (Grasland et al., 2007). The localisation of the main European airports allows highlighting a double duality of the European space: core-periphery and West-East (Cattan, 1995, 2004; Pumain, 1999). Thus, cities located in the core of Europe are by defintion favoured and are characterized by ”oversuplly” because of connecting passengers, while more peripheral cities are disadvantaged, unless they serve as hubs due to their location, the traditional airlines often setting up hub-and-spokes networks (Dobruszkes et al., 2011; Burghouwt and de WIT, 2005; Cattan, 2004).

III. DATA AND CARTOGRAPHIC SUPPORT

The data we use for the model is provided by two sources: the ETIS[1] PLUS project's database and the ESPON[2] Database. The first provider published tabled data on the European air flows for 2005 and 2010, the information being collected from official sources such as IATA, Eurostat, the airports Internet pages and from the air companies. These statistics are organized on datasets that describe the average trip cost between any pair of European airports, the time distances and the annual number of departures for all the origins and the destinations. The air_network_table_2005_2010.xlsx file provided by ETIS is a matrix of flows that also includes the distances between the airports (kilometers, time and cost). The description of these airports is contained in the eplus_apts_with_ind_2010.xls file that was needed in order to extract the data we use as one of the mass variable in the gravity model (the total number of European destinations for each airport). As the GDP is often used as an independent determinant in the gravity models dealing with the air flows, we have made an option for the FUA (functional urban areas) database provided by ESPON (Chang, 2014; Dobruszkes et al., 2011). This dataset is more appropriate to use with the matrix of origins and destinations because the spatial unit of reference is the functional urban area, and not the NUTS3 or NUTS2 territorial frame. We assume that linking the airports to these functional urban areas is a good method to capture the determinant role played by the metropolitan economic performance in the air flows structure (DSA et al., 2013).

The basic file that we have collected and exploited for our research contains more than 1400000 lines that characterize all the possible links between an European airport and a world destination. This huge quantity of information was filtered in several steps. In a first approach we eliminated the cargo air links and conserved only the passengers' connections. Focusing only on the airports in Europe, we have also eliminated the inter-continental links. The dataset was severely reduced to only 10 % of its initial size, more precisely 144576 links out of 190969 possible, if we take into account the 385 airports we finally maintained in

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[1] ETIS is the acronym for European Transport policy Information System, a portal that allows download and visualisation of data useful for policy makers, in the field of transportation. The information can be extracted from the official page of the project : http://www.etisplus.eu/default.aspx.

[2] ESPON (European Spatial Planning Observation Network) is European Programme that supports the policy makers and decision takers with relevant studies, targeted analysis and applied research. Also, an innovative database is under construction, providing indicators on "exotic geographical objects" - LAU2, LAU1, FUA, grid data etc.

the analysis. In this moment, we have added a spatial filter based on the distance between a FUA and the nearest airport. A double join field operation was implemented, in order to attach the FUA's GDP at origin and destination airports. The final step was to reduce more the flows dataset, selecting only the links that present more than 500 departures per year.

The final table contains 21352 links between the airports and 38 statistical variables (quantitative data and territorial nomenclatures). This flows matrix is not symmetrical in respect to the number of annual departures, as this aspect is generally a matter of decision for airlines and airports management. Taking into account the strong dependence of the metropolitan hubs for the small airports, especially in countries with an unbalanced urban system like France or Romania, we have maintained all the possible links in the model, including those that require two transfers for reaching a destination (Redondi et al., 2013). Table 1 is a synthesis of the variables that we use to estimate the air flows and to calibrate the gravity model.

Table 1. Selected list of variables extracted from the ETIS PLUS database (Source of data: http://www.etisplus.eu/default.aspx)

Variable	**Unit of measure**	**Observation**	**Year of reference**
Length	Km	Great circle distance	constant
Orig	Nomenclature	IATA code	2010
Orig_Name	Nomenclature	Name of the airport (origin)	2010
Dest	Nomenclature	IATA code	2010
Dest_Name	Nomenclature	Name of the airport (destination)	2010
CostB	Euro	Annual average cost for business trip. Estimated value.	2010
CostP	Euro	Annual average cost for private trip. Estimated value.	2010
CostH	Euro	Annual average cost for holiday trip. Estimated value.	2010
LinkTime	Minutes	Time of flight in minutes	2010
TransferTi	Minutes	Time needed for transfer in other airports.	2010
TotalTrave	Minutes	Total time of travel between the origin and the destination airports, if transfer is needed.	2010
Annual_Dep	Flights/year	Number of flights per year.	2010
Daily_Depa	Flights/day	Number of flights per day.	2010
EuropeanDe	Number	Number of European destinations at origin airport.	2010

European_1	Number	Number of European destinations at destination airport.	2010
id_FUA	Nomenclature	Unique string identifier of the nearest FUA for an origin airport.	2006
GDP_ORIG	Mil. Euro	Estimated GDP for the origin FUA	2008
GDP_DEST	Mil. Euro	Estimated GDP for the destination FUA.	2008
FUA_DEST	Nomenclature	Unique string identifier of the nearest FUA for a destination airport.	2006

The reliability of the data is a general problem when analyzing the air passenger flows system. As the financial crisis altered the economic performance of the European metropolitan areas, using the GDP of 2008 for a model that describes the air links for 2010, could interfere with the model's soundness. More recent data related to the FUA GDP are not yet available, being under construction in the ESPON Database 2013 Phase II (2011-2014) Multi Dimensional Database Design and Development (M4D) Project. As the time distance is generally stable during a year of operation, the cost distance is very variable. According to the ETIS PLUS D6 Database Manual, the travel costs were estimated using a tariff function that includes distance, observed prices, cost per km and the presence of low cost companies operating on the airport.

Mapping the results of the model and the cartographic exploration of the data needed a map template that contains the next geometries: the European countries (EuroStat GISCO), the functional urban areas (ESPON DB) and the airports' position (ETIS PLUS DB). This basemap served also to the process of outlier detection (Fig.1), showing more some intriguos spatial patterns than suspect values.

As the outliers technique of detection suggests, the average cost for business trips corresponds to a core-peripheral model, correlated with the accessibility or the remoteness of the airport (Redondi et al., 2013; Dobruszkes et al., 2011). The organization of the outliers is regulated by spatial auto-correlation (Moran's Index: 0.15 and Z score of 15.15, a significantly clustered distribution). Excepting this logic of spatial organization of costs, we suspect that the national borders, combined with some classic West-East territorial discontinuities, will have an impact on the costs we analyzed. If this hypothesis is true, the orientation of the European air flows and their volume is subject to territorial auto-correlation. Our methodological frame will explain how we intended to detect and estimate this effect.

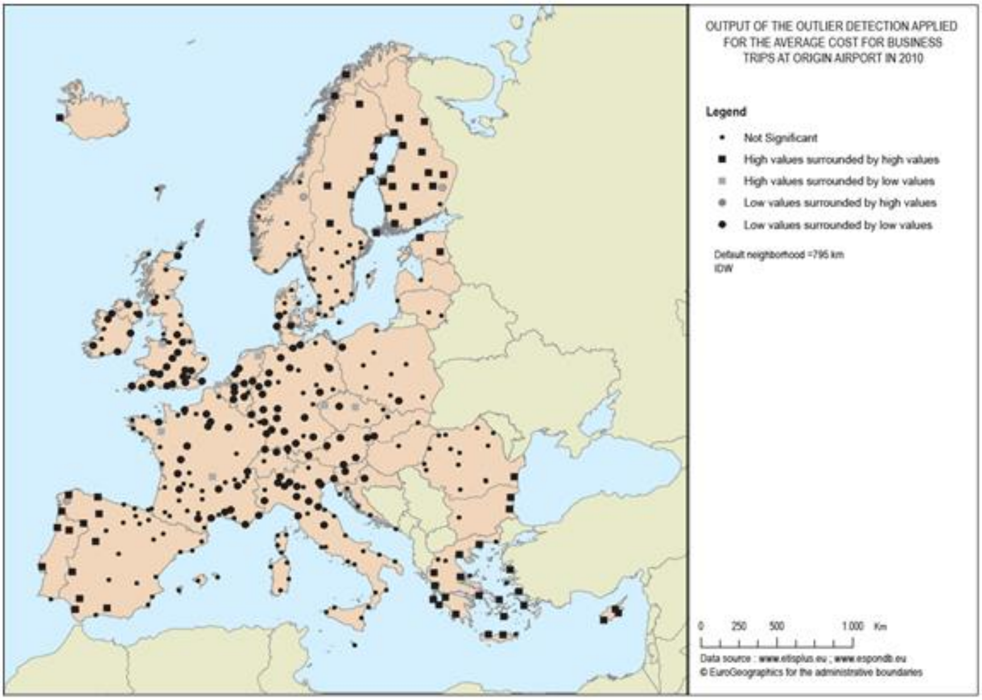


Fig.1 Spatial patterns in the outlier distribution of the average cost for business trips (origin airport)

IV. METHODOLOGY

As geographers, since Tobbler enounced its famous rule concerning the relation between distance and attribute's dissimilarity, we are all resigned that the data we analyze risk to present, at some moment, a pattern of spatial autocorrelation. When dealing with common spatial distributions (points, surfaces), this effect is simple to measure (Moran's I, Geary Index) because one can easily implement a distance matrix and use it to weight spatial dissimilarities (Decroly and Grasland, 1997). For the spatial interactions (flows), this effect might still be present, but we don't benefit from a clear, uncontested and easy to implement methodology of detection. However, the spatial data is not only organized by distances, it is also patterned by borders (territorial belonging) or by hierarchies (Dobruszkes et al., 2011, Cattan, 1995). If we are generally cautious with the spatial autocorrelation in geographical studies, we place the territorial context on a secondary priority. As the European air flows database indicates, modeling the impact of the spatial discontinuities on the flows presents interest for a better understanding of the airports interactions.

The methodology we propose to estimate this effect is based on two concepts, the concept of territorial belonging and the concept of flows' dissimilarity. Each pair of origin-destination airports was analyzed in a triple territorial context: domestic vs. inter-national links, Core vs. EU member states flights and in a regional context (Baltic region, Eastern Europe, South and Core countries). For each context, we have calculated coefficients of territorial autocorrelation that proves in what measure the official frontiers and the European macro-regions determine the orientation and the volume of air flows. Implementing the methodology of calculus demanded the next steps:

1) Definition of the similarity/dissimilarity variable (Decroly and Grasland, 1997). For each pair of origin-destination airports we have calculated the relative residuals of the air flows. These residuals were deduced by using an OLS regression that included 3 explanatory variables: the cost of a business trip between each pair of airports, the GDP at origin FUA and the GDP at destination FUA. The dependent variable is the annual departures - the number of annual flights registered between a pair of airports. The residuals were transformed using a simple ratio between the observed annual departures and the estimated annual departures. Values larger than 1 indicate the positive residuals and superior spatial interaction, while values smaller than 1 suggest interactions under the economic potential.

2) The relative residuals obtained by OLS regression were weighted using three matrices of territorial belonging: national, recent EU members or Core countries and geographical region. The coefficient of territorial autocorrelation is a ratio between the central values (mean) of the relative residuals, aggregated by different contexts (Beguin, 1979):

$$CTA = 1 - \frac{\sum RRintra/n}{\sum RRinter/n}$$ **(Eq.1)**, where

CTA = the coefficient of territorial autocorrelation;
RRintra = relative residuals for links belonging to the same national, political or geographical region context;
RRinter = relative residuals for links connecting different national, political or geographical regions.
n = number of links

A negative value of the CTA will indicate that, all things being equal, air flows operated within the same country, political or geographical region are less intense than the flows between any two different macro-regions. The positive values indicate that the flows are more intense in the interior of the domestic, political or geographical context.

For the geographical context, we have divided the studied space in 4 regions:

The Baltic and Scandinavian area: Denmark, Estonia, Finland, Latvia, Lithuania, Norway and Sweden.

The Eastern Europe: Bulgaria, Czech Republic, Hungary, Poland, Romania and Slovakia.

The South Area: Cyprus, Greece, Italy, Portugal, Slovenia and Spain.

The Core Area: the rest of the states in the study area.

Other regional configurations are possible and each of them will present a different coefficient of territorial autocorrelation. The challenge is to find the optimal configuration that maximizes the similarity/dissimilarity means for all the possible geographical contexts. The four macro-regions we proposed are justified by the spatial distribution of the outliers for the cost of the business trips and by the organization of the flows residuals on the map.

3) As the coefficient of territorial autocorrelation can be disaggregated at country level, for each territorial context, a typology of the European states will be proposed. This typology uses a hierarchical cluster technique to group the countries by the intensity of the borders and the spatial discontinuities' effects on their air flows system (Sanders et al., 2001).

V. ANALYSIS

Following the steps proposed in the methodology of our study, the analysis of the air flows between airports in 2010 is based on an OLS regression. The flows in our database are represented by the variable annual departures and the independent variables such as the FUA's GDP at origin, the FUA's GDP at destination, the cost of the business trip between any two European airports, the number of European destinations served at origin and by the partner airport. All the variables were transformed in logarithm values and evaluated by a classical OLS regression (Table 2).

Table 2. Results of the gravity model (OLS regression - no.1)

Regression Statistics	**Values**
Multiple R	0.359
R Square	0.129
Adjusted R Square	**0.129**
Standard Error	0.184
Observations	21352

	Coefficients	Standard Error	t Stat	P-value
Intercept	2.933	0.018	155.673	0.000
LOG_COSTB	**-0.104**	0.004	-23.438	5.622
LOG_GDPO	**0.021**	0.002	8.225	2.050
LOG_GDPD	**0.023**	0.002	9.203	3.774
LOG_EDO	**0.046**	0.002	16.917	8.724
LOG_EDD	**0.034**	0.002	12.444	1.977

where:
Y = the annual departures from airport i to airport j
X1 (LOG_COSTB) = cost of business trips in 2010 (Euro), between i and j
X2 (LOG_GDPO) = FUA's GDP at origin in 2008 (Mill. Euro)
X3 (LOG_GDPD) = FUA's GDP at destination in 2008 (Mill. Euro)
X4 (LOG_EDO) = number of European destinations served by the airport i
X5 (LOG_EDD) = number of European destinations served by the airport j
i, j= airports of origin and destination

As expected, the distance still plays a negative role in the configuration of the European air flows, the business cost's coefficient suggesting a limited but observable decay. The GDP (at origin and destination FUA) has a limited impact on the annual departures. The adjusted R2 is reduced and makes this first attempt to estimate the flows unreliable. In this case, a new combination of the variables was proposed for a secondary gravity model (Table 3).

Table 3. Results of the adjusted gravity model (OLS regression - no.2)

Regression Statistics	Values
Multiple R	0.702
R Square	0.494
Adjusted R Square	**0.494**
Standard Error	0.299
Observations	21352

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.250	0.030	8.227	2.019
LOG_COSTB	**0.116**	0.007	16.317	1.689
LOG_GDPO	**-0.293**	0.003	-93.211	0.000
LOG_GDPD	**-0.299**	0.003	-96.886	0.000

where:
Y = the intensity of flows between airport i and airport j, defined as follows

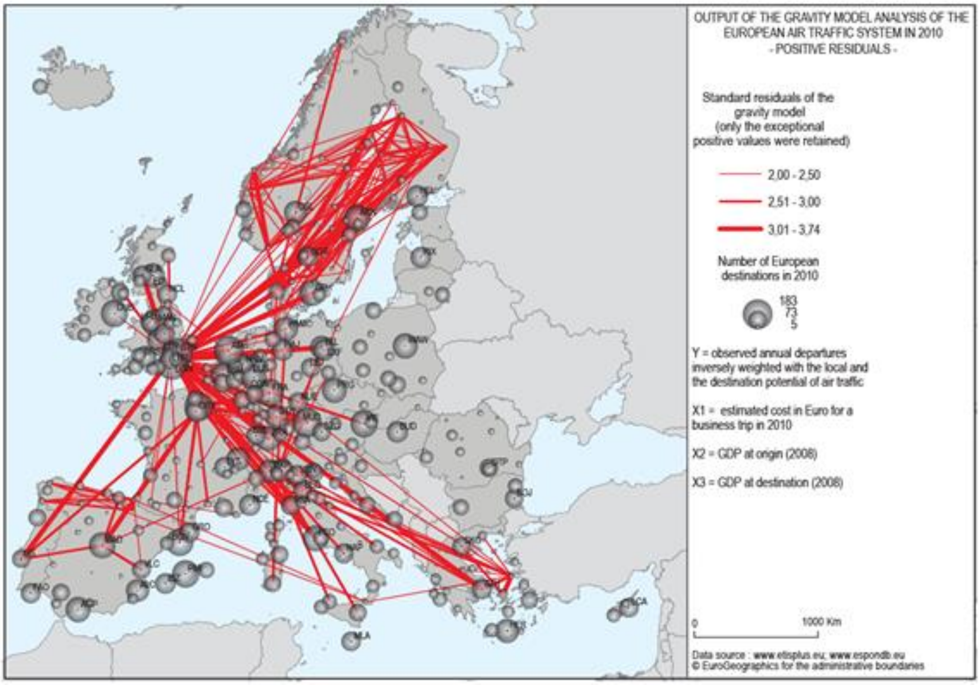
$$\log Y = \frac{Annual\ departures}{((365 * DOD * EDO) + (365 * DOD * EDD))} \quad \textbf{(Eq.2)}$$

DOD = daily departures between i and j
EDO = European destinations at airport i (origin)
EDD = European destinations at airport j (destination)
X1 (LOG_COSTB) = cost of business trips in 2010 (Euro), between i and j
X2 (LOG_GDPO) = FUA's GDP at origin in 2008 (Mill. Euro)
X3 (LOG_GDPD) = FUA's GDP at destination in 2008 (Mill. Euro)

This adjusted gravity model benefits from a fair R2 and can be used to estimate the residuals of the airflows in 2010. The distance decay of the business cost is still limited when it is compared to the GDP coefficients; however it indicates that a spatial pattern affects the number of links between the European airports. The estimated values for logY were calculated and the residuals were standardized (z score). Mapping all the 21352 links would be an impossible task and a selection of the most relevant residuals was implemented. All the residuals superior to +/- 2 standard deviations are candidates for mapping.

The positive residuals (Fig.2) present a specific spatial concentration. Completely absent in the recently integrated EU countries, the over-intensity of flows is organized by two major European hubs - Paris and London (Dobruszkes et al., 2011; Cattan, 1995, 2004; Sassen, 2001). An interesting pattern of positive residuals creates a more polycentric air network in the Scandinavian Area, with consistent residuals but not exceptional ones. This Scandinavian spatial pattern that suggests the existence of the territorial autocorrelation of flows is very well connected to the London region and isolated, in terms of high positive residuals, from the rest of the European major air gates (Halpern and Bråthen, 2011).

The negative residuals (Fig.3) are distributed according to three geographical contexts. In the southern European countries, the islands are the major providers of exceptionally high and under potential air flows. They provide negative residuals at several scales of analysis: national (e.g. Crete vs. Greece mainland), international limited range (e.g. Cyprus vs. Greece) and continental (Baleares Islands vs. Scandinavian countries). For the Eastern countries we assist to a lack of intensity of interaction between the capital cities and the secondary national air gates (e.g. Bucharest vs. Timisoara), combined with continental long range links under potential (Grasland et al., 2007). For the Scandinavian Area we observe an unexpected situation. The connection between the major airports from the North to the Netherlands' air hubs is dominated by negative residuals, difficult to understand if one will take into account the potential of spatial interaction induced by the GDP at origin and destination.



OUTPUT OF THE GRAVITY MODEL ANALYSIS OF THE EUROPEAN AIR TRAFFIC SYSTEM IN 2010 - POSITIVE RESIDUALS -

Data source : www.etisplus.eu; www.espondb.eu
© EuroGeographics for the administrative boundaries

Fig.2 Spatial patterns of high positive residuals of air flows in 2010

In the hypothesis that the cost of air transportation will increase steadily and taking into account the effects of the economic crisis on the economic growth, expecting another configuration of the spatial interactions between the European airports is rather improbable. In many regards, the distribution of the negative and positive residuals emphasizes the image of the European continent still shaped by core vs. peripheral areas logics of economic performance and by a network of air links responding to the GDP stimulus (Dobruszkes et al., 2011; Cattan, 1995, 2004). The gravity model and the analysis of the residuals suggest that these air links are also influenced by territorial frames. As some of the residuals we obtained are highly exceptional for the analysis of the territorial autocorrelation, we have excluded them from the analysis and re-implemented the OLS regression analysis and the gravity model. After eliminating 273 links (all the standardized residuals larger than +/- 3 standard deviations), the results of the OLS regression were not significantly modified. The new R2 is 0.509 instead of 0.494 and the coefficients are stable and reliable (Table 4) .

Table 4. Results of the adjusted gravity model no.2 (OLS regression - no.3)

Regression Statistics	Values
Multiple R	0.713
R Square	0.509
Adjusted R Square	**0.509**
Standard Error	0.295
Observations	21079

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.353	0.030	11.626	3.758
LOG_COSTB	0.106	0.007	15.108	2.633
LOG_GDPO	-0.301	0.003	-95.976	0.000
LOG_GDPD	-0.309	0.003	-100.071	0.000

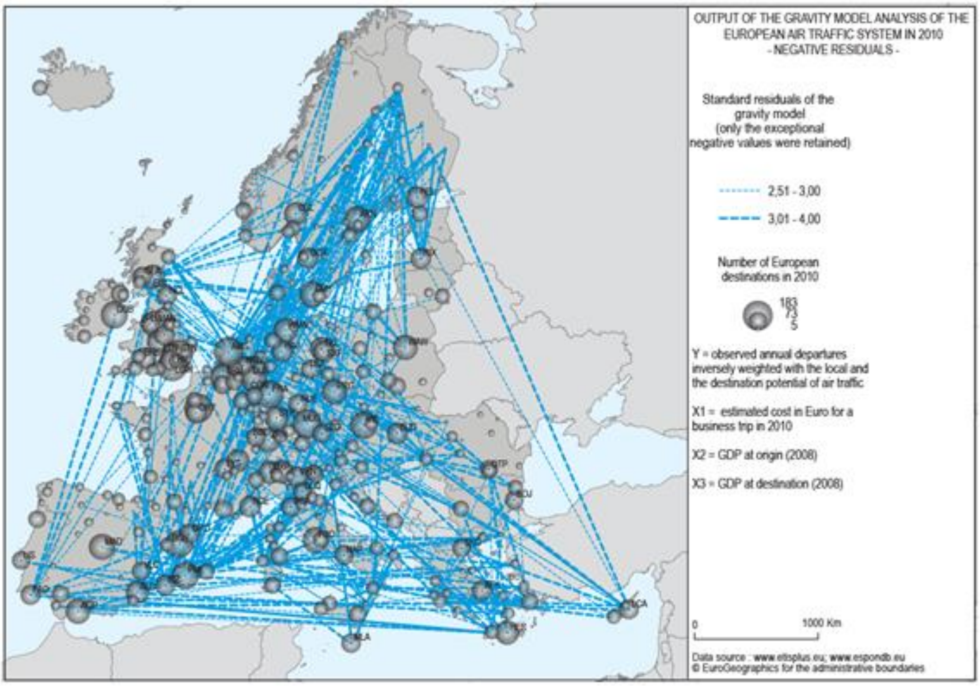


Fig.3 Spatial patterns of high negative residuals of air flows in 2010

The new matrix of origin-destination relative residuals was multiply filtered by territorial contexts - domestic, EU historical opposition West-East and geographical region. For each context, a national standardized mean of the relative residuals was obtained. If the values of the territorial autocorrelation indicators are inferior to 1, it suggests that the air flows are strongly influenced by a spatial discontinuity. At the opposite, a value larger than 1 indicates that the air links ignore the territorial barriers (political or geographical), being explained by other factors - economic potential, local attractiveness, tourism etc.

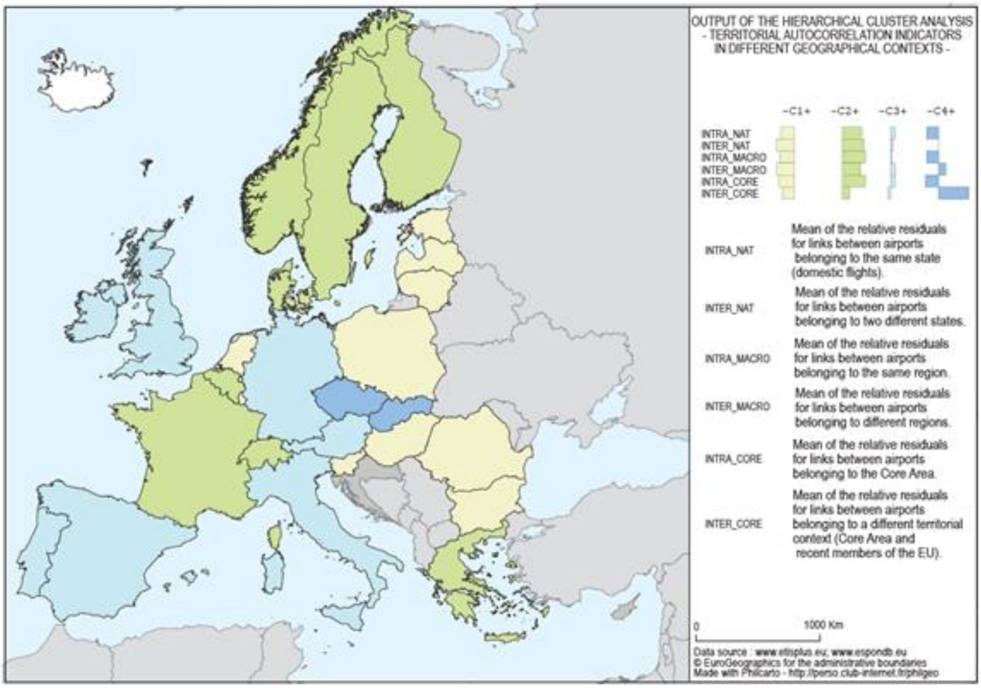


Fig.4 Typology of states based on indicators of territorial autocorrelation for different geographical contexts

These coefficients were analyzed using a hierarchical clustering technique that provided a final typology of the European states (Fig.4). The first type should be labeled the introverted one. As the values of the CTA show (Table 5), the air flows with origin or destination in these states are still strongly influenced by the territorial context (especially national and political). The second type of states is the opposite - extroverted, the case of France, the Scandinavian countries, Belgium, Switzerland, even Greece. The CTA are largely superior to 1 and suggest a strong disconnection between the air flows system and the territorial belonging frame. The third class includes states closed to the average European profile with low deviations to the mean for the flights within the European core or at national level. The final class is composed by only two countries - the Czech Republic and Slovakia. Taking into account their size and the hierarchy of their urban systems, it looks normal to have low national CTA. They compensate by larger deviations to the mean for the air connections with the European Core and in their geographical regions (Eastern Europe). The cartographic pattern that results from this typology is more closed to a dispersed logic of spatial distribution than to a clustered one, the clustering occurring only in a contiguity neighborhood of the states. If the European air flight system is disconnected from the classical regional oppositions (West-East, economic performance vs. catching-up states or North vs. South), this aspect should be integrated in the definition of the transportation policies at continental scale.

Table 5. Coefficients of territorial autocorrelation calculated for the European countries

Country ID	**INTRA_NAT**	**INTER_NAT**	**INTRA_MACRO**	**INTER_MACRO**	**INTRA_CORE**	**INTER_CORE**
BE	0.000	1.790	2.310	1.252	1.880	0.728
BG	0.000	0.648	0.475	0.671	0.470	0.676
CY	0.000	0.958	0.746	1.056	0.525	0.995
EE	0.000	0.604	0.610	0.586	0.446	0.619
HU	0.000	0.817	0.621	0.842	0.624	0.847
LU	0.000	0.950	1.059	0.827	0.987	0.639
LV	0.000	0.520	0.493	0.571	0.458	0.528
MT	0.000	0.500	0.524	0.463	0.277	0.521
SI	0.000	0.485	0.516	0.479	0.365	0.514
SK	0.000	1.244	0.754	1.292	0.783	1.299
NL	0.539	0.802	0.997	0.565	0.820	0.521
LT	0.573	0.753	0.729	0.779	0.542	0.797
PL	0.625	0.780	0.633	0.794	0.608	0.805
RO	**0.628**	**0.670**	**0.551**	**0.690**	**0.562**	**0.691**
CZ	0.773	0.968	0.684	1.003	0.654	1.020
AVERAGE	0.839	1.058	1.119	0.995	1.010	0.785
PT	0.898	1.072	1.192	0.982	1.074	0.708
AT	0.942	1.023	1.051	0.997	1.079	0.759
DE	0.984	1.113	1.057	1.127	1.137	0.717
IT	1.036	1.152	1.124	1.129	1.161	0.784
IE	1.135	1.036	1.057	1.019	1.063	0.671
UK	1.174	1.197	1.249	1.137	1.214	0.893
ES	1.284	1.227	1.256	1.226	1.250	0.823

EL	1.343	1.337	1.278	1.452	1.367	1.094
CH	1.717	1.438	1.280	1.577	1.504	0.984
NO	1.917	1.491	2.058	1.085	1.581	0.923
DK	**1.930**	**1.547**	**2.065**	**1.284**	**1.634**	**0.807**
SE	1.957	1.486	2.058	1.152	1.675	0.659
FR	1.979	1.536	1.707	1.608	1.700	1.000
FI	2.901	1.534	2.328	1.202	1.849	0.738

In the case of Romania, despite the fact that all the coefficients are low (less than 1), one will observe a stronger orientation of the flights towards the external territorial contexts, suggesting the beginning of limited process of internationalization of the air flights system. Excluding the non-European links of the major Romanian air gateway (Bucharest Otopeni International Airport) from the database might also explain why the CTA are so reduced. The case of Denmark is also remarkable. Strong coefficients at national scale coupled with high values in its geographical macro-region (Scandinavian states) describe an air flows system that emphasizes the domestic and proximity territorial contexts, with reduced links towards the European Core.

VI. DISCUSSIONS AND CONCLUSIONS

The discussions and conclusions, we proposed in this part, focus on two topics: the methodological limits and challenges of the model we propose and the results of the typology. From a methodological point of view, we should firstly insist on the limitations induced by the gravity models approach on the air flows. Using a basic intensity of flows indicator, the coefficient of statistical determination is not suitable for explanation purposes, despite the fact that might be representative for the amount of data we mobilized. Even with more reliable coefficients (R2 of 0.509), a large amount of information is still not explained by the model we propose. As a matter of fact, the quantity of residuals derived by the OLS multiple regression is directly linked to the quality of adjustment and an average-quality equation inflates these residuals. A secondary observation should be made in relation with the conceptualization of distances in the model. As the kilometric distance or the time distance make sense for flows described at local or regional scale (e.g. commuters' flows), at European level an option was made for cost distances that are less reliable than the previous two variables, for data collection reasons. Final remark, using a proxy for the GDP (FUA) might seem spatially inconsistent with the gravity model. However, taking into account the fact that the catchment areas of the airports largely overlay the European FUA, this option is the optimal compromise. The results derived from the residuals of the gravity models (CTA) should be interpreted prudently. There is a chance that these indicators are also dependent on the regionalization techniques applied for the territorial contexts (e.g. choosing more geographical macro-regions would have an impact on the calculation process). That's the reason why we consider that the final map and the final typology indicate rather trends than actual situations of the national air flows systems.

The stakes when analyzing the European air flows are multiple. From a policy oriented perspective, observing the evolution of the territorial discontinuities and how they affect this system of spatial interactions is a matter of major concern, especially when placing the discussion in the context of the territorial competitiveness. Better articulating the geographical macro-regions between them and the peripheral areas with the core should theoretically have an impact on the national and regional economic performance. At local decisional scale, studying the distribution of the air flights residuals would eventually suggest the preferential links and it allows better policies of air connectivity. From a scientific perspective, using tools like the gravity models and filtering the residuals with multiple frames of territorial belonging might be the way to elaborate more sophisticated territorial impact assessment instruments to measure the output or the increasing returns of the political and administrative decisions.

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