ESPON

EUROPEAN UNION

Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence

FINAL REPORT //

Pan-european systemic analysis

IRiE - Interregional Relations in Europe

Annex 23 // May 2022

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Disclaimer

This document is a interim report.

The information contained herein is subject to change and does not commit the ESPON EGTC and the countries participating in the ESPON 2020 Cooperation Programme.

The final version of the report will be published as soon as approved.

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Abbreviations

CEPII	Centre d'Études Prospectives et d'Informations Internationales
ESPON	European Observation Network for Territorial Development and Cohesion
EU	European Union
EUROSTAT	European Statistical Office
FDI	Foreing Direct Investment
GDP	Gross domestic product
H2020	Horizon 2020
IRiE	Interregional Relations in Europe
JRC	Joint Research Center
NUTS	Nomenclature of Territorial Units for Statistics
OD	Origin-Destination
OLS	Ordinary least squares
PPML	Pseudo Poisson Maximum Likelihood
R&D	Research and Development
R2R	Region to region
UK	United Kingdom

Abstract

We use several indicators to analyse the trend of flows and a region's position in the space of flows as well as to describe regional interdependencies in the ESPON countries. We analyse four indicators — weighted intensity, balance, concentration, and distance — but also consider other dimensions, which include flow-unrelated typologies, the urban/rural dimension (based on total FUA populations) and geography (macroregions in the EU and EU enlargements). We also use two-dimensional typologies and structural typologies, including dominant flow and clustering. The results are as follows:

- Interregional flows are growing across Europe, in line with the cohesion policies in effect. The intensity of interregional flows increased in 2010-2018 at a stable annual pace, while the average cumulative increase in nine flows for 2010-2018 was 22.5%.
- We identify a network of metropolises that concentrate the strongest flows, mainly in western and northern Europe, mostly close to the European core. These metropolises anchor the flows in Europe. The countries of the new Europe (enlargements since 2004) in principle do not create flows on a larger scale. We find strong similarities in the space of flows between regions at similar levels of economic development. It is difficult to draw similar conclusions for functional urban areas except in the case of knowledge flows, for which it is of great importance. The greater the population of a region's functional urban area, the more it participates in the exchange of knowledge.
- The weighted intensity indicator is the index that provides the most possibilities. We used it in many ways (dominant flow, clustering, etc.). Six groups of regions emerged in our cluster analysis:
    - Cluster 1 includes mainly capital city regions in the core of Europe and the countries that joined the European Union in 2004 as well as other regions that represent "islands" of greater flows and at the same time serve as gateways between peripheral areas and the core.
    - Cluster 2 includes most of the peripheral regions of southern and central-eastern Europe. Interestingly, this group also includes French and Italian as well as several Finnish regions. These regions are less involved in the space of flows and can be described as peripheral.
    - Cluster 3 represents the core of the European space of flows. It includes Austria, Switzerland, most of Germany, the Benelux countries, southern Scandinavia, and most of the Irish regions. They are active in the space of flows, with intense socioeconomic flows (trade, freight, migration, tourism) that are usually accompanied by high values of flows in the form of commuting and knowledge (especially patents).
    - Cluster 4 includes port-city regions in northwestern Europe and northern Scandinavia that specialise primarily in trade flows. The position of these regions in terms of service flows is also relatively high. Although not a port, Liechtenstein is in this group.
    - Cluster 5 is Luxembourg, which appears as an outlier, with high capital flows in FDI and very high participation in H2020, commuting and services.
    - Cluster 6 is dominated by regions with strong air-passenger and tourism flows, including island regions.
- In many countries, the most intense flows are between capital cities and regions in their immediate vicinity. This is the result of several elements, such as transport hubs, commuting distance, and suburbanization. Regions with seaports, financial centers, and such are also large centers for economic flows. By contrast, the lowest flows are in peripheral regions of the ESPON space, affected by their distance from the European core. Regions in countries that joined the European Union after 2004 (in particular Poland, Slovakia, Hungary, Romania, Bulgaria, and Croatia) show a lower value of flows.
- The more partners a region interacts with, the more resilient that region tends to be. In general, metropolises, including state capitals, have a much greater dispersion in terms of involvement in particular flows, while low-population, peripheral areas are more exposed to a high concentration on one flow.
- To explore interlinkages between flows, we conducted an econometric analysis, including the other flows as explanatory factors. The results are meaningful and provide new grounds for a discussion of relationships between flows.
    - Trade of goods has a positive influence on migration, FDI, and knowledge.
    - Services shows have a positive influence on trade of goods, migration and knowledge estimations.
    - Migration relates positively with knowledge flows and negatively with FDI.
    - FDI shows a positive influence on migration and knowledge.
    - Erasmus shows a positive relation with trade of goods.
    - H2020 and patents show a positive relation with services and FDI.

Keywords

intensity, balance, concentration, average distance, border effect, clustering, econometrics, dominant flow, dynamics

Highlights

Data

- To **standardize** our R2R matrices we have used the so-called 'standardized flow unit'.
- Calculation of the sum matrix for each flow: addition of 9 yearly matrices from 2010-2018 pre-COVID period for each indicator.
- **Indicators** (intensity, weighted intensity, balance, concentration, UK (Brexit) dependency, average distance, border effect, structural concentration, dynamics, time dependency) were calculated for **11 matrices** (goods trade, goods freight, services, capital FDI, air passengers, migration, labour mobility, tourism, patents, H2020 (2015-2018), and Erasmus (2010-2014)).
- 11 flows were divided into **three baskets**: (1) goods/services/capital, (2) people, (3) knowledge.

Methodology

- We have therefore analysed the objects on four **dimensions**: (1) **size** (intensity, weighted intensity); (2) **balance** (balance); (3) **concentration** (concentration, UK (Brexit) dependency); (4) **distance impact** (average distance, border effect).
- **Flow-unrelated aggregations of regions** are used in our cohesion/competitiveness analysis for each of the four dimensions for three baskets and synthetic matrix.
- Three **two-dimensional typologies** are based on two indicators describing particular flows or their aggregations in combination of size dimension with each of the other three dimensions.
- We have limited our two **structural typologies** to selected dimensions and applied them to synthesize results in relation within the set of 11 flows. The first is **dominant flow**. The second is **clustering**, which we use to detect distinctive co-occurrence combinations within a flow's intensity or balance.

New territorial evidence

- The role of internal flows (especially in large countries) is still very important. It affects international relations, as competition between foreign and domestic flows is sometimes evident (e.g. tourism, and also in migration in peripheral countries).
- Some of our results (including for the cluster analysis) can be treated as measures of the success of European integration. This is especially true for economic flows (primarily trade). Even non-metropolitan regions there participate in Castells' "space of flows".
- The distribution of flows of people and of knowledge differentiates the European space much more than economic flows (especially trade) do. This may mean that social integration is slower than economic integration.
- In the European space there are 'islands' of clearly higher intensity of flows of various types. They include regions with national capitals, financial centers (especially Luxembourg), seaports, and areas highly attractive for settlement and tourism.
- Metropolises in peripheral countries (southern and central-eastern Europe) play a special role. The structure of their connections is special compared with that of other regions, as confirmed by cluster analysis. They serve as "gateway cities" connecting their countries with the European space of flows.
- The pattern of migration flows combined with their dynamics suggest a gradual rebalancing of the system of people flows. The increase in migration intensity that took place after the EU's enlargement has slowed down. The metropolises of Central and Eastern Europe have become alternatives for mass foreign migration.

1 Introduction

1.1 Background

The purpose of the “Interregional relations in Europe” project is to provide a pan-European understanding of the interdependencies of Europe’s economies (in a broad sense) at the regional level. The study of relations between regions provides a new point of view on territorial diversity in Europe: that of the space of flows in Castells (2004). In this context, it is possible to look at the territorial structure of Europe from the viewpoint of two sets of data: a) a set of regions characterised by their network of external relations, b) a complete set of matrix relations between all regions of the studied area.

We use inputs (OD matrixes) from Tasks 1.2-1.5 to prepare characteristic flows and typologies for regions, considering different features. In both cases, the typologies are drawn from 2010-2018 pre-COVID regional datasets.

1.2 Research needs and objectives

Our most general aim is to answer the following research questions:

1. What are the **characteristics** of each of the flows? How to compare them?
2. For which relations are particular high flows observed? Which relations constitute the **super league of flows**?
3. **Size.** Is the region generally flow dependent? If so, does the dependency apply to one flow or is it more diverse?
4. Are the flows in the region **balanced**, **concentrated**, or **dispersed**, **spatially dependent/independent**?
5. **Balance**. Is region a sender or a receiver? What is the region’s distribution of balance for all flows? For which flows is the region among the senders, for which among the receivers?
6. **Concentration**. Is the region strongly focused on any of the flows? Which flow is dominant? This question applies in particular to regions for which the weighted intensity has turned out to be particularly high. We find the answer also to the question: Is there a spatial concentration of flows related to a given region? To what extent is the region dependent on relations with the UK (Brexit)?
7. **Distance impact**. What is the average flow length from the region? Is a region distance dependent?
8. **Border effect**. For which of the flows is the region more internationally concentrated, and for which is the domestic part more important?
9. How do the flows **co-exist** within the whole set?
10. **Cohesion and competitiveness**. We analyze four indicators — weighted intensity, balance, concentration, and distance — in the context of cohesion and competitiveness but also with respect to other dimensions, such as the urban/rural dimension (based on total FUA) and geography (macroregions in the EU and EU enlargements). We try to determine how the abovementioned dimensions affect the results for individual indicators (weighted intensity, balance, concentration, and distance), e.g. whether less-developed or rural regions have smaller links than richer or urban regions, whether they receivers or senders, whether flows more concentrated in these regions, whether they are over shorter or longer distances, etc.

2 Methodology

2.1 Objects and approaches

The key role in our approach plays territorial diversity in Europe from the point of view of the Castells space of flows (Castells, 2004). In this context, it is possible to look at the territorial structure of Europe from two sets of data:

- a **set of relations** rendered as R2R flow matrices between all regions,
- a **set of regions** characterised by their network of external relations.

Therefore the **research procedure** will rely on the gradual narrowing down the level of the **objects** which are:

(1) **flows' aggregation**, which is derived from more than one O/D matrix, constructed for the purposes of given analysis (dynamic approach or aggregation of flows – baskets etc.);

(2) **flow** – individual OD matrix;

(3) **region** – row and/or column of matrix;

(4) **relation** – pair of cells between the same regions;

(5) **cell** – individual cell of the matrix – the most elementary object – volume of given flow from i-region to j-region, noted as $flow_{i,j}$.

Three **approaches** are taken into account while analysing the sum matrices/flows/regions/relations/cells:

(1) **spatial** approach (cartographic analysis, groupings of regions etc.);

(2) **structural** approach (crossreferencing within the set of selected flows, clustering, analysis of a dominant flow etc.);

(3) **dynamic** approach (time dependency, dynamics).

While spatial and dynamic approach are used as an independent perspective for analysis regarding particular flows and regarding all flows for baskets and as total (synthetic indicator), the structural approach is applicable only taking into account all or set of selected flows simultaneously as a measure of checking the relations between entire flows.

2.2 Dimensions and indicators

At the first stage a quantitative indicators (W_i) of various aspects and features of given flows' aggregation, individual flow, region or relation has been applied in each of three approaches. The list of applied indicators is ordered according to four different aspects (dimensons), which they are devoted to. These distinguished aspects to be measured are to some extent parallel in all approaches, although fully represented only in the first of listed approaches.

Dimensions are four different aspects of knowledge on given objects:

(1) **size** – how large is flow;

(2) **balance** – what is the relation between inflow and outflow;

(3) **concentration** – how much share of total flow is cumulated in some part of the analysed set;

(4) **distance** – what is the remoteness impact on the flow.

Indicators in spatial approach.

In spatial approach full list of four dimensions has been covered by measurement. Therefore, four primary indicators has been proposed. They are accordingly**: weighted intensity index**, **balance index**, **concentration index** and **average distance index**. Nevertheless, to answer to some more specific research questions, additional three indicators has been constructed and applied in this aproach: **intensity index** (only for relations – object 4), **UK (Brexit) dependency index** and **border effect index** (see tab. 2.1).

Table 2.1: : Indicators used in spatial approach

Dimension	Indicator	Equation	Objects of referrence	Standardization
Size	Intensity index	$W_{i,j} = flow_{i,j} + flow_{j,i}$ Superleague: the relations of the highest intenisty, which are cumulating 25% of the total volume of sum matrix	Relation	100 equals average volume of relation within set of sum matrix relations
	Weighted intensity index	$W_i = \sum_{j=1}^{296} \frac{flow_{i,j} + flow_{j,i}}{population_i}$	Region	100 equals average index value within set of NUTS 2
Balance	Balance index	$W_i = \frac{\sum_{j=1}^{296}(flow_{j,i} - flow_{i,j})}{max(\sum_{j=1}^{296} flow_{i,j}\,;\sum_{j=1}^{296} flow_{j,i})}$	Region	value range from -1 to 1, where zero means perfectly balanced flow, -1 means outflow only, 1 means inflow only
Concentration	Concentration index	$W_i = \frac{\sum_{j=1}^{296}(\boldsymbol{flow}_{i,j} + \boldsymbol{flow}_{j,i}) \times \sum_{j=1}^{296} \boldsymbol{population}_j - \sum_{j=1}^{296}\left((2 \times (297 - j) - 1) \times (\boldsymbol{flow}_{i,j} + \boldsymbol{flow}_{j,i}) \times \boldsymbol{population}_j\right)}{\sum_{j=1}^{296}(\boldsymbol{flow}_{i,j} + \boldsymbol{flow}_{j,i}) \times \sum_{j=1}^{296} \boldsymbol{population}_j}$ where: $\forall j \in N: \left(j \in \{2,3,\dots,296\} \rightarrow \left(\frac{flow_{i,j}+flow_{j,i}}{population_j} \geq \frac{flow_{i,(j-1)}+flow_{(j-1),i}}{population_{(j-1)}}\right)\right)$	Region	0 means that distribution of the given region's flow(s) intensity across all other regions is ideally proportional to their population number, 1 means that it is ideally concentrated and total flow(s) intensity of the region i is covered by its relation with only unpopulated region(s) (theoretical value, not possible to achieve for the empirical set of NUTS, which are all populated to some extent)
	UK (Brexit) dependency index	$W_i = \frac{\sum_{UK=1}^{41}(flow_{UK,i} + flow_{i,UK})}{\sum_{j=1}^{296}(flow_{j,i} + flow_{i,j})}$	Region	Share of UK expressed from 0 (no flow in relations with UK regions) to 100% (no flow in relations with non-UK regions)
Distance	Average distance index	$W_i = \frac{\sum_{j=1}^{296} dist_{i,j} \times (flow_{i,j} + flow_{j,i})}{\sum_{j=1}^{296} flow_{i,j} + flow_{j,i}}$	Region	Distance expressed in kilometers of orthodromic distance between population weighted centroids of NUTS 2
	Border effect index	$W_i = \frac{\sum_{j=1}^{296}(flow_{i,j} + flow_{j,i})}{\sum_{k=1}^{n_c}(flow_{i,k} + flow_{k,i}) \times \frac{\sum_{i=1}^{297}\sum_{j=1}^{296}(flow_{i,j} + flow_{j,i})}{\sum_{i=1}^{297}\sum_{k=1}^{n_c}(flow_{i,k} + flow_{k,i})}} \times 100$	Region	100 means equal share of i-region in total flow volume of domestic relations within entire matrix

		where: k – index of international relation; n_c – number of all i-region's international relations: $n_c = (297 - number\ of\ NUTS\ in\ the\ country\ of\ i)$.		and in total flow volume of all relations. The index value grows exceeding 100 with the relative advantage of i-region's share within the subset of domestic relations over its share within subset of international ones (and decreases below 100 with the relative disadvantage).

Indicators in structural approach.

In structural approach a full set of primary indicators has been used at the level of flow objects (histograms), for which the percentage of the regions within given range of indicator's value has been taken into account. Only two of that primary indicators were taken into account to synthesize the relations across set of flows in each individual region by means of typologies (see 2.6). At this level of objects they have been supplemented also by two additional indicators (**coefficient of variantion** and **structural concentration index**) for deeper insight into disparities across flows.

Table 2.2: : Indicators used in structural approach

Dimension	Indicator	Equation	Objects of reference	Standardization
Size	Weighted intensity index	$W_i = \sum_{j=1}^{296} \frac{flow_{i,j} + flow_{j,i}}{population_i}$	Flow/region	1 means 1 flow unit per 1 inhabitant of region
Balance	Balance index	$W_i = \frac{\sum_{j=1}^{296}(flow_{j,i} - flow_{i,j})}{max(\sum_{j=1}^{296} flow_{i,j}\,;\sum_{j=1}^{296} flow_{j,i})}$	Flow/region	value range from -1 to 1, where zero means perfectly balanced flow, -1 means outflow only, 1 means inflow only
Concentration	Concentration index	$W_i = \frac{\sum_{j=1}^{296}(\boldsymbol{flow_{ij}} + \boldsymbol{flow_{ji}}) \times \sum_{j=1}^{296} \boldsymbol{population_j} - \sum_{j=1}^{296}\left((2 \times (297 - j) - 1) \times (\boldsymbol{flow_{ij}} + \boldsymbol{flow_{ji}}) \times \boldsymbol{population_j}\right)}{\sum_{j=1}^{296}(\boldsymbol{flow_{ij}} + \boldsymbol{flow_{ji}}) \times \sum_{j=1}^{296} \boldsymbol{population_j}}$ where: $\forall j \in N: \left(j \in \{2,3,\dots,296\} \rightarrow \left(\frac{flow_{i,j}+flow_{j,i}}{population_j} \geq \frac{flow_{i,(j-1)}+flow_{(j-1),i}}{population_{(j-1)}}\right)\right)$	Flow	0 means that distribution of the given region's flow(s) intensity across all other regions is ideally proportional to their population number, 1 means that it is ideally concentrated and total flow(s) intensity of the region i is covered by its relation with only unpopulated region(s) (theoretical value, not possible to achieve for the empirical set of NUTS, which are all populated to some extent)

	Coefficient of variation	$W_i = \frac{\sqrt{\frac{\sum_{f=1}^{11}\left(\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)\right)^2}{11} - \left(\frac{\sum_{f=1}^{11}\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)}{11}\right)^2}}{\frac{\sum_{f=1}^{11}\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)}{11}}$	Region	1 means that standard deviation of weighted intensity index for particular flows is equal to its average value and 0 means that weighted intensity index has equal value for all 11 flows. The coefficient of variation has higher value if wiegthed intensity for 11 flows is more diverse in relation to average.
	Structural concentration index	$W_i = \frac{\sum_{f=1}^{11}\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)\times\mathbf{11}\right) - \sum_{f=1}^{11}\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\left(\mathbf{2}\times(\mathbf{12}-f)-\mathbf{1}\right)\times\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)\right)}{\sum_{f=1}^{11}\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)\times\mathbf{11}\right)}$ where: $\forall f\in\boldsymbol{N}:\left(f\in\{\mathbf{2},\mathbf{3},\ldots,\mathbf{11}\}\rightarrow\left(\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\boldsymbol{flow}_{f,i,j}+\boldsymbol{flow}_{f,j,i}\right)\geq\sum_{i=1}^{297}\sum_{j=1}^{296}\left(\boldsymbol{flow}_{(f-1),i,j}+\boldsymbol{flow}_{(f-1),j,i}\right)\right)\right)$	Region	0 means that total volume (intensity) of each individual flow of the region, has equal number of standard units. The index can reach its maximum value of 10/11~0,909, when only one of 11 flows is empirically present in the region.
Distance	Average distance index	$W_i = \frac{\sum_{j=1}^{296} dist_{i,j}\times\left(flow_{i,j}+flow_{j,i}\right)}{\sum_{j=1}^{296} flow_{i,j}+flow_{j,i}}$	Flow	Distance expressed in kilometers of orthodromic distance between population weighted centroids of NUTS 2.

Indicators in dynamic approach.

In dynamic approach only size dimension analyzes has been conducted, by means of primary intensity index and additonal **average yearly dynamics index** and **time dependency index**, applied particular for flow objects.

Table 2.3: : Indicators used in dynamic approach

Dimension	Indicator	Equation	Objects of referrence	Standardization
Size	Intensity index	$W_f = \sum_{i=1}^{297}\sum_{j=1}^{296}\left(flow_{f,i,j}+flow_{f,j,i}\right)$	Flow	Value expressed in natural units
	Average yearly dynamics index	$W_f = \left(m_f - 1\right)\times 100\%$ where: $\sum_{i=1}^{297}\sum_{j=1}^{296}\left(flow_{f,i,j,year}+flow_{f,j,i,year}\right) = reg_f(year) = b_f\times {m_f}^{year}+\varepsilon_{f,year}$ and $year\in\{2010,2011,\ldots,2018\}$	Flow	Value means y/y change of flow's total volume in the period 2010-2018 (or shorter if H2020 or Erasmus, see 2.3), according to the model of geometric temporal progression, expressed in percentage

	Time dependency index	$W_f = \frac{\sum_{year=1}^{n_f}\left(reg_f(year) - \sum_{year=1}^{n_f}\frac{\left(\sum_{i=1}^{297}\sum_{j=1}^{296}(flow_{f,i,j,year} + flow_{f,j,i,year})\right)}{n_f}\right)^2}{\sum_{year=1}^{n_f}\left(\sum_{i=1}^{297}\sum_{j=1}^{296}(flow_{f,i,j,year} + flow_{f,j,i,year}) - \sum_{year=1}^{n_f}\frac{\left(\sum_{i=1}^{297}\sum_{j=1}^{296}(flow_{f,i,j,year} + flow_{f,j,i,year})\right)}{n_f}\right)^2}$ where: $\sum_{i=1}^{297}\sum_{j=1}^{296}(flow_{f,i,j,year} + flow_{f,j,i,year}) = reg_f(year) = m_f \times year + b_f + \varepsilon_{f,year}$ and $year \in \{2010,2011,\dots,2018\}$	Flow	Conventional coefficient of determination estimated by OLS method. It express how large part of the flow's total volume temporal variability in the period 2010-2018 (or shorter if H2020 or Erasmus, see 2.3) can be stochastically explained by time variable. Its value's range extends from 0 (lack of co-ocurrence) to 1 (all temporal changes of flow's total volume are linearily proportional to time variable).

2.3 Flows and their aggregations (baskets)

Flows and baskets. Flows (object 2 – eleven flows) and their aggregation according to three **baskets** and as one **synthetic matrix of flows (multiflow matrix).** The selection of flows was made on the basis of the following premises:

(1) representativeness of the various flows of goods, services, capital, people and knowledge;

(2) high data reliability;

(3) no linkages with other matrices (e.g. remittances were abandoned due to the fact that the matrix was created partly on the basis of assumptions about the migration matrix).

The list of matrix groups (flows) that were selected on the basis of the above assumptions is 11 matrices or matrix groups, due to the fact that each flow is represented by a number of matrices equal to the number of years for which data was collected for each flow. At the same time, the indicated 11 matrix groups were divided into three baskets depending on the flow type:

1. **Basket Goods/services/capital**
   - 1.1. Goods_trade_total (2010-2018)
   - 1.2. Goods_freight_total (2010-2018)
   - 1.3. Services_total (2010-2018)
   - 1.4. Capital_FDI (2010-2018)
2. **Basket People**
   - 2.1. People_Airpassengers (2010-2018)
   - 2.2. People_Migration (2010-2018)
   - 2.3. People_Labour_mobility (2010-2018)
   - 2.4. People_Tourism (2010-2018)
3. **Basket Knowledge**
   - 3.1. Knowledge_H2020 (2015-2018)

3.2. Knowledge_Patents (2010-2018)

3.3. Knowledge_Erasmus (2010-2014)

4. Synthetic matrix

Most matrices are available for the entire period under study (2010-2018). However, there are exceptions, i.e. Knowledge_Erasmus (data only for 2010-2014) and Knowledge_H2020 (data only for 2015-2018). Despite the lack of a full time series, it was decided to include these matrices eventually, as part of standardization, in order to obtain a greater representation of knowledge flows.

Different flows have different units and it is difficult to judge which of them affects in what way the economy and inhabitants of ESPON space. Therefore, we assumed that all flows are equally important and their weight is the same.

2.4 Flow unrelated aggregations of regions

Flow unrelated aggregations of regions (object 3) are used in the cohesion/competitiveness analysis for each of the four dimensions for three baskets and synthetic matrix. The output is composed by set of **box-plots** comparing particular aggregations of the regions according to characteristics applied and analyzed within IRIE:

(1) **EU accession** grouping including: (1a) Enlargement up to 1995; (1b) Enlargement (2004-2013); (1c) Non EU

(2) **Cohesion** grouping: (2a) more developed; (2b) transition; (3) less developed

(3) **Macroregional** grouping: (3a) Baltic Sea; (3b) Danube; (3c) Alpine; (3d) Adriatic-Ionian

(4) **Total FUAs population**: (4a) very high; (4b) high; (4c) moderate; (4d) low

ESPON regional **classification** is produced based on the **urban rural classification** at NUTS 3 level. Nevertheless, in IRIE project we use NUTS2 level. Therefore total FUAs population provided by EUROSTAT has been taken into account. Some exceptions concerning the administrative hierarchy of urban centers were considered based on MEGA cities from ESPON 1.1.1. Thus, four categories of regions were created:

1. **Very high** total FUAs population which is more than 3.0 million inh. in FUAs plus these NUTS2 where 1MEGAs are located: Munich, Frankfurt, Madrid, Milan, Rome, Hamburg, Brussels, Copenhagen, Zurich, Amsterdam, Berlin, Barcelona, Stuttgart, Stockholm, Düsseldorf, Vienna and Cologne.

2. **High** total FUAs population which is between 1.5 and 3.0 million inh. in FUAs plus these NUTS2 where 2MEGAs are located: Athens, Dublin, Geneva, Gothenburg, Helsinki, Manchester, Oslo and Torino (if they are not in 1 category) plus all capitals within 3MEGAs which are not in 1 or 2 category (Prague and Bratislava)

3. **Moderate** total FUAs population which is between 0.5 and 1.5 million inh. in FUAs.

4. **Low** total FUAs population which is less than 0.5 million inh. in FUAs.

2.5 Standardization and calculation

2.5.1 Matrix preparation

Equate the matrices to the **same size** of 87 912 cells, what results from the following calculation: 297 regions of origin x 297 regions of destination – 297 cells of main diagonal (intra-regional flows). The number of 297 regions corresponds to the number of regions representing the entire ESPON space at the NUTS2 level (as for 2016 division). All matrices have an equal number of rows and columns to be added to the selection set of matrices.

2.5.2 Sum matrix (matrix addition)

Calculation of the sum matrix for each flow – addition of 9 yearly matrices from 2010-2018 period for each indicator with the exception of two flows, i.e. Knowledge_H2020 and Knowledge_Erasmus for which a shorter period was selected for which data was available.

2.5.3 Standardization of sum matrices

Procedure of standardization of the matrix on the basis of the so-called 'standardized **flow unit**' by equating the average value of cell to 100, what implies 8 791 200 as total volume of each sum matrix.

Standardized matrices were also created separately for three baskets, as well as for a sythetic matrix based on the sum of all matrices included in the individual baskets (three or four matrices for baskets and eleven matrices for the synthetic indicator). Thus, a total of 15 standardized matrices were obtained at the end of the analysis.

2.5.4 Calculation of indicators for standardized matrices

Calculation of indices according to the formula for each index, including **standardization of indicators** leading to express each value in standard units, equating the average value of an indicator for a region/relation in a full set (297 regions or 43 956 of two direct relations) to 100. Relations are presented only as intensity indicator (SuperLeague of the highest intensity, which are cummulating 25% of total volume of sum matrix). Region units - for other indicators.

2.6 Typologies of regions

In order to synthesize detailed results on the space of flows in major aspects, the method of territorial typology (eg. Mazur and Czapiewski 2016) has been applied finally. Despite this one general aim of the method, it has been used in various contexts and perspectives of its application are threefold. While the first perspective is the use of external, flow unrelated, typology as synthethic spatial input for this research (see fig. 2.1), the other two perspectives are to use this method to synthesize the research output. This research output has been synthesized in two different aspects: by combining dimensions applied for flows' and their aggregates' description in spatial approach (two-dimensional typologies), and by mutual relations among different flows and their aggregates applied in structural aproach (see fig. 2.2 and 2.3).

Figure 2.1: The role of flow unrelated typologies. A typology as a spatially synthetic input.

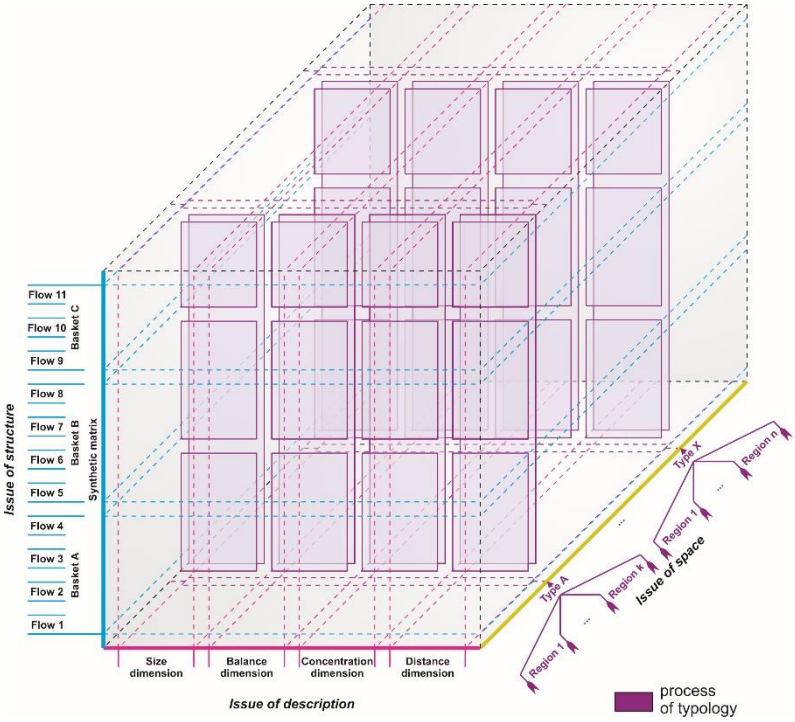


Figure 2.2: The role of two-dimensional typologies. A typology as a descriptively synthetic output.

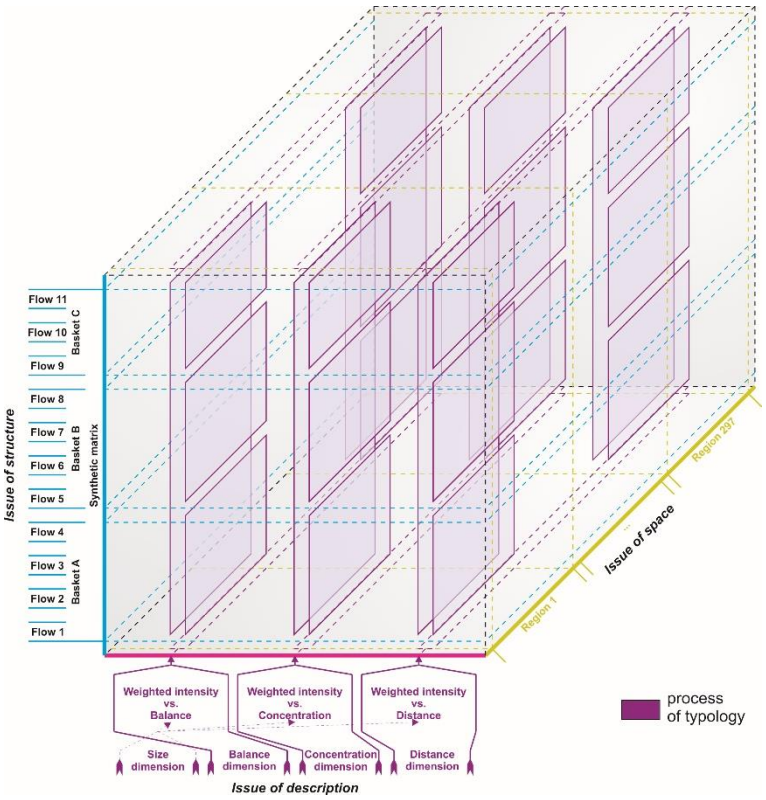
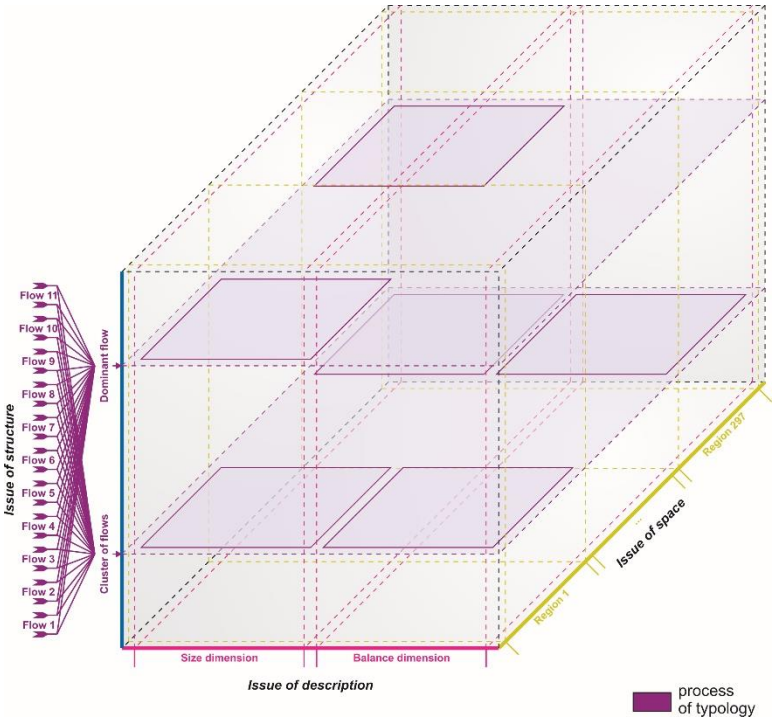


Figure 2.3: The role of structural typologies. A typology as a structurally synthetic output



2.6.1 Flow unrelated typologies

The flow unrelated typologies has been applied to deliver a synthetic input of NUTS aggregations according to four general, intentionally selected features (EU belonging, cohesion, European macroregions and urbanization) and to compare them according to characteristics of particular flows' aggregations (see definitions in 2.3) in each of four dimensions applied for description in spatial approach (see 2.2).

2.6.2 Two-dimensional typologies

Three two-dimensional typologies are based on two indicators describing particular flows or their aggregations (see definitions in 2.3) in combination of size with each of other three dimensions applied for description in spatial approach (see 2.2)**:**

- **Size and Balance** (weighted intensity index and balance index);
- **Size and Concentration** (weighted intensity index and concentration index);
- **Size and Distance** (weighted intensity index and average distance index).

In the framework of two-dimensional typologies full set of regions has been classified in four dimensions. Each region had assigned one of three classes of index value in each dimension. A tresholds between classes are defined as such, which are determining equally numerous classes in case of statistical distribution according to bell curve, thus $\overline{W_i} \pm 0{,}431\sigma$. The reason for such rule was to take into account diversity of statistical distribution and to avoid forcing any pre-defined empirical representation of classes. At the same time, value of particular indeces has been reduced from original quantitative level of measurement, towards hierarchical one. At this level particular classes have been named individually, what allowed for more intuitive interpretation of its essential nature.

2.6.3 Structural typologies

Two structural typologies have been limited to selected dimensions only (see definitions in 2.2) and applied to synthesize results regarding relations within the set of 11 flows. The objective for the first, simplier one, is to assess direction of inequality across different flows' intensity. The **dominant flow** has been indicated here, with the same importance of each of them assumed.

The objective of the second, much more sophisticated one, is to detect distinctive co-occurrence combinations within either flows' intensity or balance. The set of individual regions having assigned the most adequate combination of flows' size or balance (**clustering**) is equally important result of this procedure as indicating distinctive combinations themselves (clusters).

3 Results

3.1 Size dimension

3.1.1 Intensity index (Super League)

To introduce more elaborate indices, here we use the simplest index of flow magnitude, called intensity. By considering only the cumulative top 25% of flows (let's call it the Super League), we can tell a lot about the spatial concentration and length of flows (to be discussed in more detail with concentration and distance indices).

The Super League in the **goods/services/capital basket** is highly diversified between flows. For example, Capital FDI is a very concentrated flow, and over a dozen relations account for 25% of all flows within ESPON space. These are mainly international flows between the most important capital centers, which include the largest cities in the European core. These flows form an FDI network metropolis within the European core. Relationships within the remaining flows are much less concentrated and are often limited to domestic flows. Goods freight flows are significant within Poland, while in states that joined EU before 2004 goods trade and services flows are mainly domestic. For goods trade, exceptional large international flows exist between the regions of Norway and the UK, Germany and the Netherlands. For services, many flows exist in relation with tourist centers (Canary Islands, Balearic Islands, Sicily).

The synthetic index of Super League flows for the goods/services/capital basket perfectly illustrates the most important relations within the ESPON space, where flows within the network of metropolises dominate in the European core (Luxembourg, London, the Benelux states, and Switzerland), followed by the domestic networks of goods/services/capital in the western and northern EU states. The new EU countries (enlargements in 2004, 2007, and 2013) and Greece definitely stand apart from the Super League (with some exceptions). Luxembourg is the hub of the strongest economic linkages in Europe. The position of relations from the southern Italian regions (Sicily) and from some units in Scandinavia is also surprisingly high. A dispersed polycentric structure of strong multidirectional internal linkages is found in Germany. The opposite is true for France and the United Kingdom, where the many strong internal economic linkages that exist are all directed towards Paris and London respectively. Elements of polycentric strong internal economic systems are also evident in Italy and Spain.

The Super League in **people basket** is even more varied between flows. For air passengers there are no major inter-regional flows in Central and Eastern Europe. There is a strong presence in the largest European hubs, led by the London airports. Air passengers is the only analyzed flow for which the cumulative top 25% of flows are primarily international over long distances, and exist primarily between southern Europe and London. In turn, tourist flows within the Super League are also realized over long distances, but these are mainly domestic connections in large countries of western and southern Europe, with France, Spain, and Italy dominating. The largest migratory flows and greatest labour mobility are mainly short-distance relations in agglomerations between a city's core and the surrounding NUTS 2 area or, in exceptional cases, intra-agglomeration migrations between the capital and major cities in France, Spain, and Italy. The flow of labour mobility in particular is much more dispersed, and in the cumulative top 25% of flows there are only single short-distance flows, mostly in metropolitan areas.

The synthetic index of the Super League of flows for the people basket clearly underscores the crucial role of links between the capitals of the largest European countries and the largest cities in these countries. This is particularly the case in France. Elements of polycentric systems appear only in Germany. An international network of metropolises is also observed between London, Madrid, and Paris, as well as between London and Munich and Frankfurt am Main. Relations inside Italy seem to be more concentrated on the internal market. Because of the great importance of tourism and numerous passenger flights, relations with tourist centers on the Canary Islands, the Balearic Islands, and Sicily are visible again. The distribution of the strongest flows of people reflects the direction of migration and tourist travel from Western Europe to Mediterranean regions and islands. In Central and Eastern Europe there are only single relations, indicating the lesser importance of this part of the continent in flows of people.

The basket where the Super League is most dispersed is **knowledge**. Few relations stand out. Patent flows are the most spatially concentrated and focused mainly on the western part of Germany. H2020 flows concern mainly countries that joined the EU before 2004, and the greatest relations are those linking Paris with

Madrid and Rome, although the network is quite dense and also includes many smaller academic centers in states that joined EU before 2004. Regions of the new Europe also take part in Erasmus linkages, although mainly through capital cities such as Warsaw and Bucharest. The strongest Erasmus relations in the ESPON space are between Spain and Italy, where student exchange is the most intense. Spain is the country with the greatest participation in the Erasmus Super League.

The synthetic index for the knowledge basket lacks large dominant relations over the rest of relations, as we see in other baskets. The network of metropolises is once again observed between the most important academic centers of western and southern Europe. The lack of domestic links within Erasmus flows results also in the dominance of international links in the synthetic indicator. The strong position of certain Scandinavian cities (Stockholm, Helsinki) is evident. In Central and Eastern Europe, relations are much weaker and all but limited to national capitals.

The **synthetic index** of the Super League for 11 flows shows the key importance of linkages between the capitals of Western European countries. In the case of Germany and the Scandynavian states, networks of internal connections are also clearly visible. In the Nordic countries they are centered on the capitals of these countries, while in Germany these links are more polycentric. There is a dense network of relations between the EU member states that joined EU before 2004, and relatively weak relations, with some exceptions, between new EU countries (2004, 2007 and 2013 enlargements) and Greece. In peripheral countries, the strongest relations are found between the largest metropolitan areas and the NUTS 2 units directly surrounding them. This is indirect evidence of the dynamic development of local flows. The synthetic index also enable us to list the nodes that concentrate the strongest flows (within the group of 11 analysed). These are: London, Paris, Luxembourg, Amsterdam, Frankfurt, Munich, Hamburg, Berlin, Madrid, Rome, Milan, and Stockholm.

Figure 3.1: Intensity dimension. Intensity Super League index for flows of goods, services, and capital

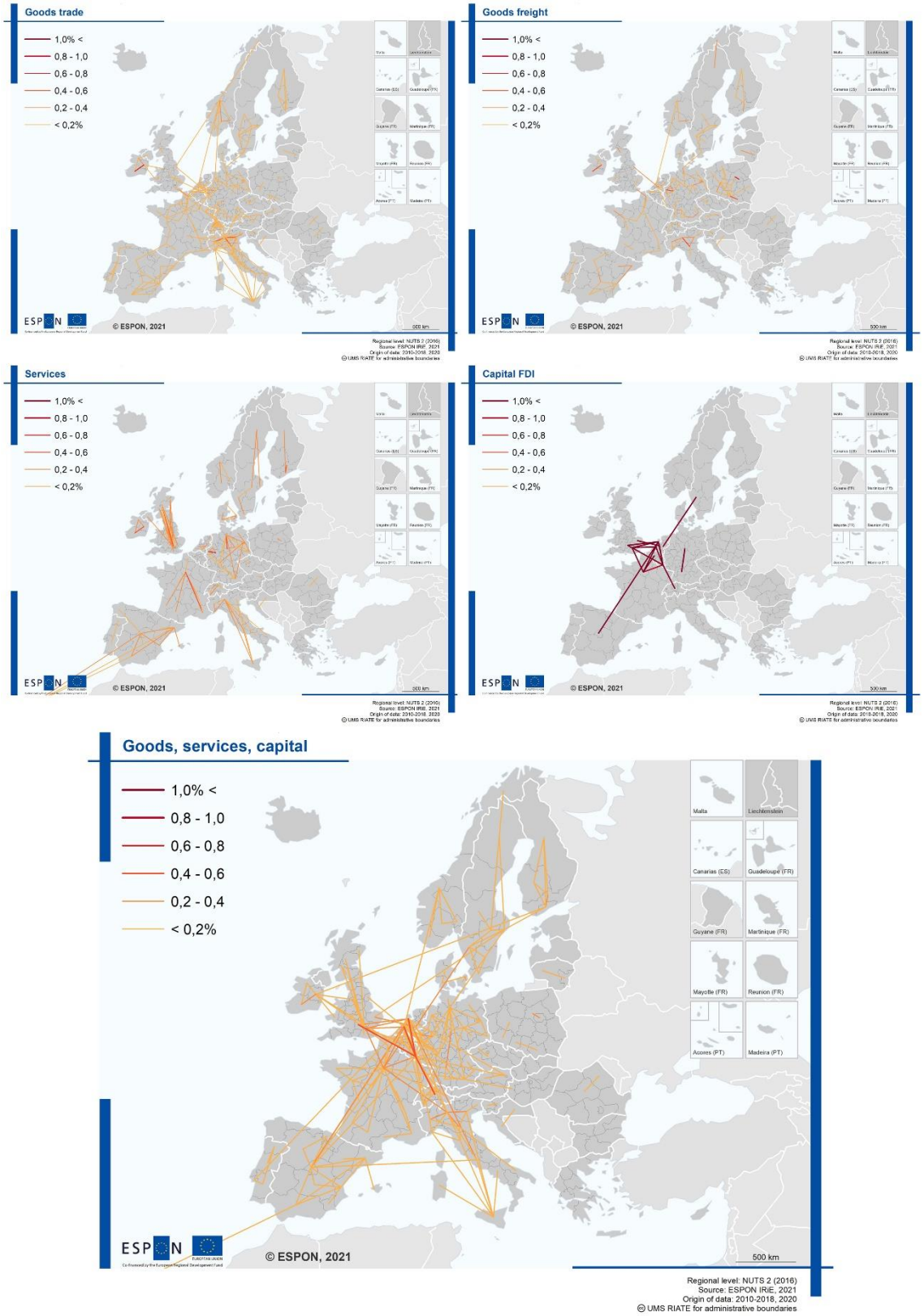


Figure 3.2: Intensity dimension. Intensity Super League index for flows of people

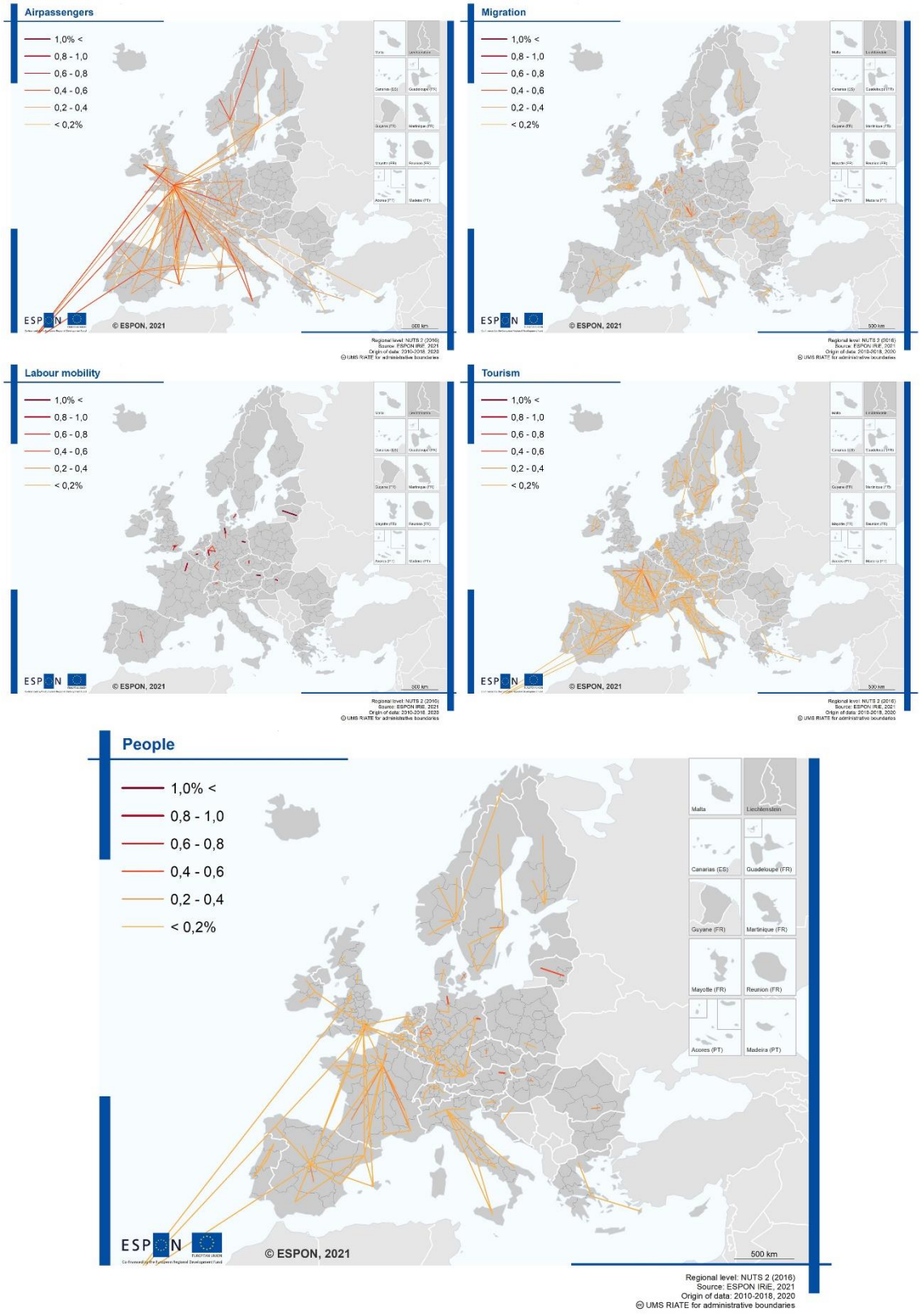


Figure 3.3: Intensity dimension. Intensity Super League index for flows of knowledge

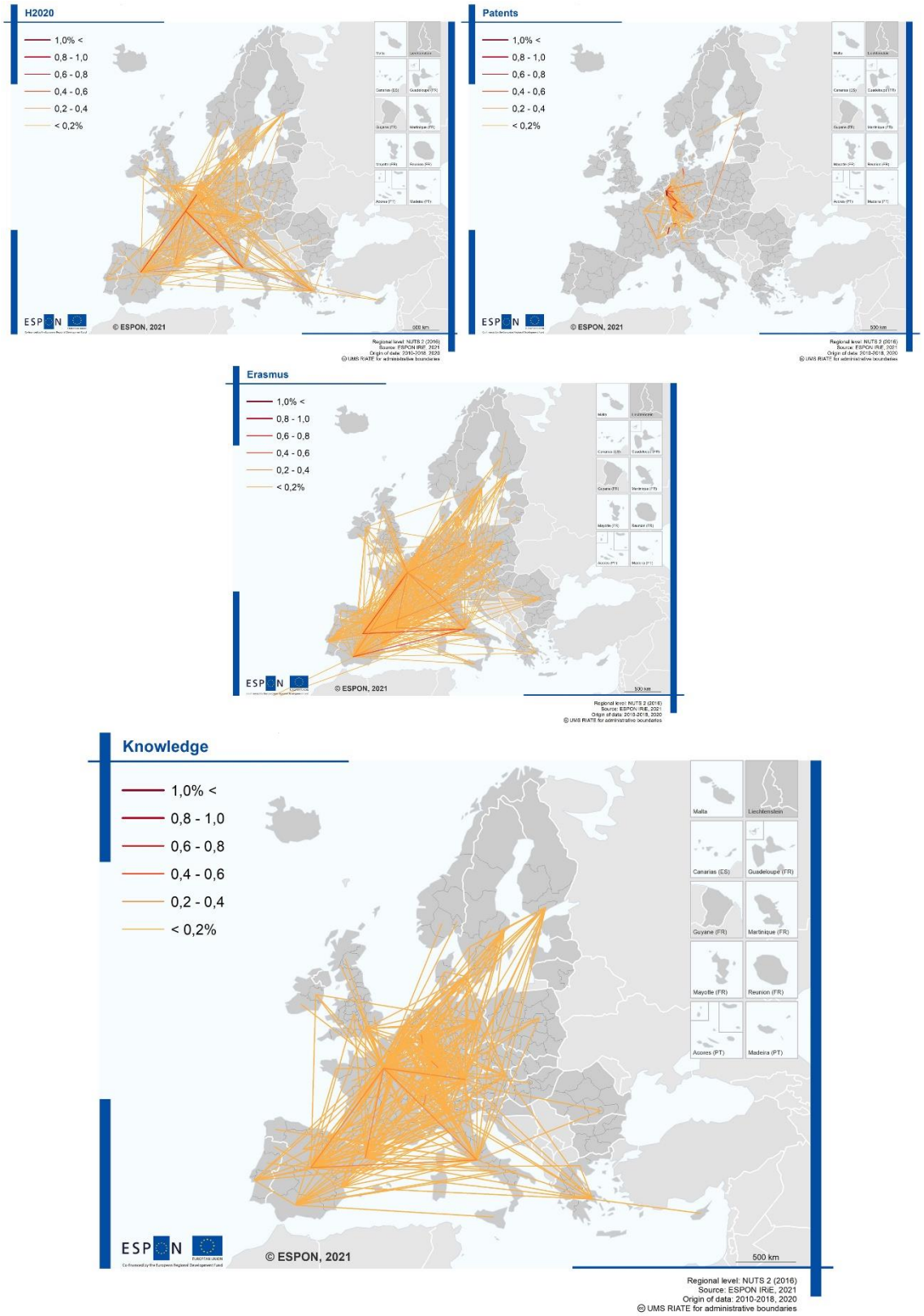
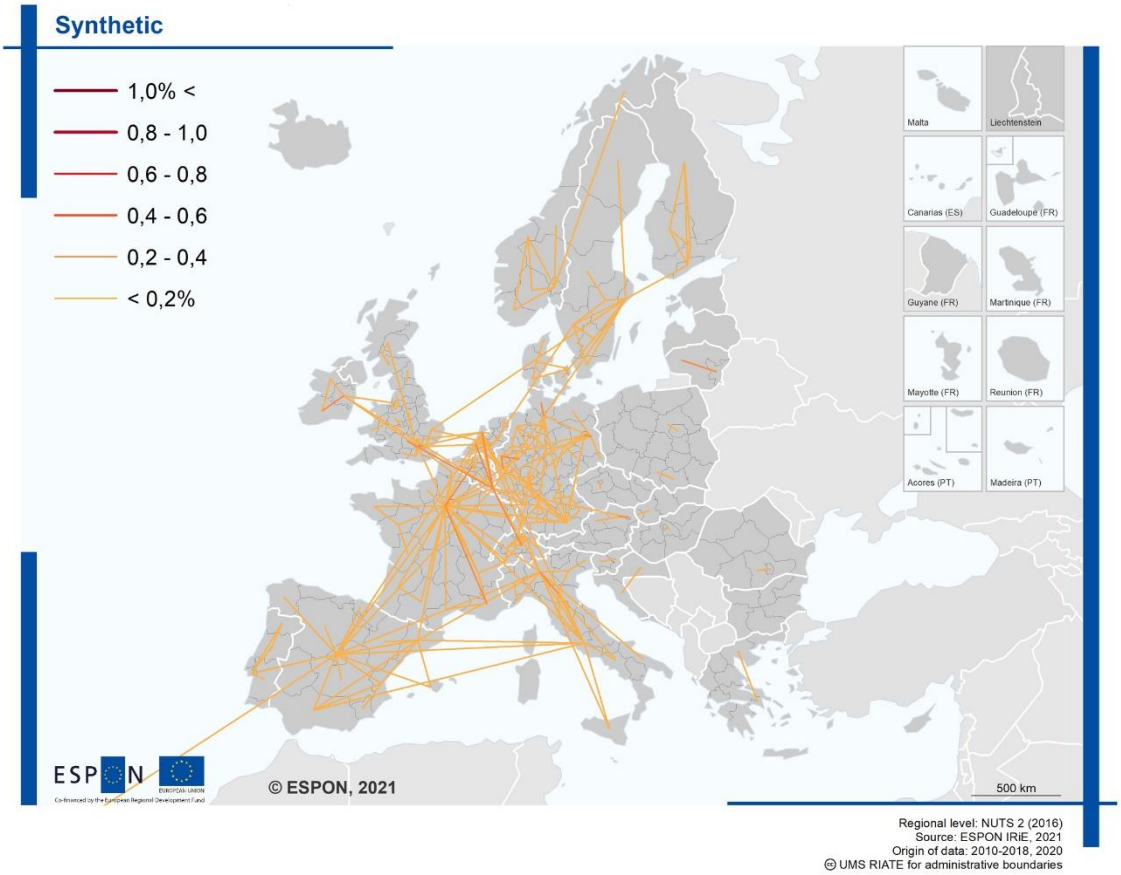


Figure 3.4: Intensity dimension. Intensity Super League index for all flows



3.1.2 Weighted intensity index

The weighted intensity index (WII) (total flow = inflow + outflow) helps determine whether a region is generally flow dependent or not. It is a measure of regional autarky / flow dependency. The average value of the index for all of a region's analysed flows can be treated as that region's overall flow dependency. Regions with high WII values are strongly dependent on interregional flows. On the other hand, those with low values are strongly autarkic and only slightly connected with other regions.

In spatial terms, for the **goods/services/capital basket** there is a clear division of the ESPON space into regions highly dependent on interregional flows, located in Scandinavia, Scotland, Ireland, Switzerland, Austria, Germany, Benelux, Greater London, and elsewhere. Goods trade is more oriented towards Western Europe, including northern Italy and eastern France, while for goods freight the index value is high also in Poland and the Baltic states. In general, services are heavily point-centered for selected NUTS 2 regions and particularly important for Scotland, northern Sweden, and, to a lesser extent, eastern Germany and selected Mediterranean islands. In turn, FDI capital definitely dominates the capitals of countries, especially in Western and Northern Europe. The core-periphery pattern for goods trade, goods freight, and services is clear between the European core and the European periphery, while for capital FDI the core-periphery pattern is more domestic and results from the difference between capital centers (mainly capital cities) and other regions of member states.

The value of the **synthetic weighted intensity indicator for the goods/services/capital basket** is highest in the Netherlands, Luxembourg, and Switzerland. High values are observed in Scotland and Ireland as well as northern Norway and Sweden. On the other hand, the regions that are the most independent and the least "flowing" are located in Romania, Bulgaria, Croatia, and Greece. The indicator is characterised by very large territorial differences. The regions with the highest values are financial centers (such as Luxembourg, Zurich, London), but also regions with important logistical functions. In Southern, Central, and Eastern European countries there is a clear core-periphery structure. Areas closer to the economic core of the EU participate more in the flow economy. This division is visible in France, Spain, and Italy as well as in Poland and Hungary. This is not the case in Scandinavia, for whose remote northern regions the weighted intensity indicator also takes on a high value. Moreover, in many countries (including Scandinavia) the position of capital cities is stronger than that of their surrounding areas.

This result is confirmed by our **boxplot analysis**. There are significantly lower flows per capita in countries that joined the EU in 2004-2013 than in the rest of the ESPON space's countries. The difference between less-developed and more-developed regions is even more noticeable. Richer regions are definitely less autarkic than poorer regions. Among the European macroregions, the highest values of the index are characteristic for Alpine space, and the lowest for the Adriatic-Ionian domain. Quite surprisingly, there is no clear urban/rural differentiation. In both urban and rural areas there are more- and less-flowing regions.

The **people basket** is very diverse internally in terms of the weighted intensity indicator. A clear core-periphery pattern at the European level is visible for migration. This type of flow is crucial for Scandinavia, Great Britain, Germany, Hungary, Romania, and Greece, while the regions of Spain, Italy, France, and, quite surprisingly, Czechia, Poland, and the Baltic states are less "involved" in the migration process. The rest of the flows in the people basket vary more from country to country than migration. Austria and the Dalmatian coast in Croatia are among the most flow-oriented for tourists, as are the south of Portugal, the Balearic Islands, Corsica, Norway, and Sweden. On the other hand, labour mobility is particularly high within the European core, from England to the Benelux countries, and from West Germany to Switzerland (but not in northern Italy). Strong labour mobility flows are also visible around agglomerations in Central and Eastern European countries (Prague, Vienna, Budapest, and Vilnius). The biggest differences between regions are visible in the context of air passengers, where there is a zero-one system, for regions with and without an airport. The largest flows are characteristic of regions with large air hubs, but also peripheral regions of richer countries (northern Scandinavia) and tourist destinations in southern Europe.

The pattern of the **synthetic indicator for the people basket** is surprisingly similar to the one for the goods/serices/capital basket. Western European metropolises clearly dominate in both. Scandinavia and Scotland are also strong. In the people basket, there is also a strong flow within areas attractive to tourists, i.e. in Austria, Croatia, Portugal Algarve, and on the islands of the Mediterranean Sea. On the other hand, the periphery in this aspect consists of Poland (in particular regions located along the border with Belarus and Ukraine), Czechia (except Prague), Bulgaria, and also southern Italy and northwestern Spain. In Western Europe, similarly to the goods/services/capital basket, France is less connected than Germany or the

Benelux countries. Once again, the role of capital cities in many countries is evident, as centres for a relatively large proportion of the flows of people. This is the case in all parts of Europe. The countries where high intensity of people flows covers many regions are Germany, the United Kingdom, the Netherlands, Sweden, Switzerland, Austria, and Norway. In peripheral areas of the states which traditionally send migrants to the abovementioned countries, the value of the indicator is low (except for the Vilnius region in Lithuania). This is probably due to the low intensity of non-migratory flows (e.g. tourism). In the spatial distribution there are also regions with long-standing strong external migration and cultural linkages. An example is the Polish Opolskie voivodeship (with a large German minority migrating to and from German regions).

The **box-plot analysis** shows the clearly less flow-oriented status of regions located in countries that joined the EU in 2004-2013. In addition, the people basket shows a greater importance of flows in ESPON-space countries outside the European Union. As in the goods/services/capital basket, the role of flows in the people basket is clearly more significant in more-developed than in less-developed regions. Among the macroregions, the Alpine region again dominates, while the Adriatic-Ionian is in last place. Again, no great differentiation was observed between urban and rural regions. What's more, regions with a very low total FUA population are much more involved in population flows than regions with moderate or even high index values, which may indicate that flows between regions of low and very high urbanization are higher than flows between regions of similar urbanization. This conclusion, typical only for the people basket, can be explained by the importance of people flows in poorly urbanised tourist regions, as well as in some rural regions of strong migration outflows.

The **knowledge basket** is spatially very diversified. While the significance of patent flows is greatest in Germany and Switzerland and in individual regions of Scandinavia (e.g. Helsinki), student flows under the Erasmus program are important for regions located peripherally to the European core, e.g. in Finland, Estonia, and Spain. On the other hand, the importance of H2020 projects resembles a mosaic spatially. In other words, regions very "involved" in H2020 projects are adjacent to those in which this type of activity is of very little importance. This can be explained by the distribution of university centres with high potential for international cooperation. In general, the spatial distribution of regions with intense patent linkages corresponds to the core-periphery model, while for the H2020 and ERASMUS student exchanges the pattern is far more polycentric.

The **synthetic indicator for the knowledge basket** shows the leaders of individual flows, but because these leaders are located in different parts of Europe for different flows, the synthetic indicator shows mainly peripheral areas, where regions participate, or participate to a very small extent, in knowledge flows. These are, apart from the capital regions, regions in Poland, Czechia, Slovakia, Hungary, Croatia, Romania, and Bulgaria, but also in Greece and southern Italy, as well as Sardinia, Corsica, and the Balearic Islands, and single regions in central France and England. In the case of knowledge flows, the core of Europe is southern Germany and Switzerland, followed by the entire belt from central Italy through Germany, the Benelux countries, Denmark, Sweden, and Finland. It is characteristic that the group of regions with the strongest knowledge flows does not include the British regions, even those with the strongest university institutions of global renown. This should be interpreted as a lower willingness of these institutions to cooperate, or as a focus on non-European linkages.

Our **box-plot analysis** highlights the differentiation within knowledge flows between old and new member states. Unlike with the goods/services/capital or the people basket, the ESPON space outside the European Union is less involved in knowledge flows than the states that joined EU before 2004. Another difference between the knowledge basket and other flow baskets is the large differentiation of flows between urbanized and rural regions. Regions with high total FUA populations, especially academic centers, are far more important players in knowledge flows than rural areas. As for differences between macroregions, the Alpine region is the strongest and the Adriatic-Ionian the weakest in the knowledge basket as in the other baskets. The cohesion is also very visible. Less-developed regions are clearly overshadowed by the knowledge flows characteristic of more-developed regions.

Summarizing the **11 flows** is the **synthetic indicator**. It shows the combined importance of all flows for a region. The more flow-oriented regions are located in the European core, from the London area, through the Benelux countries, West Germany, to Switzerland and Austria. The flows within the European core are less important in France and Italy, which are less dependent on flows than their neighbors from central Europe. The importance of flows apart from the European core is visible also in Ireland, Scotland, and Scandinavia, although with Finland it concerns mainly Helsinki (the rest of the country is less involved in flows, except through Erasmus student exchanges). Moreover, as a relatively greater importance of flows is observed in

all capitals, we can conclude that there exist two levels of flow peripherality, including also the extreme periphery. At the common periphery level (indicator level 50-100 with a few regions below 50) are regions of Spain, France, Italy, Czechia, and the Baltic countries, where capitals such as Madrid, Paris, Rome, Prague, and Vilnius stand out above the level of 100 (ESPON space average). On the other hand, at the extreme periphery, where most regions have a weighted intensity index below 50, are Poland, Slovakia, Hungary, Romania, Bulgaria, and Greece. Capitals are more important for flows also at the extreme periphery, but the level of the index in these capitals does not exceed the average (100) for the ESPON space. It is possible to identify countries where the overall weighted intensity of all flows varies internally in a core-periphery spatial distribution (e.g. United Kingdom, Finland, Austria). In most central, eastern, and southern European countries, however, the European rather than the national dimension seems to be decisive. The weighted intensity of flows decreases as one moves away from the European core (especially Germany). This is clearly observed in Italy, Poland, and Hungary. In Germany itself, an internal polycentric structure is visible. The inner cores are Frankfurt as well as Munich and Berlin. When interpreting the overall picture of weighted intensity, we must beware of the technical factors that disturb it: a) the size of the units (strengthening of flows in Germany, where a larger part of the internal linkages are taken into account); b) the system of political and administrative borders (increasing intensity when they cross compact functional areas, especially in the surroundings or inside the metropolis); c) population density (strengthening of the weighted intensity in sparsely populated northern regions).

The **box-plot analysis** for all 11 flows shows:

- a much lesser importance of flows per capita for regions of countries that joined the EU in 2004-2013 and higher importance of flows for regions of countries outside of the EU than for regions in EU states that joined the EU before 2004;

- a much greater importance of flows for more-developed regions than for less-developed regions (transition regions are medium-flowed);

- the dominance of the Alpine macroregion over other macroregions (the lowest weighted intensity indicator is for the Adriatic-Ionian macroregion);

- the relatively low importance of urbanization based on total FUA populations; although regions with very high total FUA populations are the most flow-oriented, there is not much difference in the importance of flows between regions with high, moderate, and low total FUA populations.

Figure 3.5: Goods/services/capital. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

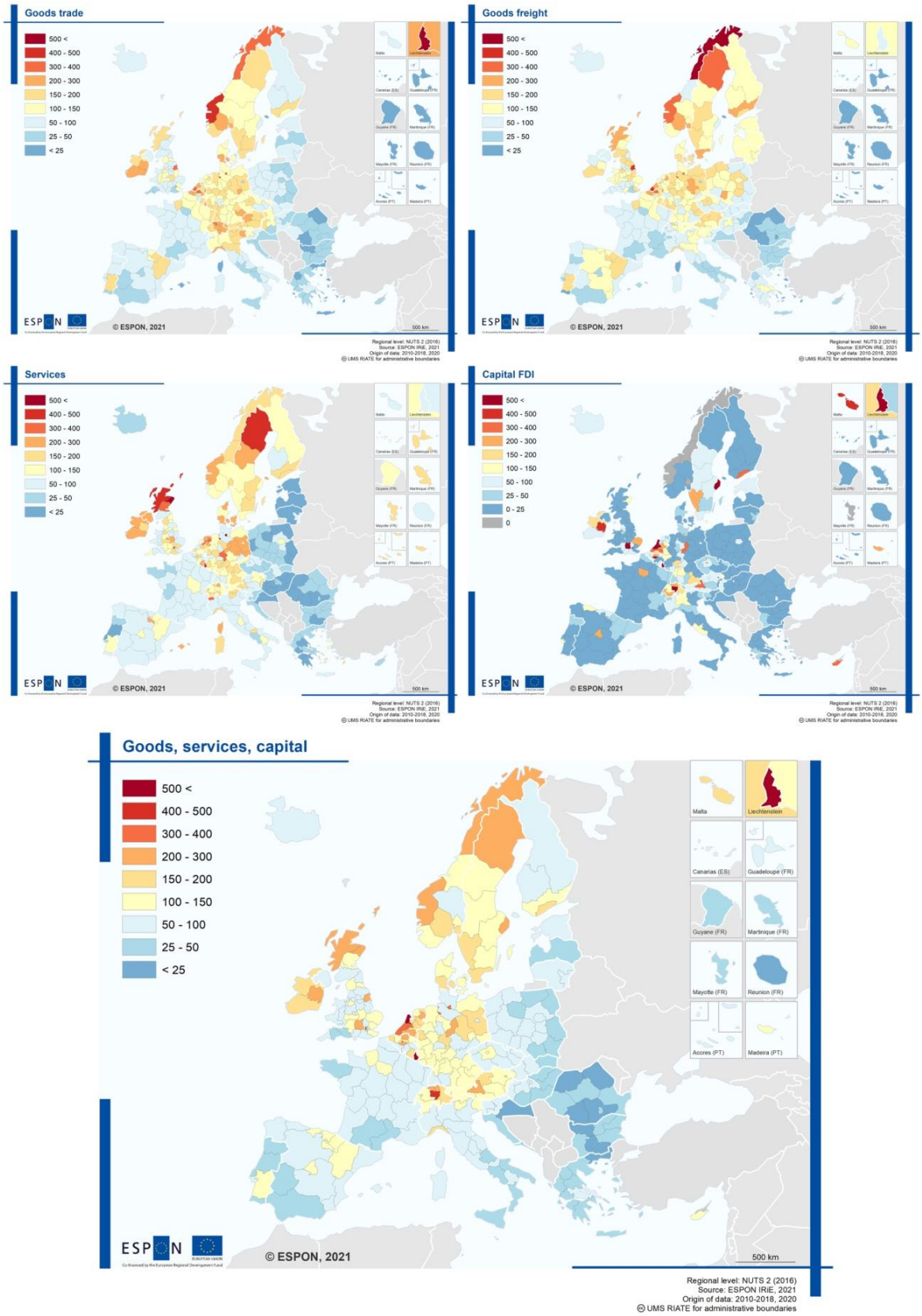


Figure 3.6: Goods/services/capital. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

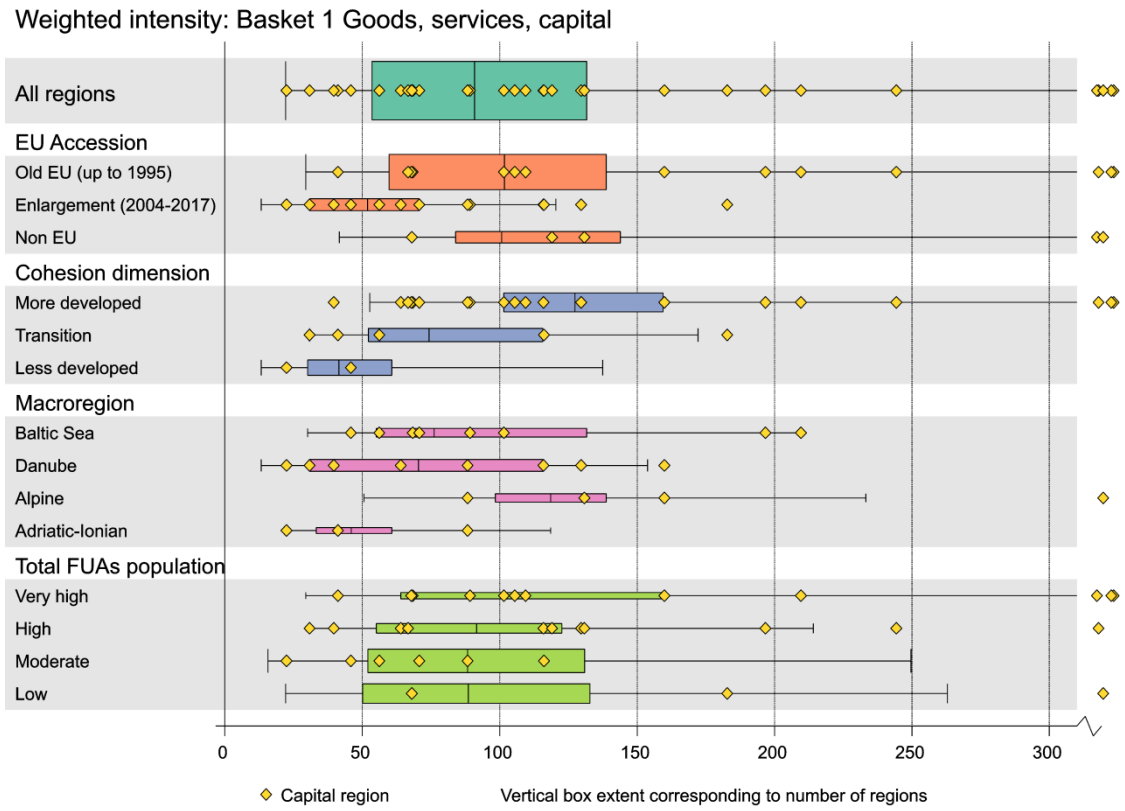


Figure 3.7: People. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

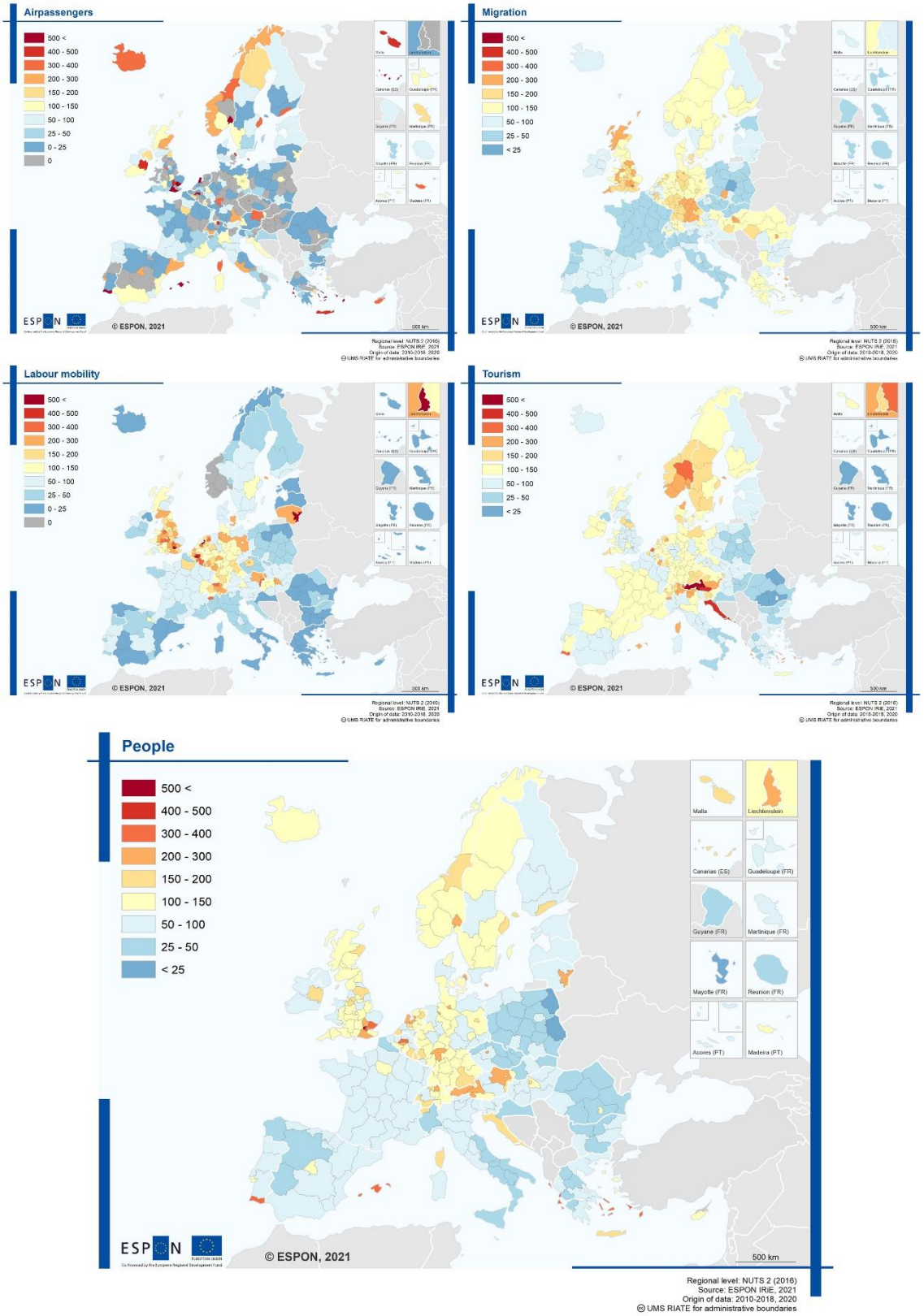


Figure 3.8: People. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

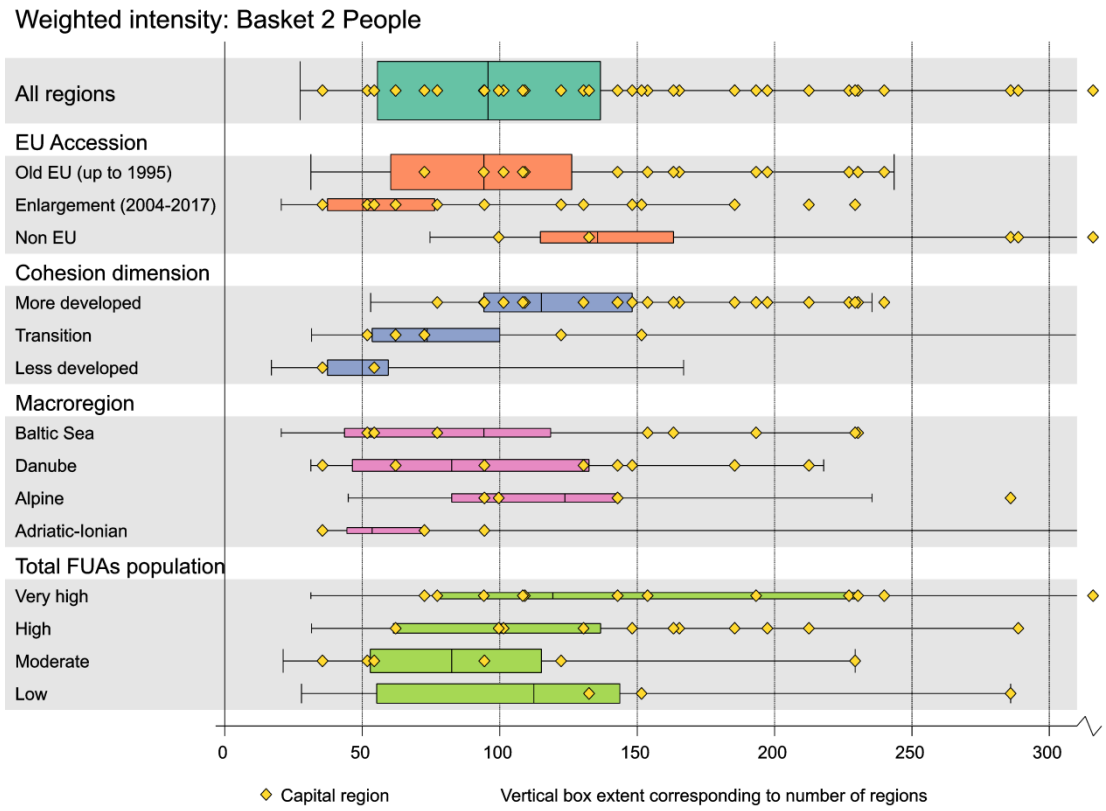


Figure 3.9: Knowledge. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

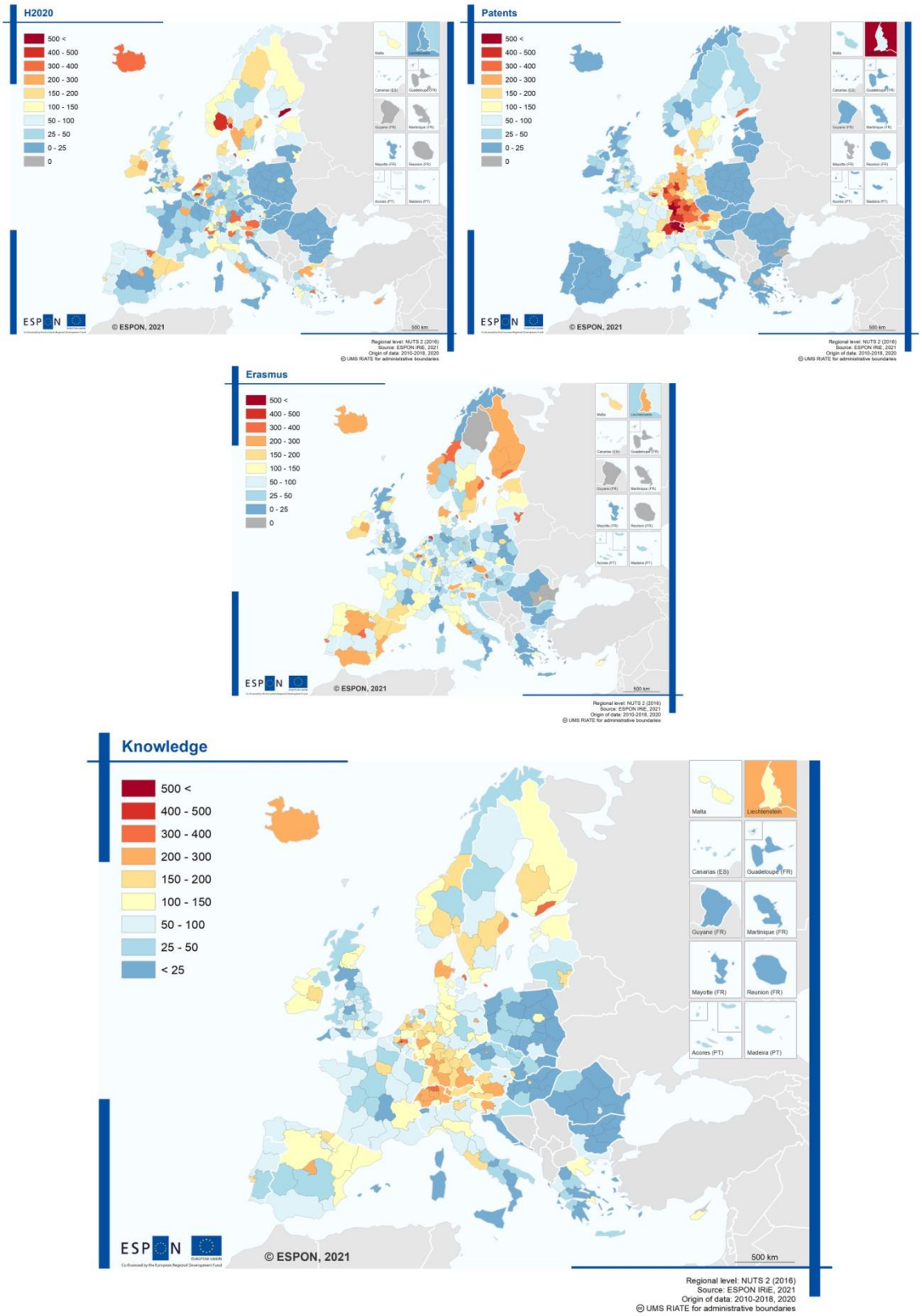


Figure 3.10: Knowledge. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

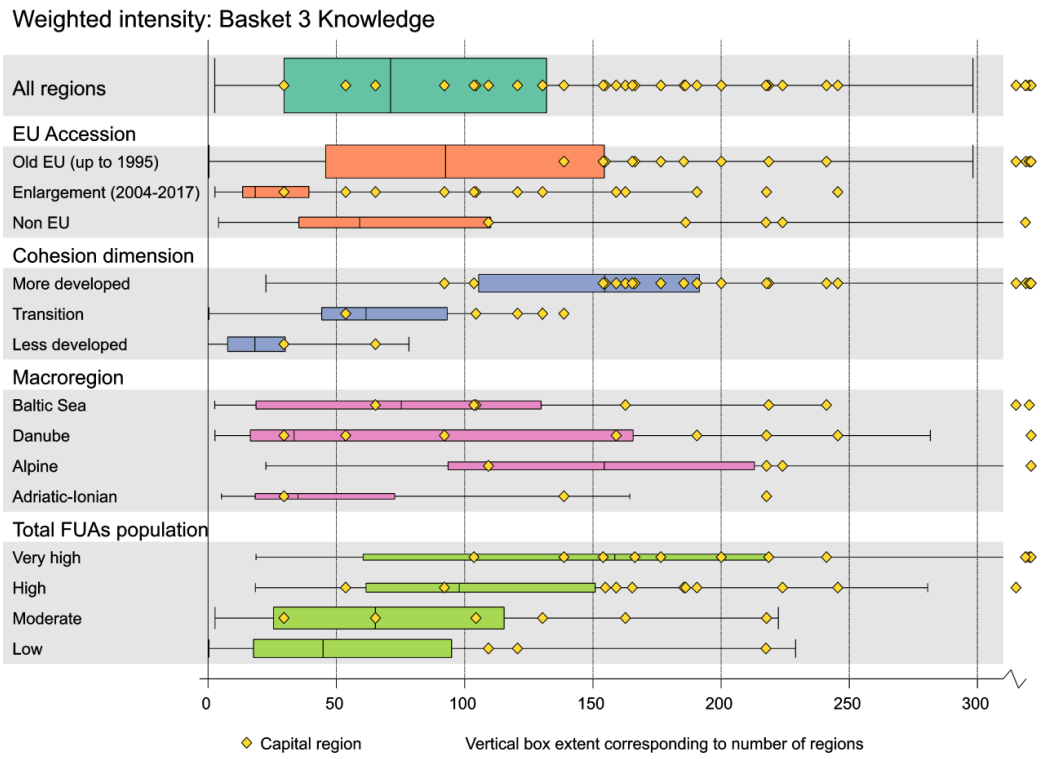


Figure 3.11: Synthetic indicator. Intensity dimension. Weighted intensity index (inflow + outflow) / total population

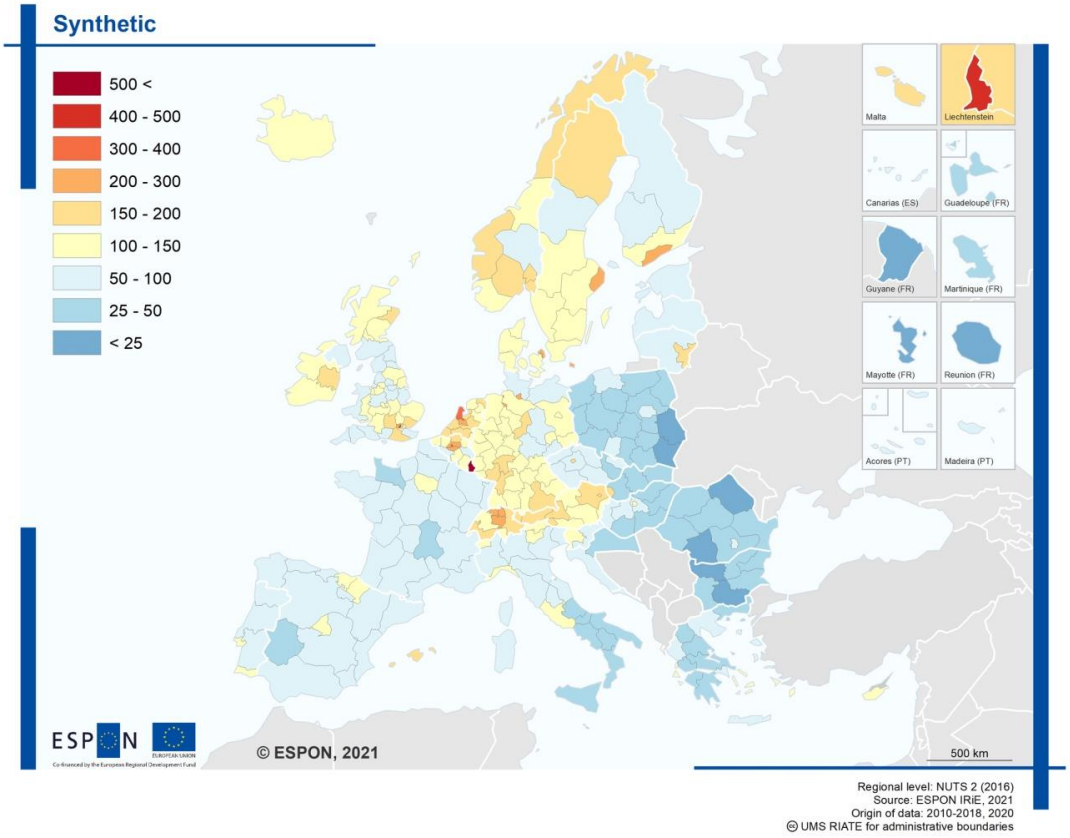
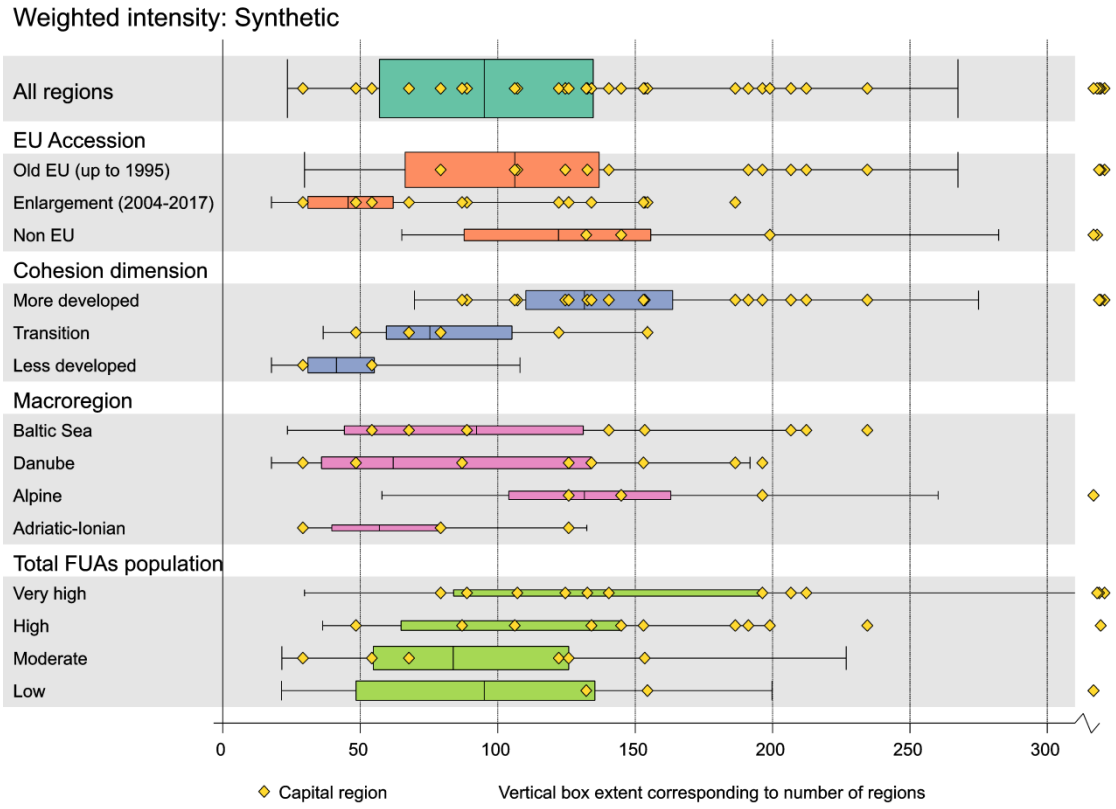


Figure 3.12: Synthetic indicator. Intensity dimension. Weighted intensity index (inflow + outflow) / total population



3.2 Balance dimension (balance index)

Within the balance dimension the primary indicator is the balance index, defined as the ratio between the difference in inflow-outflow and the maximum value of inflow or outflow. The index takes values from -1 to 1, where -1 means outflow only, 0 means perfectly balanced flow, and 1 means inflow only.

In the case of goods/trade and goods/freight it should be noted that the indicator intuitively shows opposite values than is traditional for trade, where the balance usually means export minus import, i.e. outflow-inflow. The **goods/services/capital basket** is very diverse for the balance dimension. There is some correlation between goods freight and services. In both cases, the picture of the relationship between inflow and outflow is similar for many regions in Europe, e.g. southern Germany and northern Italy. However, this is not a rule. In Finland, for example, there is a contrast between the strong correlation between goods trade and good freight and the rather different, very positive balance sheet on the services side. On the other hand, the balance in FDI capital is clearly negative for all Central and Eastern European countries (EU enlargement 2004-2013), but also for most regions of the Iberian Peninsula and Finland. At the same time, a clearly positive FDI balance is found in most German, Swiss, Danish, and British regions.

The results of the **synthetic matrix for the goods/services/capital basket** are a derivative of the results in four flows belonging to the basket. There are few regions where inflow or outflow clearly dominates. Inflow is characteristic for East England, Switzerland, and Luxembourg. On the other hand, a strong outflow occurs in Scotland and Latvia. Most countries are dominated by a spatial mosaic of adjacent inflow and utflow regions. In some countries there are internal differences. Inflow is higher in the western parts of both Germany and Poland. The eastern Länder and the provinces of eastern Poland are characterised by a negative balance. Furthermore, in the peripheral countries of southern and Central-Eastern Europe the capital cities tend to have a strongly negative balance. This is the case of Madrid, Athens, Warsaw, and Bucharest. The same cities mostly have an inflow surplus in trade and services linkages. However, this is more than compensated for in FDI flows (strongly negative balance).

The **box-plot analysis** shows a clear dominance of inflow in ESPON countries outside the European Union, while outflow slightly dominates in countries that joined the EU in 2004-2013. However, we observed no clear dependance on a region's wealth. In each group of regions, both the more-developed and the less-developed, there are both senders and receivers. Similarly, in the case of total FUA population, there is no clear correlation between urbanization and the balance of flows in this basket. Among macroregions only the Alpine is a receiver. The lack of differentiation between most of the categories in the box-plots shows that many inequalities balance out within individual countries or macroregions.

In the **people basket air passengers** is the flow type characterized by small differences in balance. For almost all regions containing airports, the number of departing passengers is almost equal to the number of arriving passengers.

In the case of **migration**, the core-periphery system is clearly visible in Europe. In Central and Eastern Europe — especially in Poland, the Baltic States, Croatia, Hungary, Romania, and Bulgaria, and to a lesser extent in Greece, southern Italy, Portugal, and Spain — a significant migration outflow dominates. On the other hand, the receivers are regions in Norway, western Germany (the territory of the former GDR is still a strong sender), northern Italy, Austria, Switzerland, and the Benelux countries. In France, the spatial range of influence of Paris is clearly visible as a center attracting migrations from the area of northeastern France. Also in Central and Eastern Europe, metropolises are noticeable as centers of attraction, i.e. Warsaw, Prague, Budapest, Bucharest, and Berlin.

A clear city-core receiver and NUTS2 senders surrounding the city are visible in **labour mobility**. Because of the relatively short distances in labour mobility, the core-periphery system in most countries is domestic, although there are exceptions. For example, Luxembourg is a strong labour mobility attractor for neighboring countries, as is Iceland. On the other hand, countries such as Estonia and Latvia are becoming strong senders, mainly to the Scandinavian countries, according to the available data.

Tourism is, in a way, a mirror of labour mobility and migration. Cities and agglomerations are the largest tourist senders, and peripheral areas attractive to tourists are receivers. This spatial pattern is visible in all countries. Even in such attractive tourist cities as Rome, Paris, and Vienna, the number of departing tourists, in the light of the project results, outweighs the number of visiting tourists. Only certain countries — above all Germany and Great Britain — are characterised by a more polycentric pattern of senders in tourism. In many other countries only one or two cities have a positive balance of tourism flows.

The results of the **synthetic matrix for the people basket** are difficult to interpret. The total balance of flows in agglomerations is usually close to zero, because large cities are senders in tourism and receivers in labour mobility and migrations. On the other hand, in peripheral areas attractive to tourists because of migratory trips, the balance is also somewhat balanced. The high positive balance is nevertheless noticeable on the Italian-Austrian border and on the Dalmatian coast in Croatia. The negative balance, in turn, consists mainly of regions which are origins of migration flows located in Central and Eastern Europe.

The **box-plot analysis** confirms the leveling of the balance due to different directions of tourist and migration-labour mobility flows. Countries that joined the EU in the years 2004-2013 are characterized by a slight negative balance, while the strength of tourism attractiveness of the Alpine and Adriatic-Ioninan macroregions indicates a positive balance. On the other hand, very interesting results are obtained from the system of balance in cities and in rural regions, where regions with a low total FUA population clearly have a positive balance. This is probably related to their being tourist attractors. The positive balance recorded in sparsely populated areas of northern Scandinavia may also be of some importance. Nevertheless, we recommend further research on this group of regions.

In terms of balance, the **knowledge basket** is strongly diversified internally. The balance distribution for **H2020** forms a mosaic; neighboring regions can be both senders and receivers. A certain compact group of regions that are all receivers lie along the eastern wall of ESPON space, from northern Norway and Sweden through Finland and the Central and Eastern European states from the 2004-2013 EU enlargement. For **patents**, the spatial pattern of receivers in Europe is similar to that of H2020. The difference is that almost all of Spain and Portugal (and part of France) join the receivers group, and the UK and Italy are more senders than receivers. In general, regions in Western Europe are much more balanced for patents than for H2020. Unlike with H2020 and patents, there is a clear divide for the **Erasmus** program between Northern Europe (Scandinavia, the UK, and Ireland) and the rest of the ESPON space. In the north, receivers dominate and countries and regions receive more Erasmus students than they send. On the other hand, the remaining part of the ESPON space consists mainly of regions with a negative balance for Erasmus students, with selected regions in Romania, Bulgaria, Poland, and Greece having a particularly negative balance. However, a positive balance is also recorded in some Mediterranean regions that are also strong university units (Portugal, Catalonia, Tuscany, Athens).

The **synthetic matrix for the knowledge basket** shows a more balanced picture, with single regions that are strong senders or strong receivers. Strong receivers are located mainly in Scandinavia and in southeastern Romania and Greece. There are no clusters of strong senders in the ESPON space. The **box-plot analysis** shows how balanced the ESPON space is for the knowledge basket. Regardless of the method of regional aggregation — whether it depend on cohesion or macroregion — there are basically no significant differences in the context of balance. In this group only regions belonging to EU states from the enlargement of the community in the years 2004-2013 indicate a slight dominance of senders of knowledge. In turn, regions characterized by low total FUA populations are mainly receivers of knowledge.

The **synthetic matrix for 11 flows** results in a more balanced balance pattern, although a positive balance is still observed in, inter alia, Croatia's Dalmatian coast, Switzerland, and western Austria, as well as northern Finland. On the other hand, the senders group includes most of the regions of Central and Eastern Europe, although there are exceptions here as well (e.g. the Zachodniopomorskie voivodeship in Poland). The spatial distribution indicates that a strongly peripheral location can determine the negative balance of flows. However, this principle does not apply to regions with high tourism potential and settlement attractiveness (the Mediterranean). The box-plot analysis confirms the above conclusions. The senders group includes mainly the EU states that joined the EU in 2004-2013, as well as less-developed regions and the Danube macroregion. In turn, the receivers group is dominated by regions from the Alpine macroregion and, surprisingly (further research is required), regions with a low total FUA population. Conclusions in this respect must be cautious, because the balance indicator is significantly influenced by the size of the region (in the case of larger NUTS 2 regions the balancing is done more internally).

Figure 3.13: Goods/services/capital. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers

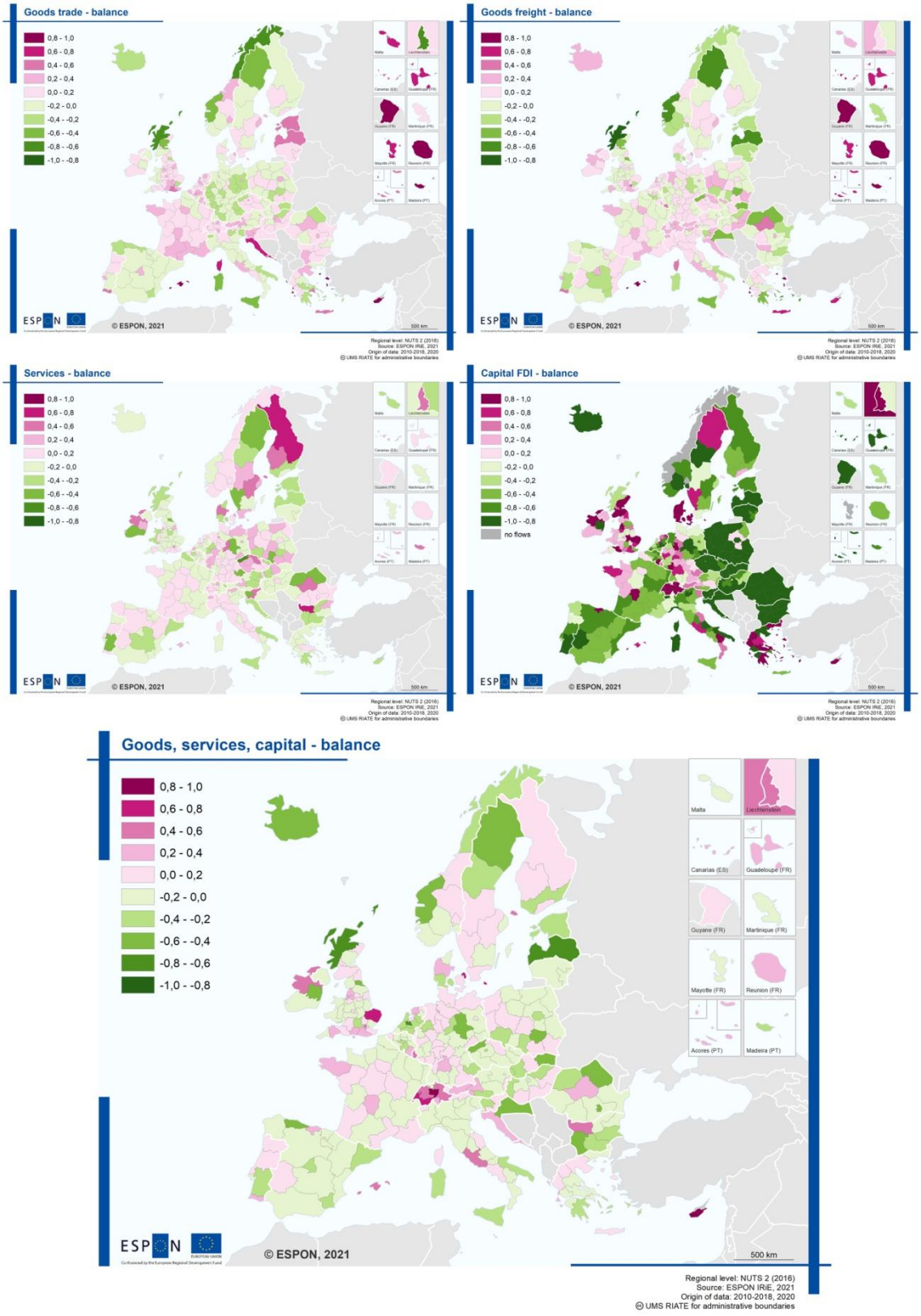


Figure 3.14: Goods/services/capital. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers

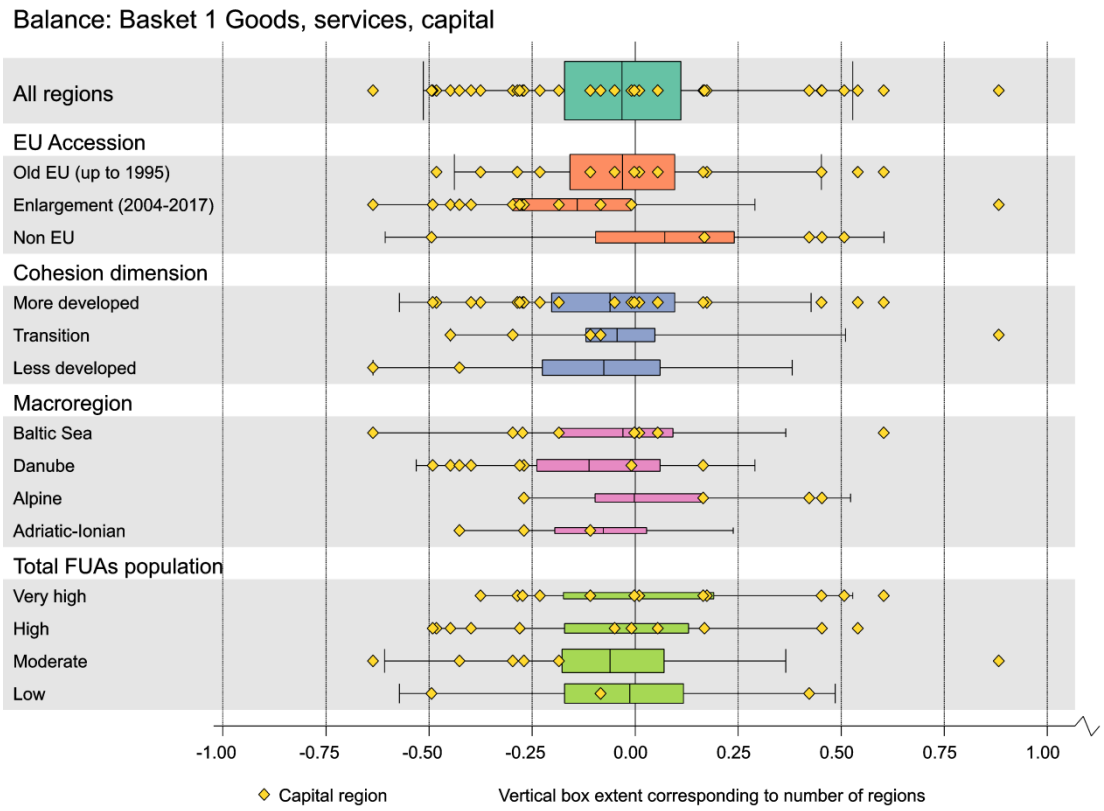


Figure 3.15: People. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers

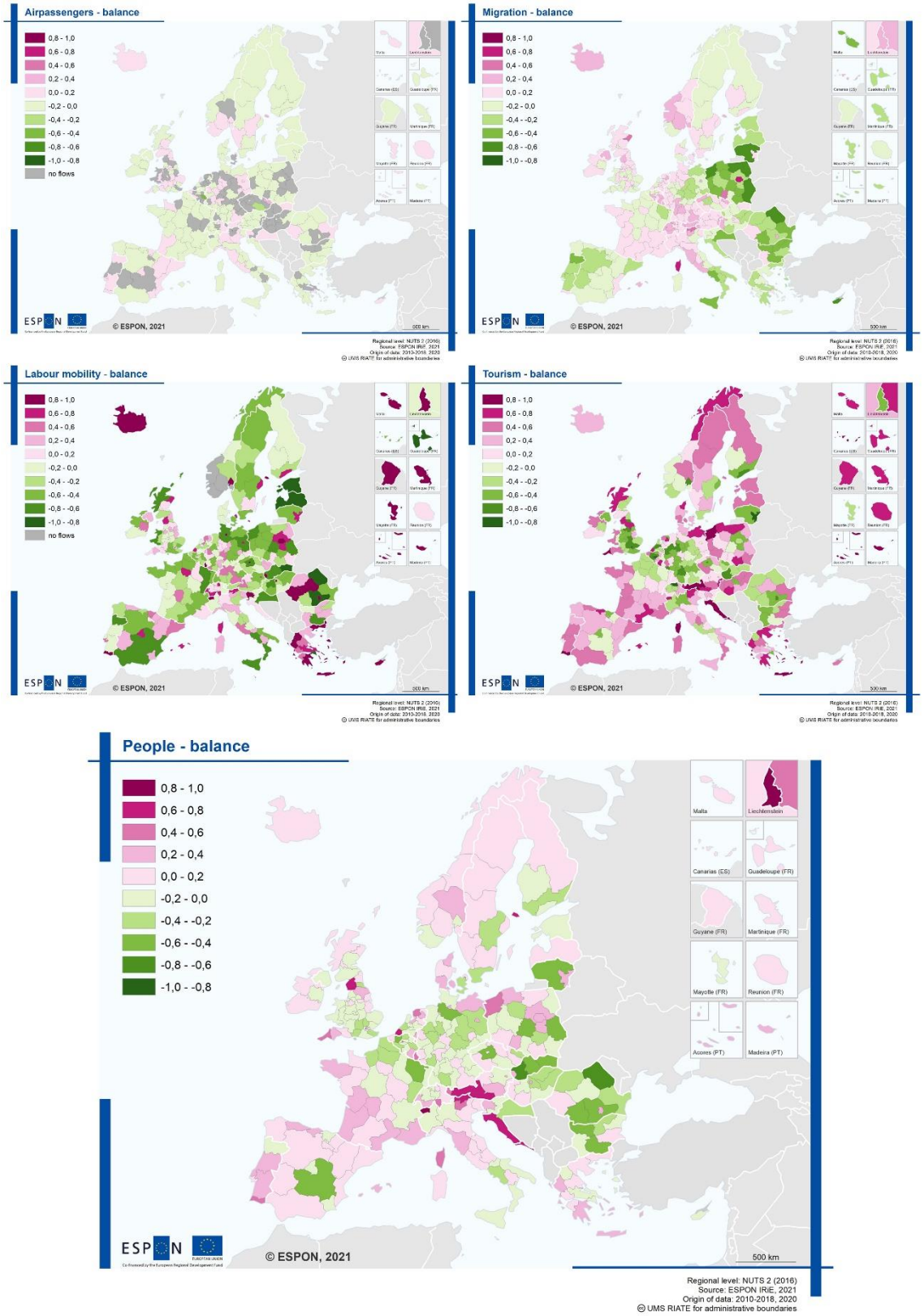


Figure 3.16: People. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers

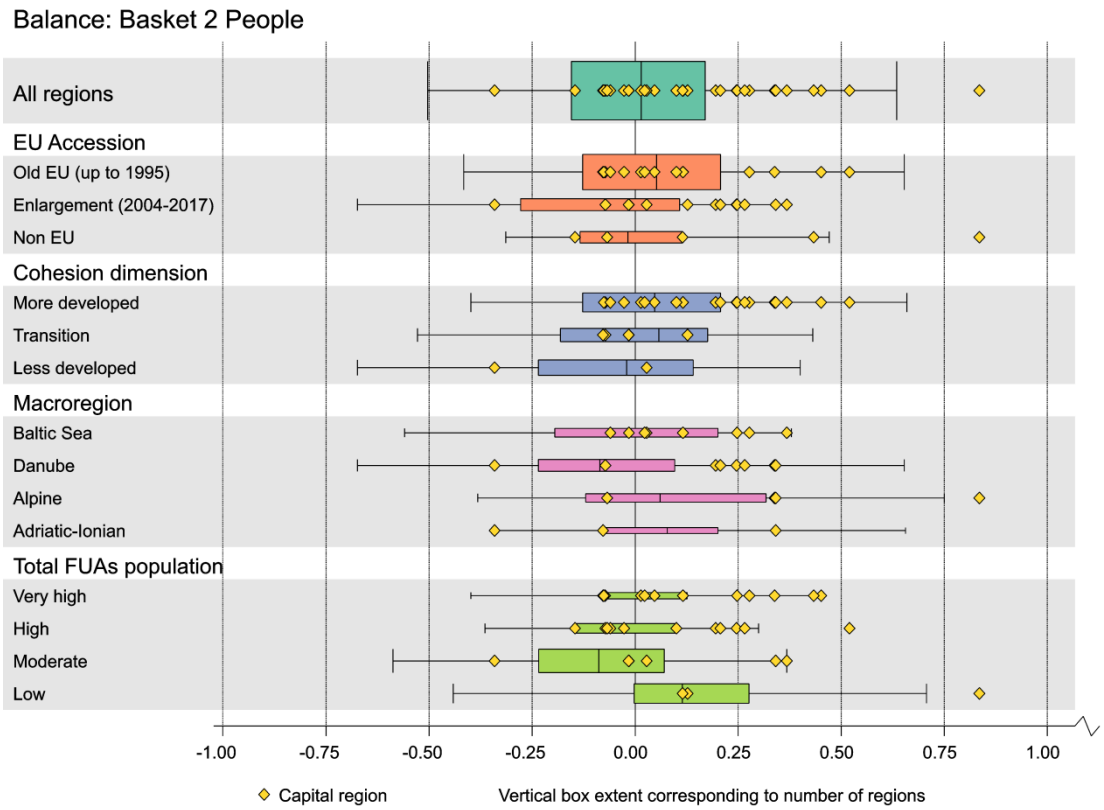
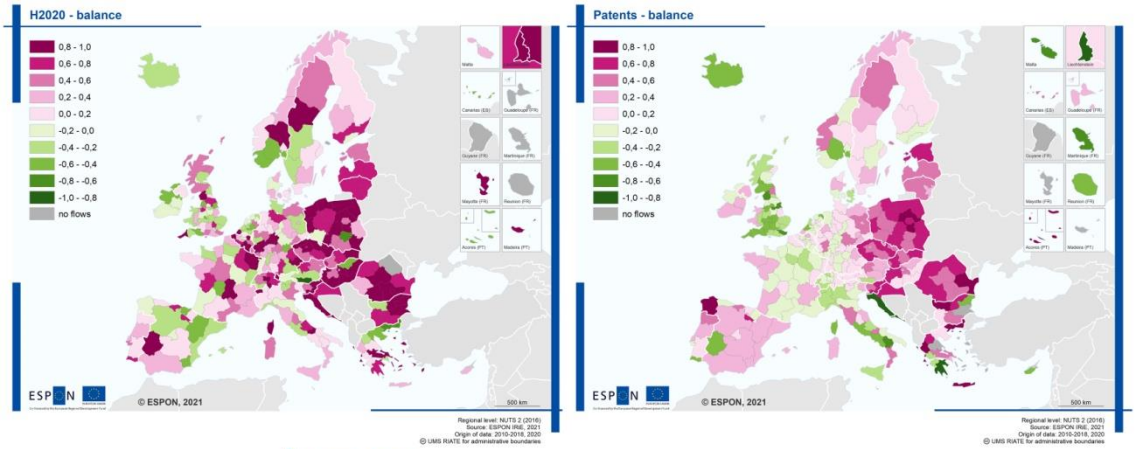
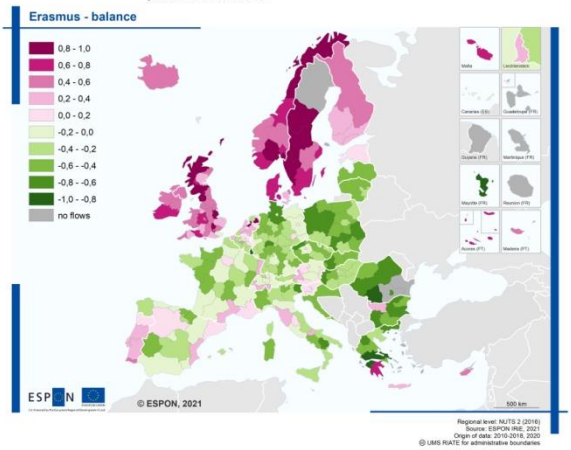


Figure 3.17: Knowledge. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers





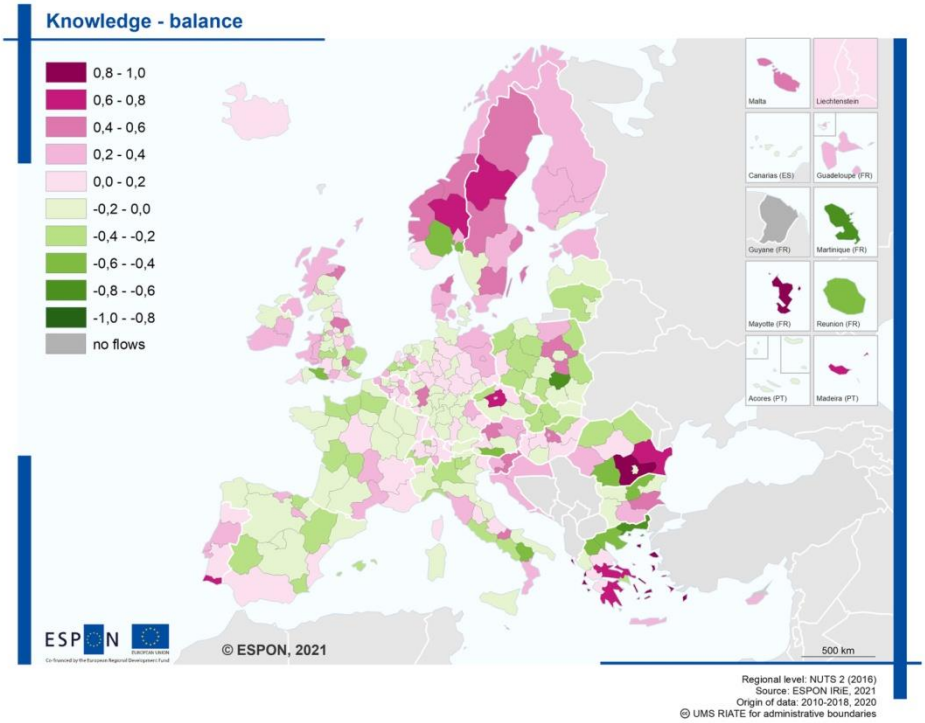


Figure 3.18: Knowledge. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers

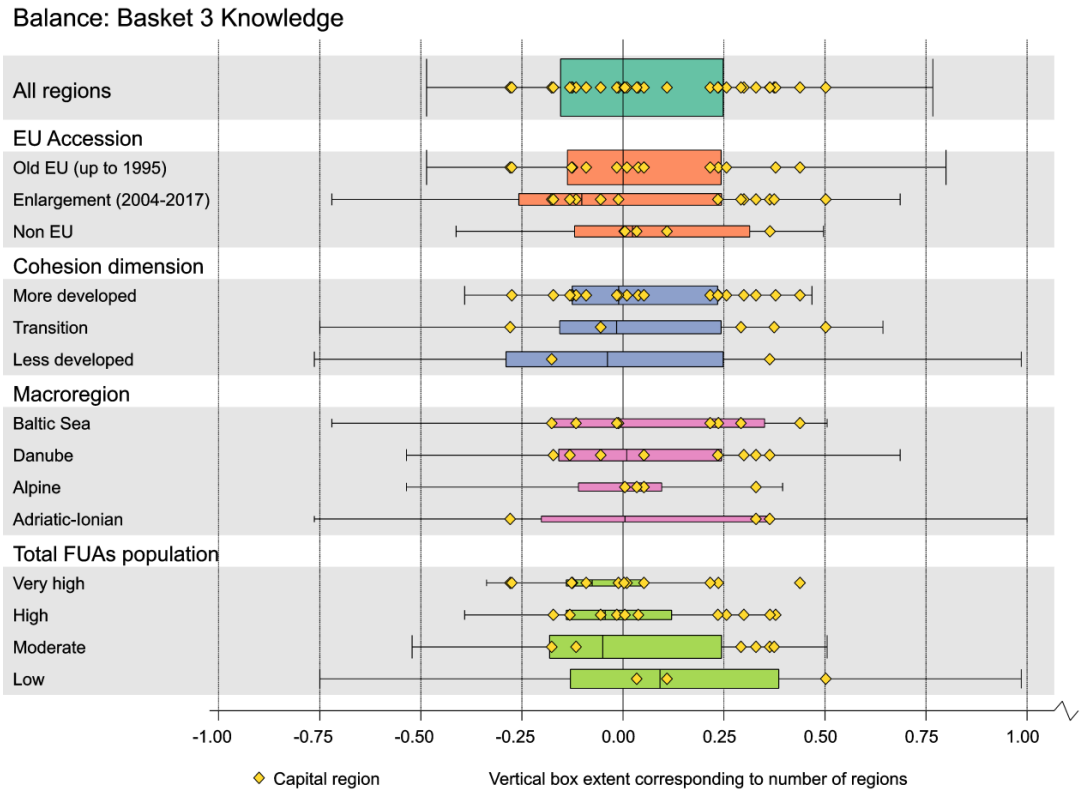


Figure 3.19: Synthetic indicator. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers

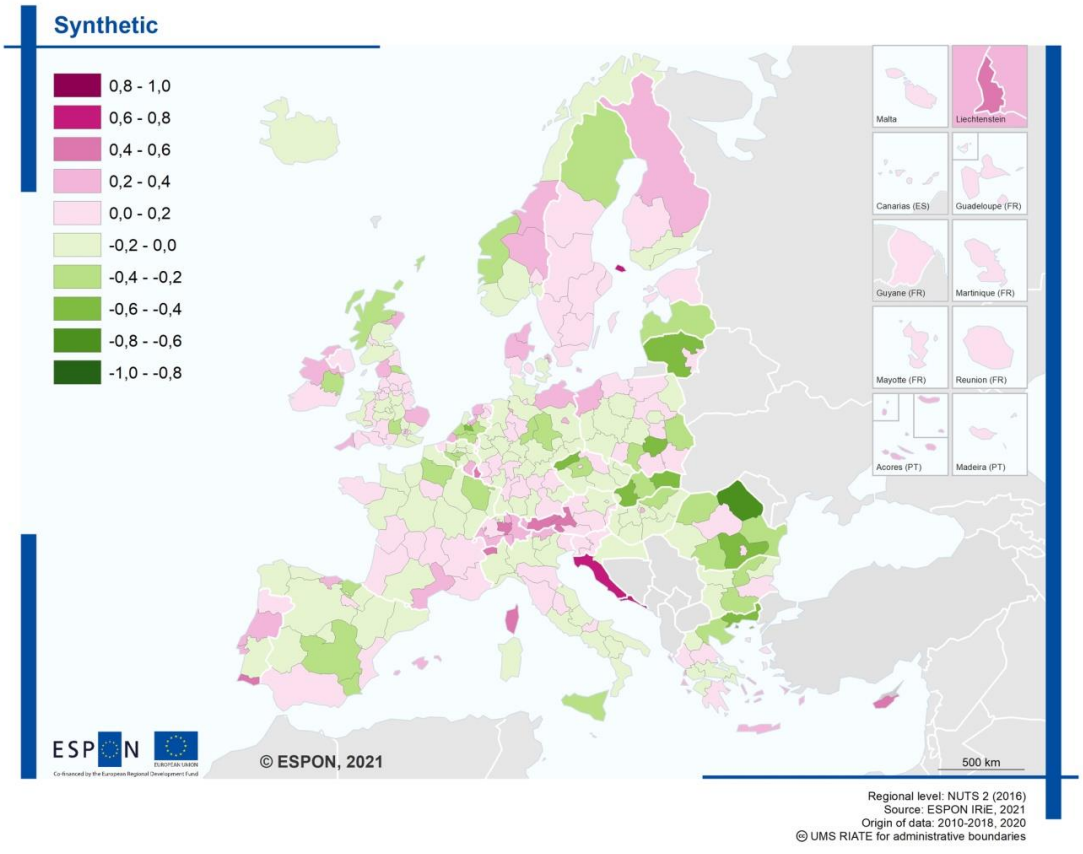
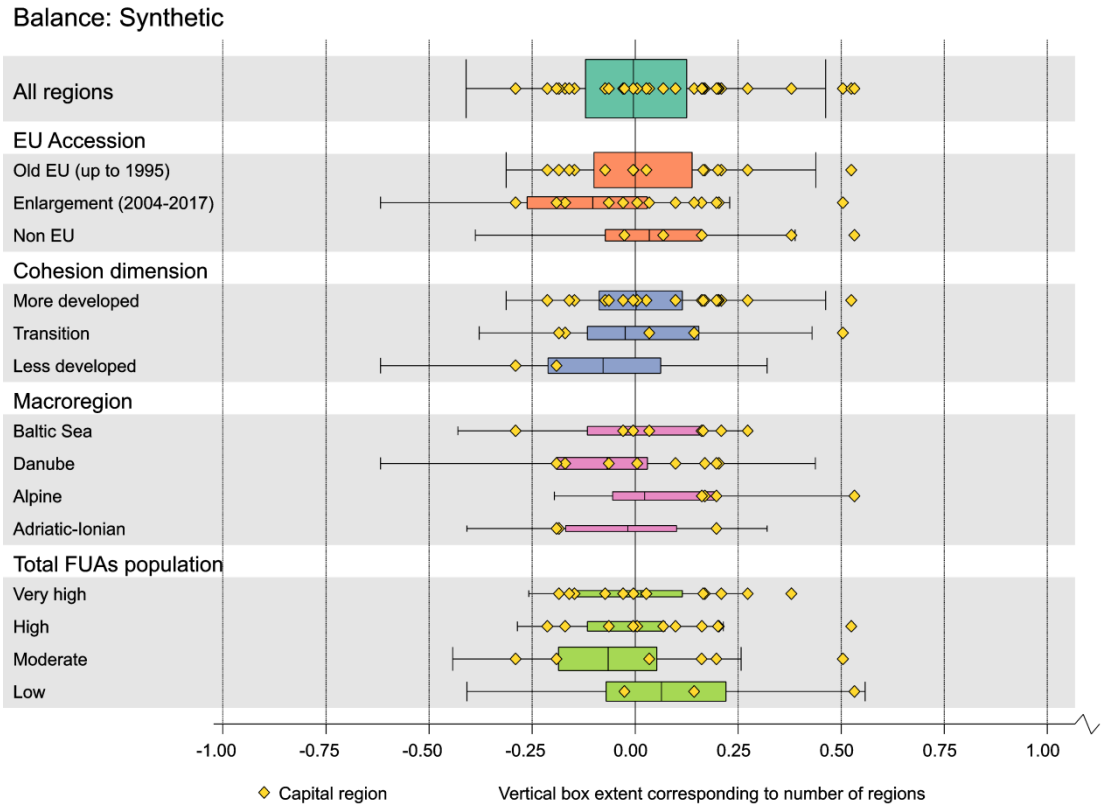


Figure 3.20: Synthetic indicator. Balance dimension. Balance index (inflow-outflow) / max(inflow;outflow). Negative values-senders, positive values-receivers



3.3 Concentration dimension

3.3.1 Concentration per population index

The concentration-per-population index is the Gini index. High values of the indicator show a high spatial concentration of flows, and low values show a low spatial concentration of flows in a given region.

In the **goods/services/capital basket**, the highest differentiation of spatial concentration concerns the flow of **goods trade**, where Scandinavian countries, but also Switzerland and Greece, are characterized by a very high concentration of flows. On the other hand, Ile-de-France and other single regions in Europe are characterized by a very large spatial dispersion of flows. The remaining flows within the goods/services/capital basket appear to have a more balanced distribution of the concentration of flows, although a strong spatial concentration of flows was also observed for **FDI capital** in Greece and Iceland. In general, a higher concentration emerges in the peripheral areas of the ESPON space. Characteristically, this applies to both wealthier (Scandinavia) and poorer (Central and Eastern Europe) regions. The core-periphery system is most visible in the case of trade.

The **synthetic matrix of the goods/services/capital** basket shows the culmination of spatial concentration for the Scandinavian countries and Greece. On the other hand, the most spatially diversified flows within the goods/services/capital basket are a feature of regions in a fairly compact spatial cluster, from Catalonia to the European core, i.e. northern Italy and eastern France to Belgium and the Netherlands, but with the exception of highly spatially concentrated flows in Switzerland and the northern Netherlands. The core-periphery system is visible, but it is also overlaid by national structures. In many countries the concentration is noticeably lower in capitals and other large metropolitan areas. This means that metropolitan regions there have a much more geographically diverse structure in terms of economic partners. They are thus less sensitive to external economic shocks. They are also probably the international economic "gateways" of their countries. Examples are Barcelona and Madrid in Spain, Athens and Thessaloniki in Greece, Warsaw in Poland, Bucharest in Romania, and even Paris in France. The **box-plot analysis** for the goods/services/capital basket confirms a relatively higher spatial concentration in non-EU ESPON countries (e.g. Norway and Switzerland), in less-developed regions, and in areas with a low total FUA populations. This confirms the previous thesis that poorly urbanised peripheral regions are oriented towards relations with a limited number of regions. This may result from both economic (sectoral) specialisation and the need to use "intermediaries" in international relations.

The spatial concentration in the **people basket** varies greatly by flow. It is natural to have a strong spatial concentration for the flow of **air passengers**. Apart from the largest hubs, which are characterized by a large diversification of air connections, most of the smaller airports serve several or a dozen directions, so naturally the flows in these regions are strongly concentrated in space. In the rest of the regions that do not have an airport, there is no concentration at all in this flow, for lack of flows. In turn, **labour mobility**, which is characterized by a strong spatial concentration, is a feature of most of the regions. Because of the above, the spatial differentiation of concentration, unlike with air passengers, is relatively small. Situations where the spatial differentiation of concentration is observed can be interpreted as hidden (unrecorded) migration to more geographically distant regions. On the other hand, there are migrations and tourism within the basket where differences in the spatial concentration of the abovementioned flows are clearly visible throughout the ESPON space. For **migration**, flows are strongly concentrated in the Scandinavian countries, as well as in Greece and Central and Eastern Europe, mainly south of Poland in the group of smaller countries, i.e. Austria, Czechia, Slovakia, Hungary, Croatia, and Slovenia. These are countries characterized by short migration distance, mainly internal to a small number of regions. In turn, Poland, Romania, and Latvia, as well as Andalusia and Catalonia, are characterized by low concentration and high dispersion of mainly international migration. In many countries the concentration is clearly higher in areas around major centres (mainly capitals) than in the core city itself. This means that the main city remains the most important migration destination for its surroundings while at the same time itself remaining in a system of multidirectional migration relations. This can be interpreted as large centres functioning as "migration gates" for adjacent areas. The reason is probably that large cities (also in peripheral areas) function in pan-European network systems, because of the concentration of international institutions and corporations in them (movement of skilled professionals). In the case of **tourism**, highly concentrated flows are visible also in Scandinavia and Ireland, as well as the Baltic States, Slovakia, Romania, and Bulgaria. In turn, strongly spatially dispersed flows are the domain of regions located in the European core, with a clear difference along the French-Belgian and

French-German border. The French are strongly spatially concentrated in their tourism decisions, while Belgians or Germans have more diversified tourist destinations.

The **synthetic matrix for the people basket** shows a clear concentration of flows in Scandinavia, the British Isles, the Benelux countries, Lithuania, Slovakia, Hungary, and Greece. On the other hand, dispersed flows in the people basket are the domain of Latvia, Catalonia, and Valencia, as well as central and northern Italy. Low concentrations are also found in parts of Central and Eastern Europe, especially in western Poland and northern Romania. Clearly higher dispersion of flows is observed in capital regions (Warsaw, Paris, Prague) and less in their immediate surrounding regions. The **box-plot analysis** shows a higher concentration in the people basket in non-EU countries, e.g. Norway, Great Britain, and Switzerland. The higher spatial concentration of flows in the people basket also affects rural regions (low total FUA populations). More-urbanized regions create networks of connections to a greater extent and are not so dependent on connections with individual regions. Among macroregions, the Batlic Sea macroregion is characterized by a higher concentration of flows, although it is also quite spatially diversified, because Latvia and Poland, as well as Mecklenburg, are regions with rather dispersed people flows.

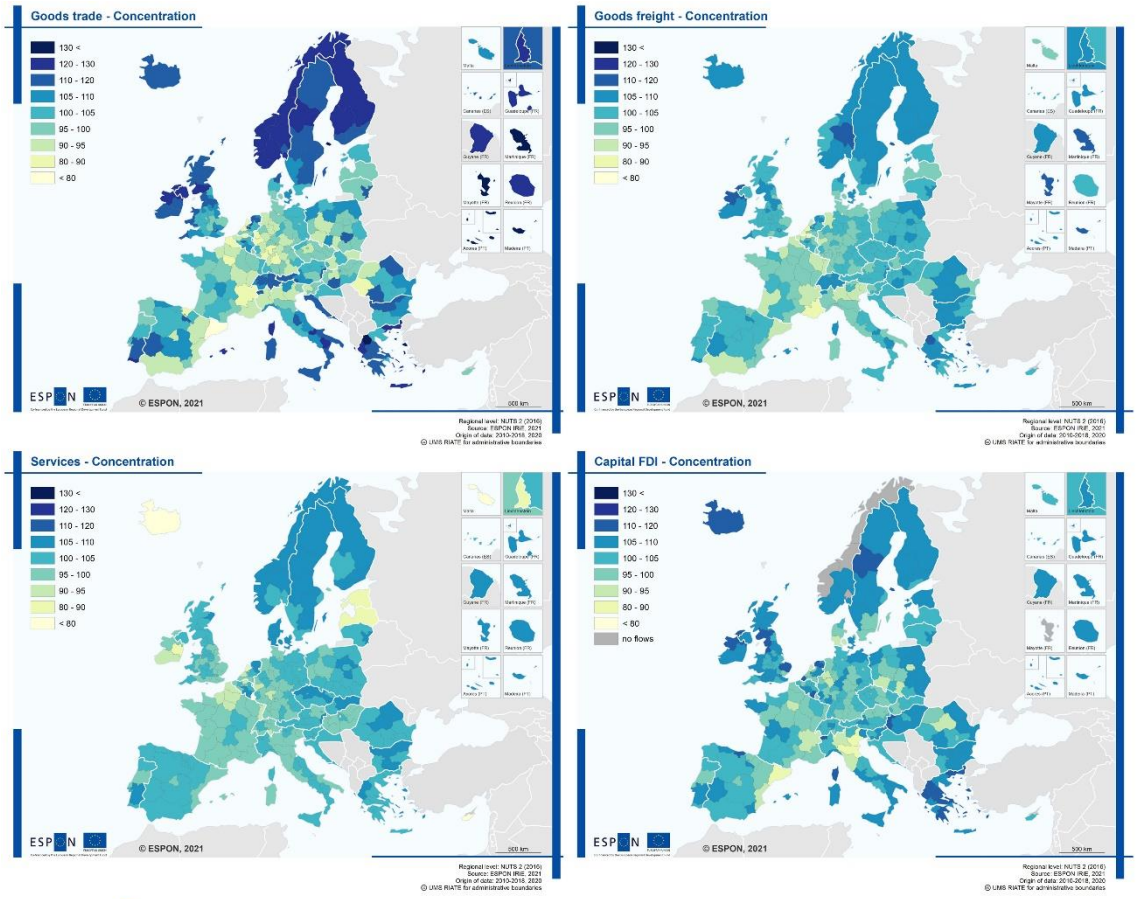
In the **knowledge basket** the concentration of **H2020** project flows is particularly high in Central and Eastern Europe, while the more differentiated H2020 flows are in strong, network-forming centers such as Madrid, Paris, Catalonia, and southeastern Germany. In the case of **patents**, there is greater variation in concentration in the ESPON space. In Central and Eastern Europe, there is still a very strong concentration, probably because the number of patents is small and there are no numerous networks of flows. The greatest diversification of patent links is visible in France and northern Italy. Interestingly, the concentration is relatively higher in the patent "basin", i.e. western Germany and Switzerland. The **Erasmus** program is characterized by a highly mosaic-like spatial pattern in the concentration of flows. Regions with a high concentration are adjacent to those in which the flow is dispersed. Regions with spatially diversified networks of connections in the Erasmus program include the whole of Finland, Warsaw, and the Małopolskie voivodeship with Kraków in Poland and Andalusia, Valencia, and Castile in Spain.

The **synthetic matrix of flows within the knowledge basket** indicates a large differentiation in the concentration of flows between neighboring countries and regions. For example, knowledge flows are spatially dispersed in Finland, and quite concentrated in Norway. Similarly, the flow is spatially diversified in Poland's Warsaw and Krakow, mainly because of the network of connections in the Erasmus program, and it is strongly concentrated in eastern Poland, as well as in Romania, Bulgaria, and Greece. In the ESPON space, the largest areas with highly dispersed knowledge flows are Spain, France, and the north of Italy, although even in these countries there are single regions with a strong concentration of flows, e.g. Extremadura. This leads us to conclude that knowledge flows are to a large extent based on a limited number of nodes (university cities, research and development centres and regions). It is with them that most other regions are linked. They are often dominated by relations with one region: the node. As a result, the concentration of knowledge flows is high.

The **box-plot analysis** confirms a much greater diversification in the concentration of flows between regions for the knowledge basket than for the other two flow baskets. There is a particularly high concentration of flows in less-developed countries, as well as in rural regions. This is due in particular to these regions' low involvement in the flows and low level of networking. Poor peripheral regions tend to have single and highly concentrated knowledge flows, while regions located in the center of Europe or metropolitan regions (also in peripheral countries) are usually also strong academic centers and tend to have numerous, strong links within a network of large academic centers, as well as its own hinterland.

The **synthetic relationship matrix for 11 flows** shows the mosaic spatial pattern for the concentration-per-population indicator. A clearly higher concentration is characteristic of northern Europe, Great Britain, Ireland, Switzerland, Hungary, Slovakia, and Greece, as well as rural and peripheral centers, while metropolises, including capitals, are usually characterized by a large spatial diversification of flows and networks of flows. Especially low values of the indicator, which mean a high dispersion of flows, are characteristic of Andalusia, Valencia, and Catalonia in Spain, of southern France, and of northern Italy. The **box-plot analysis** confirms the above conclusions. Rural regions (low total FUA populations), less-developed regions, and regions remaining outside the EU (the result, in this case, of a high concentration of flows in Norway, Great Britain, and Switzerland) are characterized by a particularly high spatial concentration.

Figure 3.21: Goods/services/capital. Concentration dimension. Concentration index (Gini index)



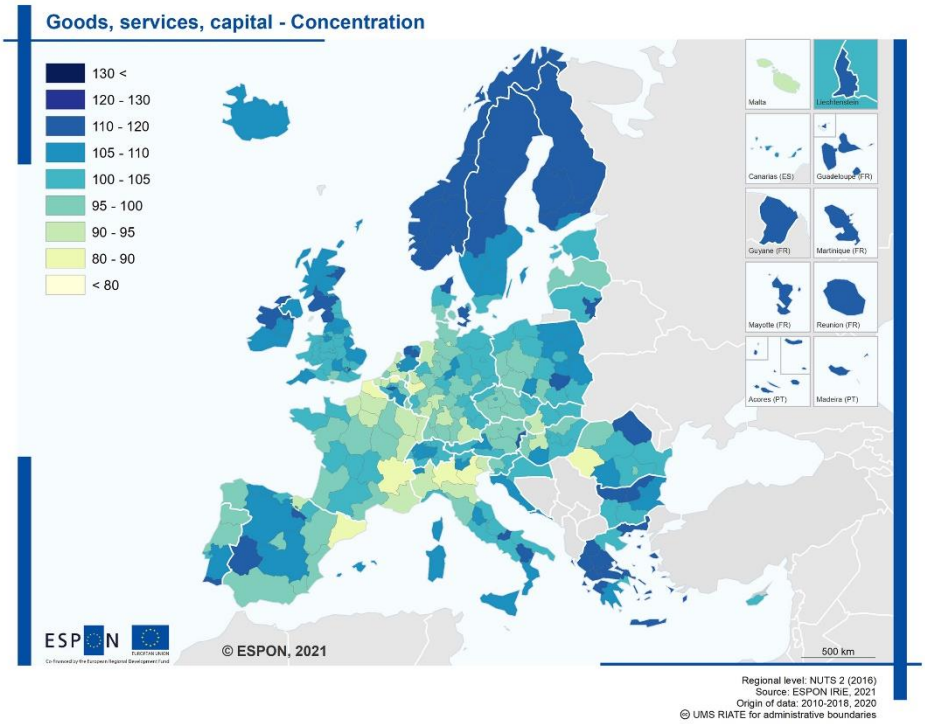


Figure 3.22: Goods/services/capital. Concentration dimension. Concentration index (Gini index)

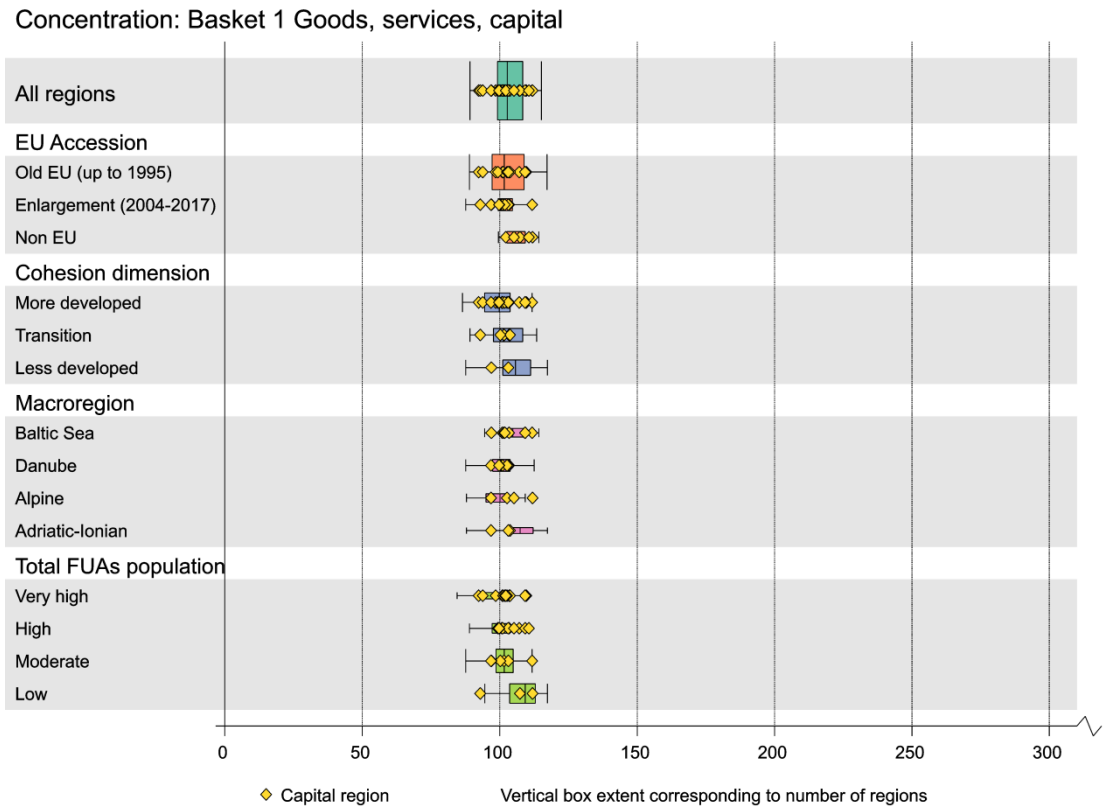
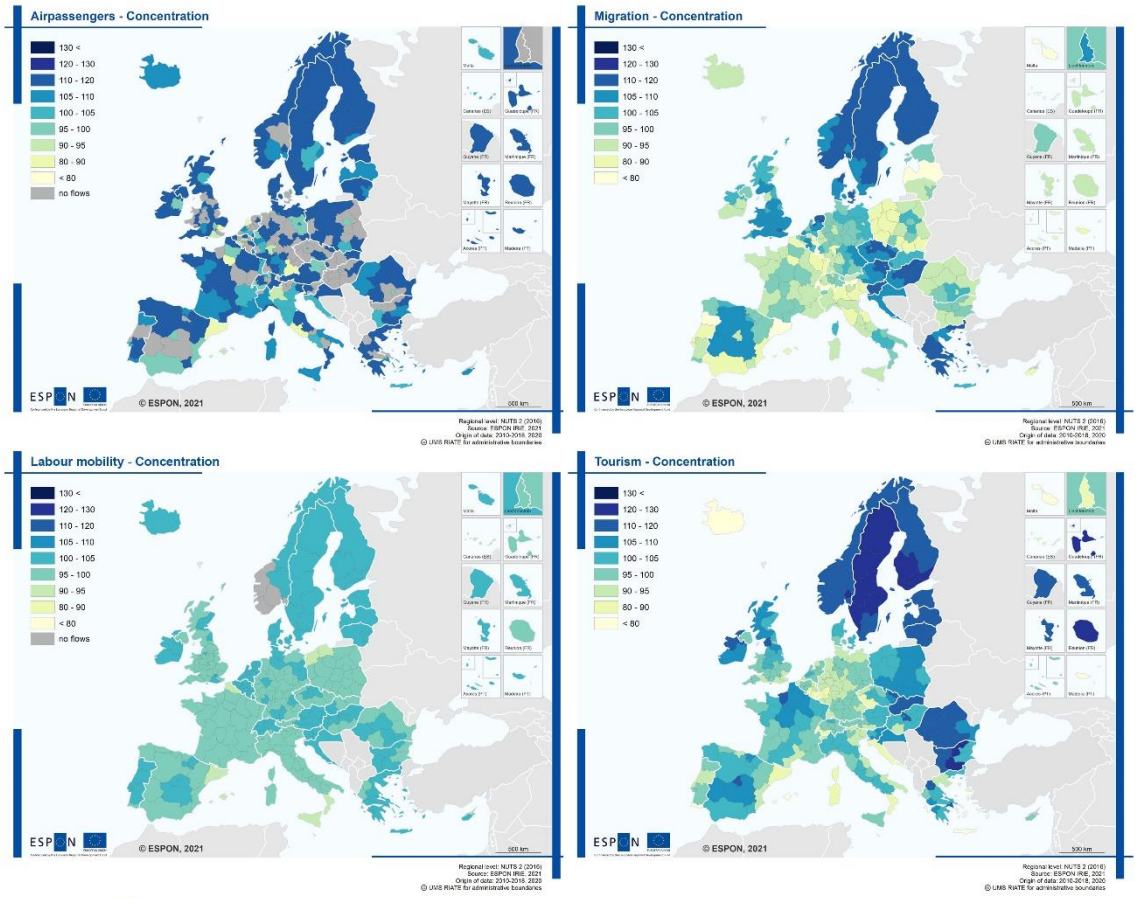


Figure 3.23: People. Concentration dimension. Concentration index (Gini index)



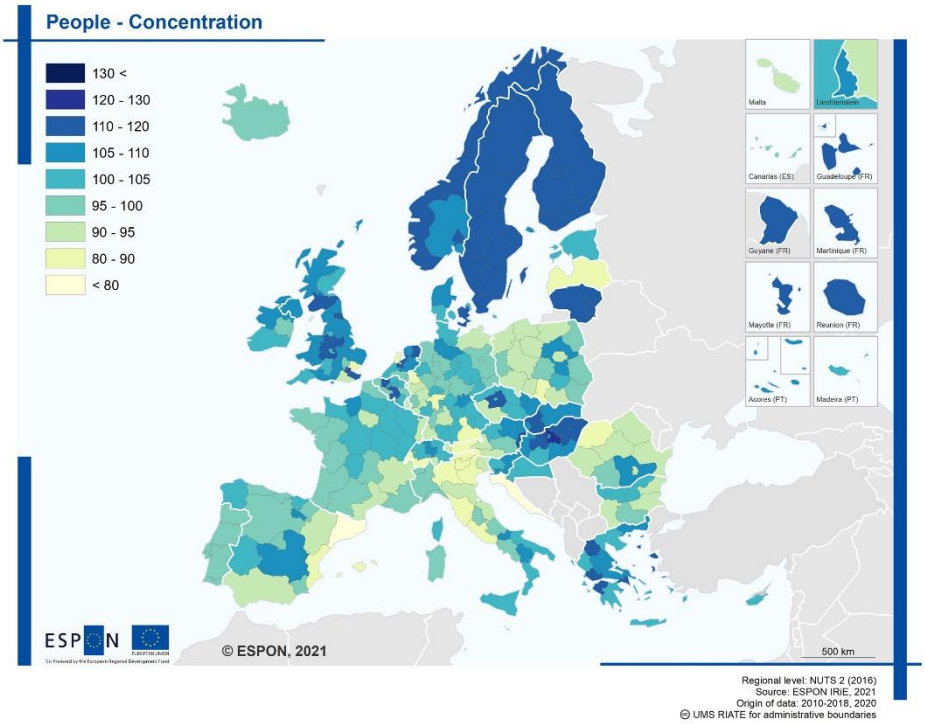


Figure 3.24: People. Concentration dimension. Concentration index (Gini index)

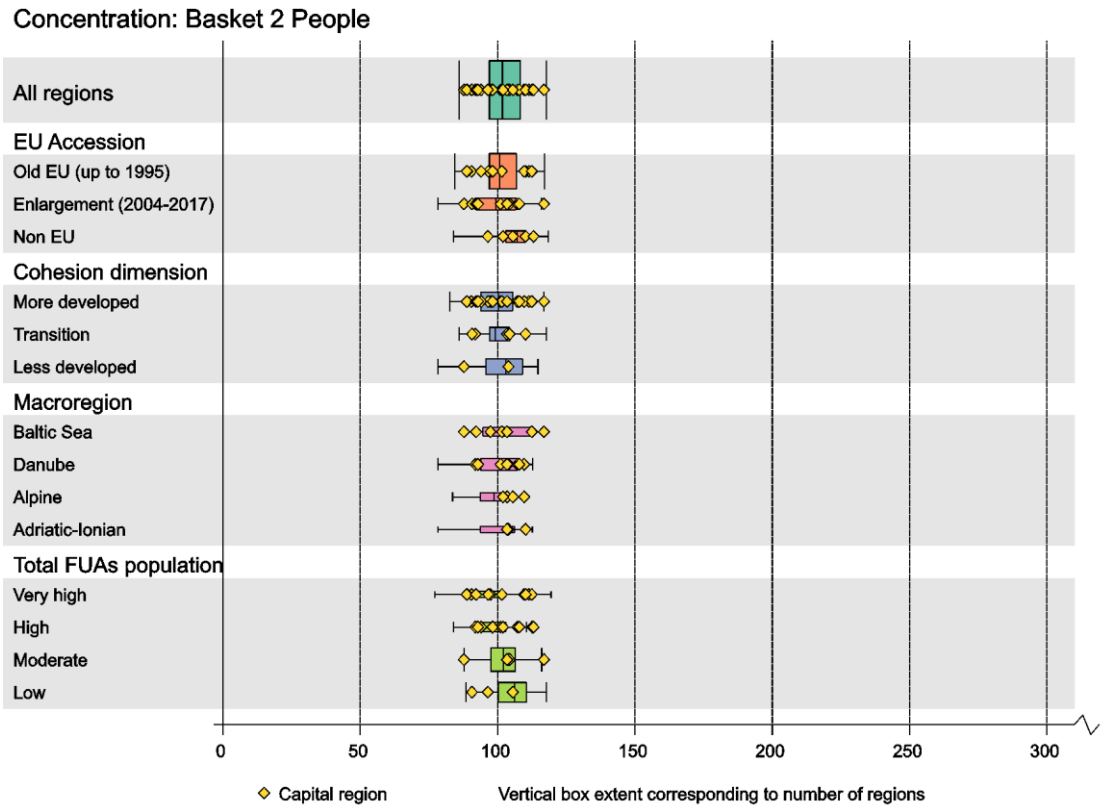


Figure 3.25: Knowledge. Concentration dimension. Concentration index (Gini index)

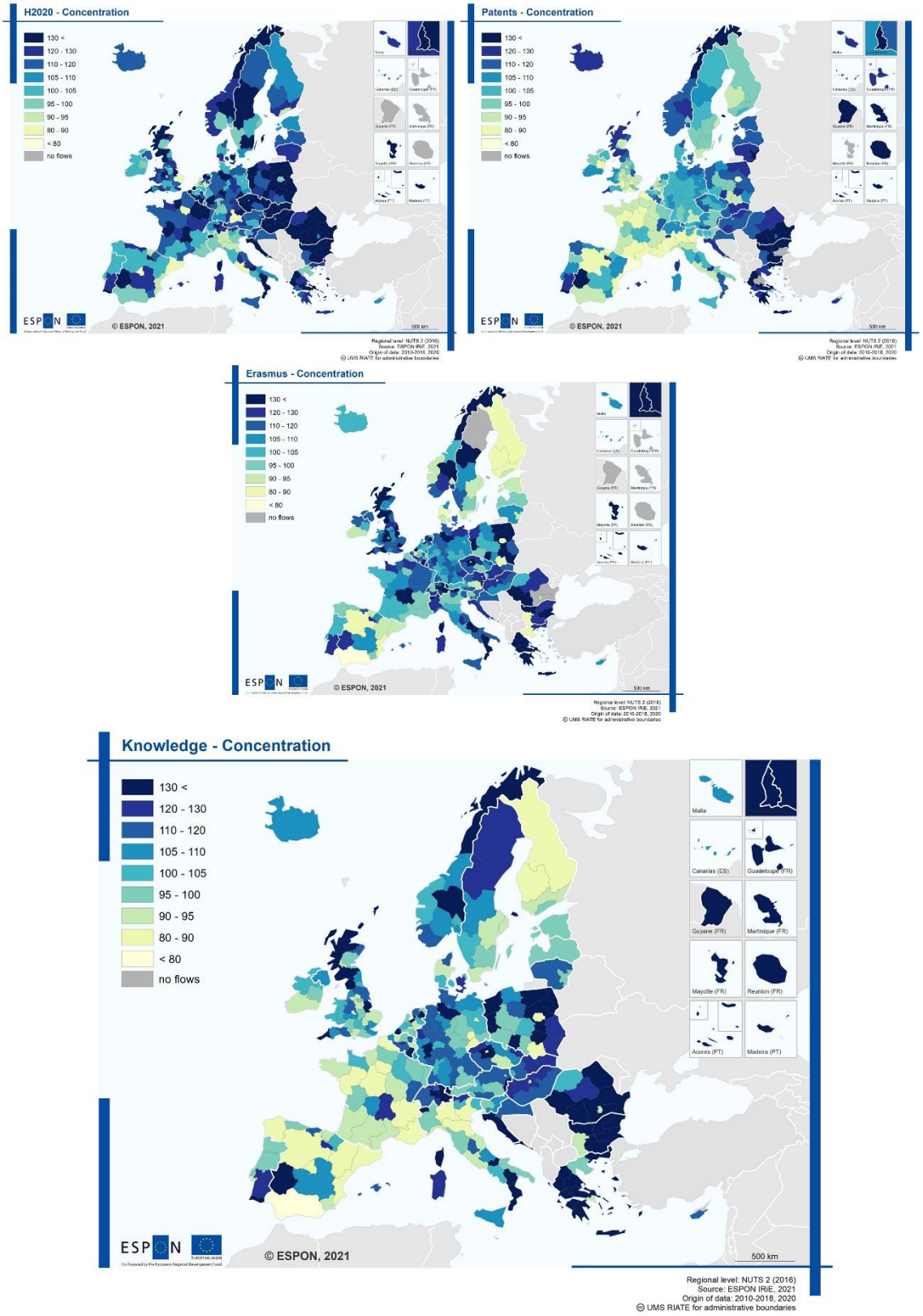


Figure 3.26: Knowledge. Concentration dimension. Concentration index (Gini index)

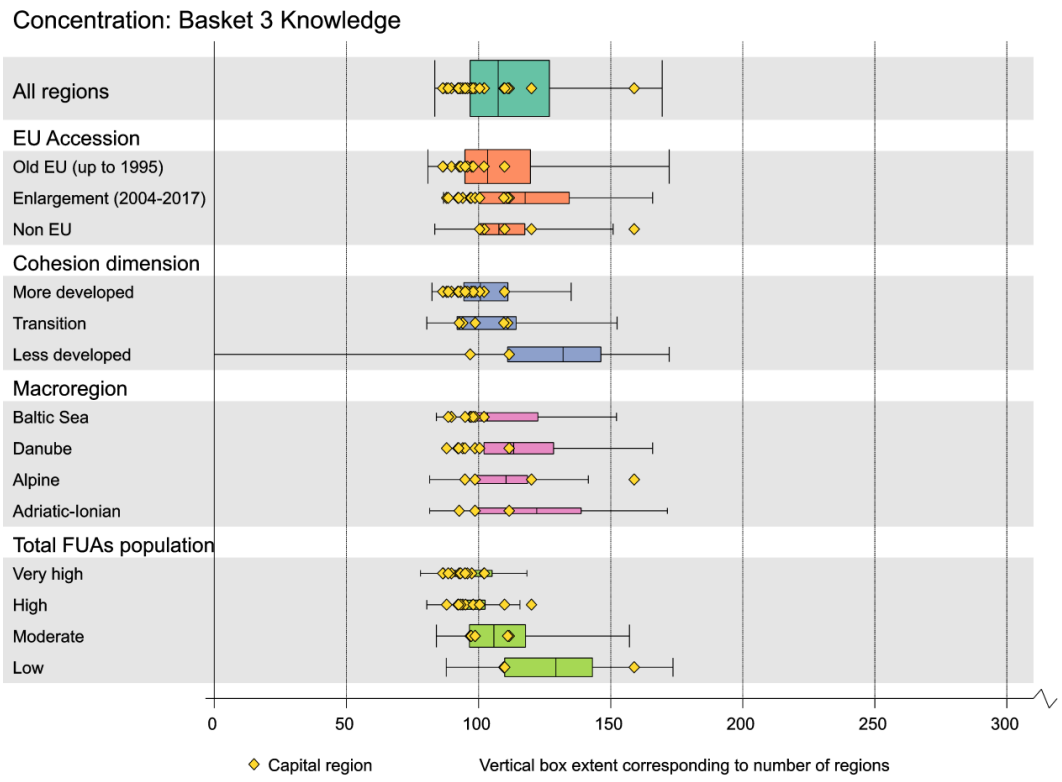


Figure 3.27: Synthetic indicator. Concentration dimension. Concentration index (Gini index)

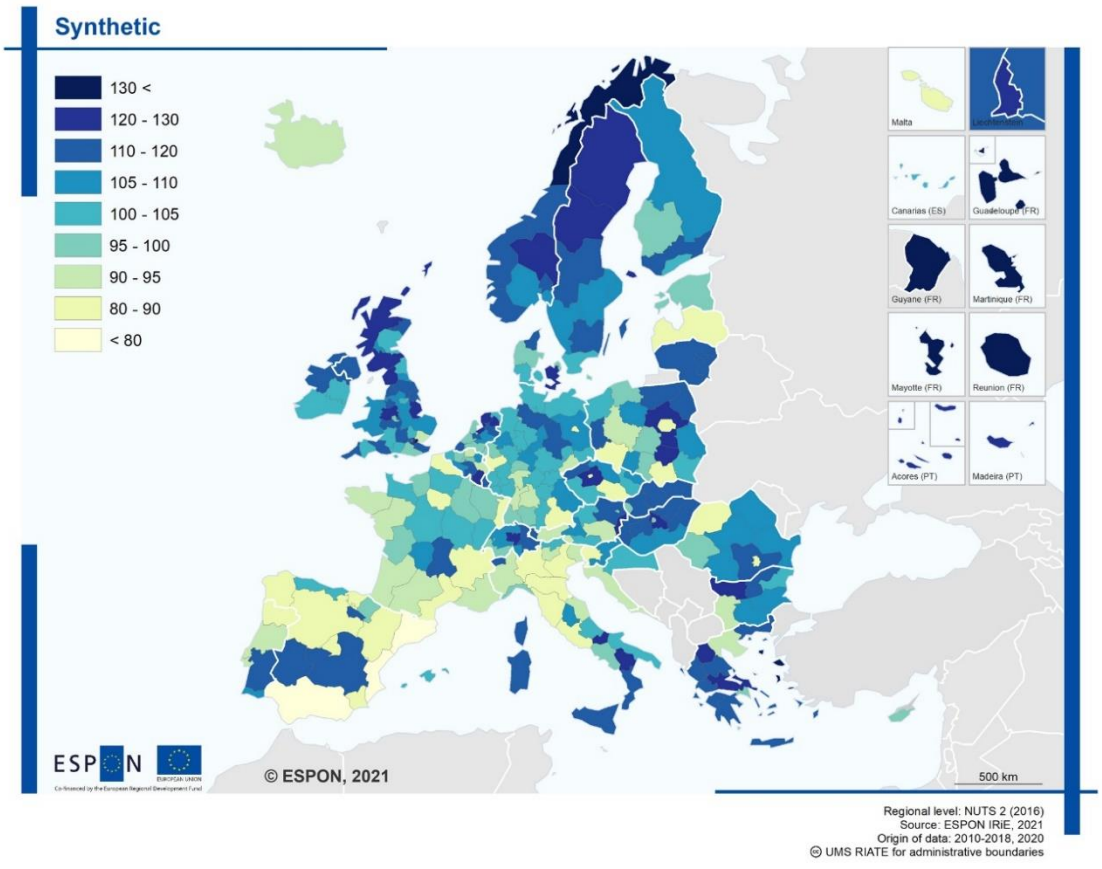
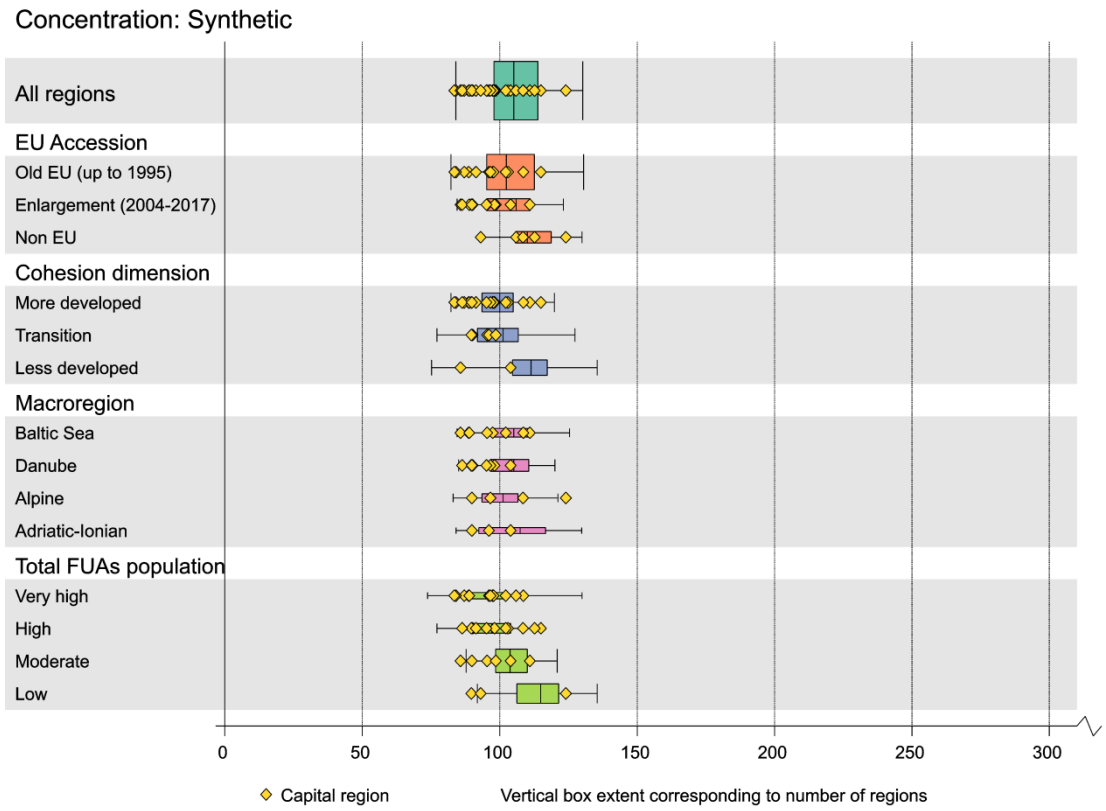


Figure 3.28: Synthetic indicator. Concentration dimension. Concentration index (Gini index)



3.3.2 UK (Brexit) dependency index

A separate part of the analysis is devoted to the share of flows from and to the UK regions. This can conventionally be referred to as dependence on the United Kingdom. It is also an indirect measure of sensitivity to Brexit-related changes. When interpreting the results, we must remember that a high UK share does not necessarily imply a collapse of a particular category of flows after the UK's exit from the EU. Because of the percentage capture, high UK shares can also be recorded in regions where specific flows are generally of low importance.

Figure 3.29 shows the percentage share of **economic relations with the UK**. The indicators show spatial concentration. For trade in goods and services and for freight, the role of distance from the UK is evident. In the case of FDI, the dependence is practically invisible. A very high share of **UK trade flows** is recorded in Ireland, as well as in the coastal regions of northern France, Belgium, the Netherlands, northern Germany and Norway, western Sweden, and Iceland. In the rest of Europe, trade links with the UK are often stronger in coastal regions (Poland, Italy, Spain). Higher shares are also found in single NUTS 2 units of Germany and Switzerland, and also in Cyprus. In Central and Eastern European countries a surprisingly high share of exchanges with the UK is found in Latvia and in the Polish Pomeranian Voivodeship. The UK's share of transport flows (goods freight) has a similar distribution. However, there is a higher (relative to trade) concentration of units with a high share in the UK's coastal areas. In some, the UK's share in transport goods flows is even higher than in trade. This is also the case in Ireland. The reason for this may be the concentration of logistics functions in areas adjacent to the UK (land and maritime relations). In most of the other regions on the continent, the share of the UK is much lower and generally does not exceed 2.5% (also in units, where in the case of trade it was about 5%). A comparison of the two maps shows that trade links with the UK, although weakening with distance, can be important components of regional economies even in remote units in southern and Central-Eastern Europe. At the same time, the more remote regions do not generate strong logistical linkages, which may indicate a lower dependence of industries on transport and the technological development of the branches in which economic cooperation takes place. At the same

time, units with major ports (and border regions in Ireland) remain economically dependent on freight transport to the UK alone.

The UK's share of **services** flows is generally lower than that of trade. By far the highest is recorded in Iceland, Ireland, in the coastal units of France, Belgium, and the Netherlands, and also in some tourist regions of southern Europe (southern Portugal, Greece, Cyprus, Malta). It is surprisingly high again in Latvia. Also notable is the large share of the UK in service flows to and from Luxembourg. In other countries there are only isolated NUTS 2 units where the role of the UK is higher than 2.5% of service flows. These are both highly industrialised (like Lower Saxony) and agricultural and peripheral units (like eastern Hungary).

For the UK's share of **FDI flows**, the spatial distribution is more difficult to interpret. To some extent it resembles a mosaic. It reflects both financial investment flows (high shares recorded in Luxembourg, Paris, Amsterdam, Stockholm) and British greenfield investments in many, often peripheral, areas of Europe (including Poland, Romania, southern Italy, Croatia). The capital cities of many countries are the units that concentrate a largest share of FDI relations. A high proportion of investment links with the UK also occurs in some tourist regions.

The **synthetic picture** of the UK's role in the external economic interrelations of the regions is the result of a coherent distribution of trade, services, and goods transport flows, on the one hand, and financial flows associated with FDI, on the other. We can consider the following factors as determining the spatial distribution of the importance of economic interdependence with the UK: a) land neighbourhood (Ireland), b) geographical proximity to the regions of continental Europe; c) locations of large sea ports; d) attractiveness for tourism and settlement (Mediterranean Europe); e) locations of national capitals and other financial centres; f) low fiscal burdens (Luxembourg, Ireland); g) attractive investment locations in peripheral areas (Central and Eastern Europe).

Passenger flights to and from the UK (Figure 3.30) accounted for a very large share of European air traffic during the 2010-2018 study period (before Brexit and the COVID-19 pandemic). In many regions, their share exceeded 30 or even 50%. It was lower in areas closer to the UK (northern France, Benelux, northern Germany), where the larger share of trips was probably made by other modes (ferries, Eurotunnel, individual vehicles, rail). The proportion of air travel directed to the UK increased with distance, towards both the south (tourist destinations) and east (journeys by economic migrants and their families). It was smaller in Scandinavia, which may be explained by the high intensity of internal flights in these countries. The highest shares of UK air traffic were recorded in southern Portugal and Spain, Greece, Malta, and Cyprus. In Central and Eastern Europe, more than 50% of the traffic in this direction was recorded by certain regional airports in Poland (except Warsaw) and Lithuania (except Vilnius). In general, in the macroregion, the share of the UK was generally lower at major airports in capitals (more geographically diversified structure of flights). The high proportion of air traffic to the UK recorded in neighbouring Ireland is also characteristic.

Air traffic is derived from other flows of people, including both business travel (reflecting economic ties) and tourism and migration-related travel (trips to one's country of origin, family visits). Dependence on the UK in **migration flows** is characterised by a high concentration in several countries and regions. A very high proportion of migration flows towards this country (more than 30%) was recorded in 2010-2018 in Ireland and throughout Lithuania and Latvia. The first case is partly intra-island migration between Northern Ireland and the Irish Republic. The second is a picture of a very strong outflow of labour migrants to the UK after the accession of these countries to the EU. In absolute terms, these migrations were more numerous from Poland (almost all NUTS 2 units), but the percentage share was lower there (about 10-15%) because of the size of the country and the much bigger role of internal migration plays there than in the Baltic States. In addition, migration to the UK from the countries of Central and Eastern Europe has been relatively more significant in Estonia and some regions of Romania. A separate group are the southern European regions, where the role of the UK is significant because of immigration from the UK. These include Portugal, coastal Spain, central Italy, Sardinia, Sicily, Malta, and Cyprus. The UK also plays a noticeably larger role in migration to and from all regions of France (especially Paris) and some units of northern Italy, Switzerland, and the Netherlands. The UK's share of migration is very small in Germany, Scandinavia, and the rest of Central and Eastern Europe (Czechia, Slovakia, Hungary, Bulgaria, Croatia, Slovenia). In summary, we can conclude that the greatest migration dependence on the UK is shown by the following types of units: a) regions in emigration countries, which provided the UK with a large number of workers after accession to the EU in 2004 (Poland, the Baltic States, Romania); b) regions in neighbouring countries (Ireland and to some extent France); c) regions attractive for UK citizens to settle in (coastal and island units by the Mediterranean); d)

some capital regions associated with two-way migration of skilled workers (Paris, Amsterdam, Madrid, Warsaw).

In the case of **labour mobility**, the role of the UK is large only within Ireland (regions bordering Northern Ireland). Small percentages recorded in other European countries (France, Spain, single emigration regions in eastern Poland and Romania) should be treated rather as hidden (unregistered) migration, or as teleworking.

The spatial pattern of the UK's share of **tourist flows** coincides mainly with the most important destinations of British citizens. The highest values are recorded in France, Spain, and Portugal, especially in the coastal and island regions of these countries. A high share is also found in Greece, Cyprus, and Malta, as well as in neighbouring Ireland and Iceland. From the countries of Central and Eastern Europe, a higher proportion of tourist relations with the UK can be observed in Croatia, Czechia, Hungary, and the Baltic States. There is relatively high traffic to the UK from Scandinavia, and to some extent in France and the Benelux countries.

A **synthetic picture of the importance of people flows to and from the UK** (based on four indicators) shows that (unlike with economic flows) geographical distance does not play the most important role. Many regions remote from the UK have strong social ties to it. This is due to migration (the British labour market hinterland after EU enlargement), the pattern of traditional tourist destinations, and even colonial dependencies (Cyprus, Malta). And it is complemented by flows generated secondarily to economic linkages. These include the migration of highly skilled professionals and business trips (included in tourism). Such flows in relation to the UK are of above-average importance in many EU capitals and some other economically strong and/or financial services regions. As compact zones strongly "dependent" on the UK (in terms of people flows), we should mention: a) neighbouring Ireland; b) the Mediterranean belt from the Atlantic to Greece, including especially southern Portugal and Spain; c) the Mediterranean and Atlantic islands; c) the emigration area in western and central Poland; d) the emigration area in the Baltic countries. The changes that have taken place after 2018 (Brexit and the effects of the COVID-19 pandemic) may significantly affect regions socially linked to the UK. This applies to Mediterranean tourist regions as well as to emigration units in Central and Eastern Europe.

The UK's share of **knowledge flows** (Figure 3.31) differs from that observed for economic and social linkages. In the case of **H2020 project implementation**, it is generally large and does not show clear territorial patterns. For a large proportion of European regions, the UK accounts for more than 10% of flows of this type. These include both scientifically strong units (with numerous and large universities) and peripheral regions where the overall level of international scientific cooperation is low. A slightly smaller share of the UK is found in some Central and Eastern European units (Poland, Bulgaria).

In the case of **patents**, the greater importance of the UK is observed in peripheral regions, especially in Scandinavia, but also in Central and Eastern Europe (Poland, Hungary, Romania). Units from large Western European countries are not "dependent" on the UK for innovation flows (measured by jointly obtained patents).

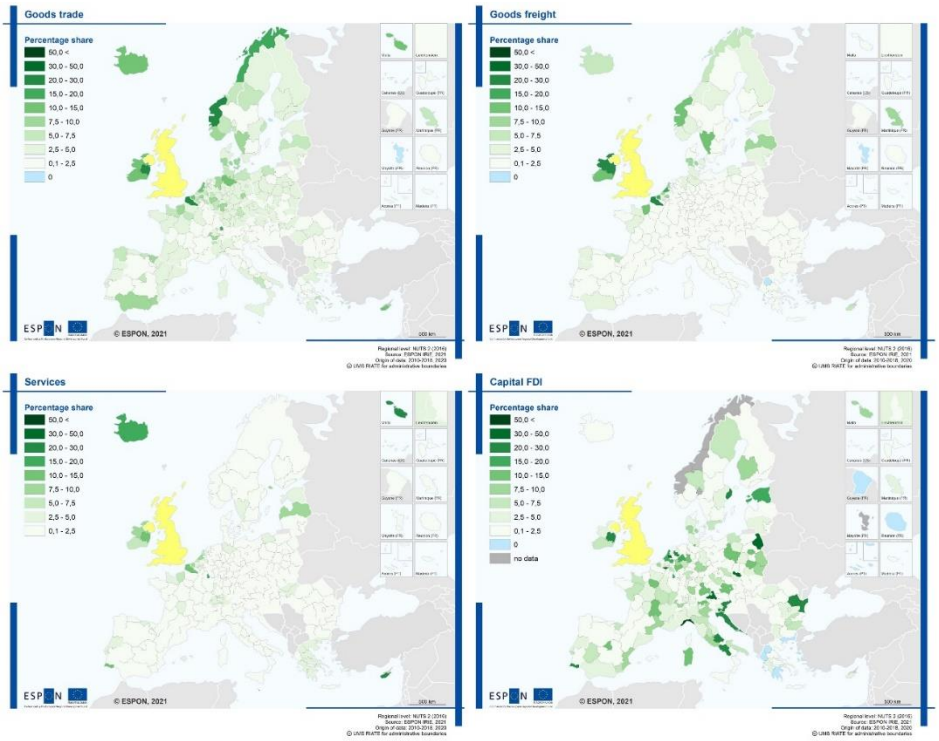
The spatial distribution of student flows within **ERASMUS programmes** is different. The UK's participation in this programme has never been dominant. Flows here were occur mainly between the UK and Western European regions (France, Germany, Spain, northern Italy). Their role is negligible in Central and Eastern Europe, as well as in southern Italy, Portugal, and some parts of Scandinavia.

The **synthetic picture for the share of knowledge flows in relation to the UK** is therefore the result of three mutually uncorrelated variables. Each of the analysed indicators has a different geographical distribution. Therefore, the territorial variations of the synthetic share are relatively small. Regions with the highest synthetic share of flows with the UK are most often those where university cooperation translates into both joint H2020 projects and ERASMUS student exchanges. Such areas include: a) central and southern France and Catalonia; b) southern Scandinavia; c) the Netherlands. Relatively smaller but still significant shares of flows to and from the UK are recorded in Germany, Italy, and Greece.

Figure 3.32 presents a **summary indicator of the UK's importance in interregional flows in Europe**. It allows us to indicate units where this relationship is exceptionally strong and multidimensional. At the same time, the obtained picture may contribute to the discussion on the regional threats posed by Brexit. Units with by far the highest importance of flows to and from the UK (up to 50% of all total relations) include Ireland, the western Netherlands (with Amsterdam), the Portuguese Algarve, Malta, and Cyprus. In addition, high figures are found in Iceland, Latvia, and southern and western France, as well as parts of Scandinavia (especially Norway). The UK (and arguably London in particular) are key destinations for various types of

flows for regions including many European capitals (Paris, Rome, Berlin, Stockholm, Warsaw, Madrid, Copenhagen, Bucharest). In general, the value of synthetic shares decreases as one moves away from the UK towards the east (despite migration relations with Central and Eastern Europe). This confirms the thesis that Germany represents an important intermediate opportunity for the region's economic contacts with other Western European countries, the UK included. German regions are generally characterised by a low share for the UK in most flow types. This is probably partly due to the size of German NUTS 2 units (higher share of internal flows). To some extent, it may also be an expression of the lower complementarity of the German and UK economies. In Central and Eastern European countries, a smaller share of the UK in flows from units surrounding large metropolises (but not from the metropolises themselves) is characteristic. We observe this in Poland, Romania, and Greece. This can be interpreted as a capture of potential flows by a neighbouring metropolis.

Figure 3.29: Goods/services/capital. Concentration dimension. UK dependency index.



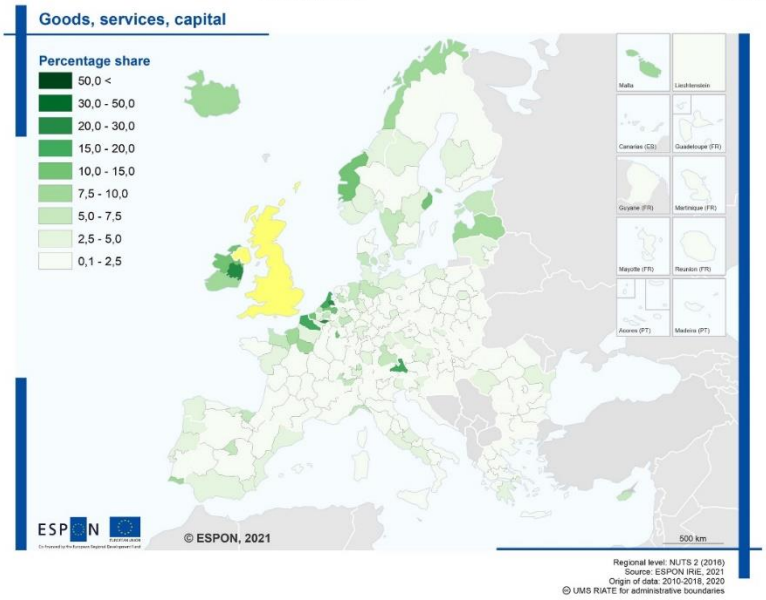


Figure 3.30: People. Concentration dimension. UK dependency index.

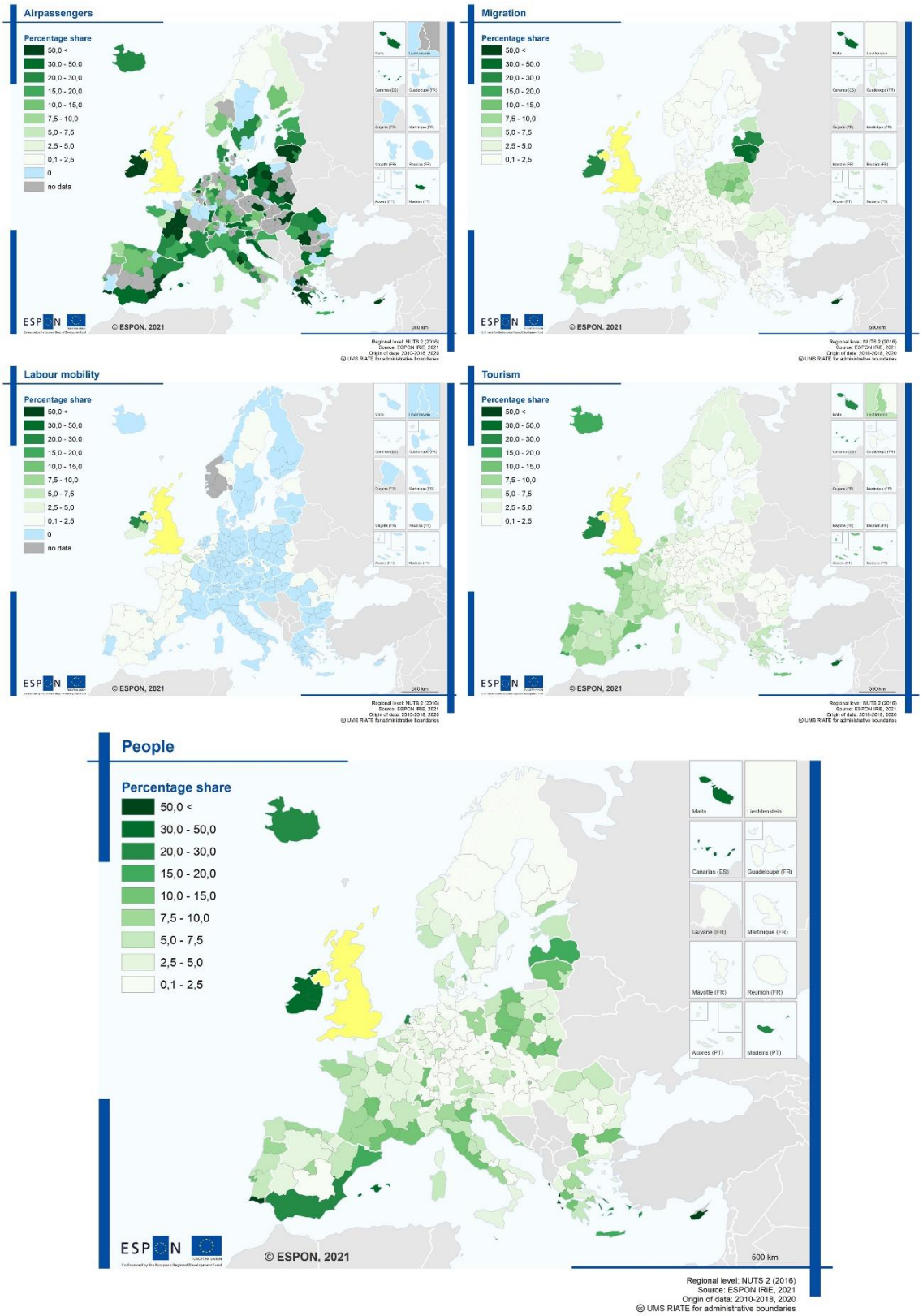


Figure 3.31: Knowledge. Concentration dimension. UK dependency index.

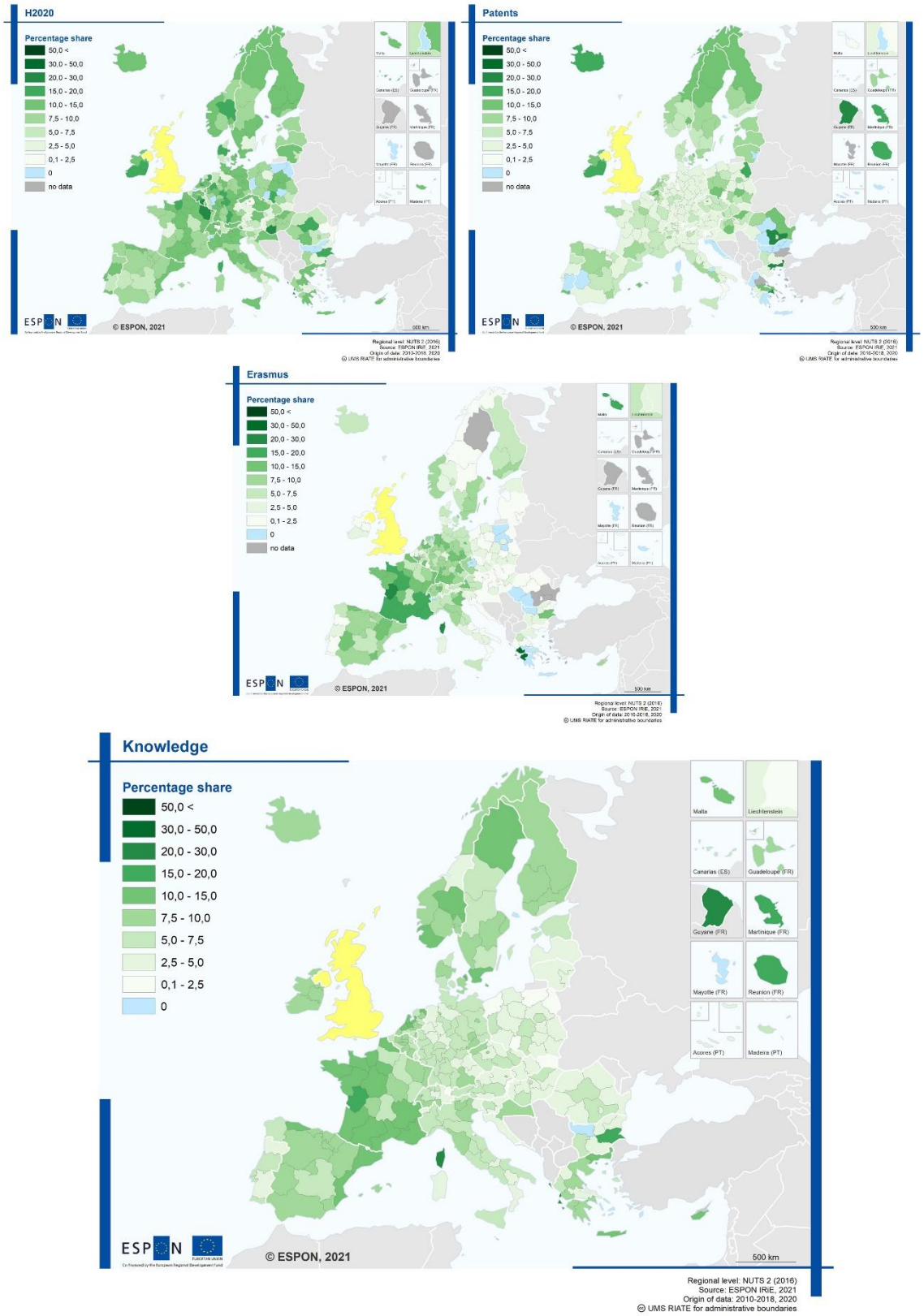
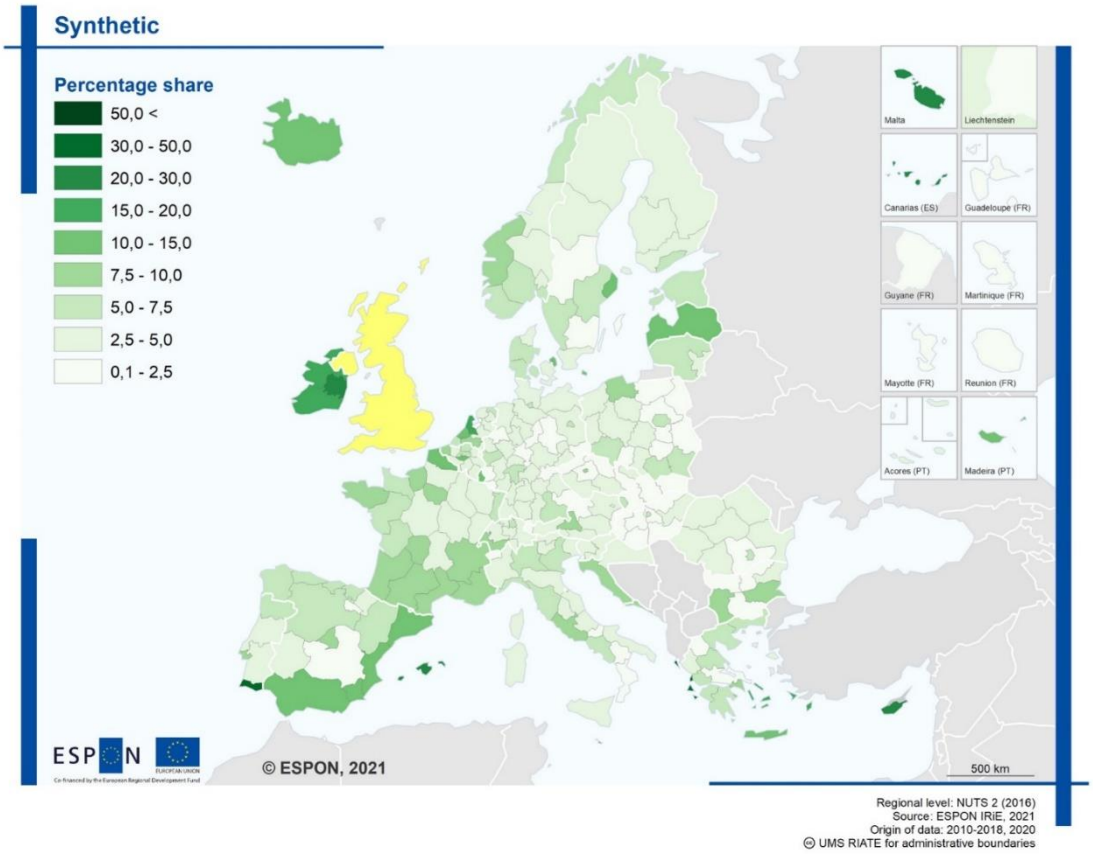


Figure 3.32: Synthetic. Concentration dimension. UK dependency index.



3.4 Distance dimension

3.4.1 Average distance index

For most flows, the average distance increases as one moves away from the European core towards the periphery of ESPON space. The longer the average distance for a given flow, the more visible the centre-periphery system becomes for the entire ESPON space. However, for shorter-range flows, there might be a different system than the dominant one.

In the **goods/services/capital basket**, the abovementioned traditional center-periphery system is maintained for all flows. However, depending on the flow, the area where shortest flows dominate changes. For example, for **goods freight** the shortest flows are in Switzerland, Belgium, the Netherlands, and also England. There are in turn longer distances for goods trade for companies located in Iceland and Cyprus. Iceland and Cyprus are characterised by longer flows. The examples of Bulgaria and of Navarre and Zaragoza in Spain are interesting; the length of flows for their **goods trade** and **capital FDI** is well above the weighted average for the ESPON space, and for goods freight and **services** it is well below the average. The relatively long service flows in Ile-de-France (Paris) are also quite surprising. The spatial pattern of the index for the average distance of economic flows is naturally concentric. The average distance increases with distance from the EU core. This increase is fastest in the case of FDI flows and noticeably slower in services and freight flows. In addition, in peripheral areas there are disturbances in the concentric pattern, most often around larger metropolises, which concentrate a large share of flows from other regions close by.

The **synthetic matrix for the goods/services/capital basket** of average distances points to the center-periphery pattern for ESPON space — with, however, a few exceptions. Distances below the average are also characteristic of selected peripheral areas, such as Castile in Spain, northern Greece, and the Romanian-Bulgarian border. On the other hand, above-average distances occur also in the European core, in particular for regions/countries that have numerous networks of commercial and financial links. These include, among others, Luxembourg and Liechtenstein. The distribution of the indicator shows indirectly the spheres of influence of certain economically strong metropolises. These are separated by belts with higher index values, forming a kind of European inner periphery. They are visible between Paris and Madrid and Barcelona (southern France has a greater average distance of economic flows than central Spain), as well as between Berlin and Warsaw and between Vienna and Budapest.

The **box-plot analysis** indicates longer distances for new member states from the 2004-2013 enlargements, located on the periphery of the ESPON space, both in the east and in the Mediterranean (Cyprus and Malta). Longer flow distances are also seen in less-developed regions, although the difference between more and less developed is not large. The longest distances for macroregions, because of their peripheral location, occur for the Baltic Sea macroregion. Selected metropolises, which are characterized by numerous connections in a network, are also characterized by relatively long connections. Regions with very high total FUA populations are also characterised by significantly long flow distances. This confirms the thesis that they operate in a pan-European network where distance is less important, while for other regions the distance factor remains dominant.

The **people basket** is much more diversified internally, between flows, in the context of average distances, than the goods/capital/services basket. For **air-passenger** flows, green dominates the map, because most of the regions where airports are located are small ports that transport mainly passengers to larger hubs, over rather short distances. Examples are airports located in northern Scandinavia where most connections are domestic. On the other hand, in particular in tourist regions of southern Europe, numerous long-distance charter flights make it impossible to talk about the traditional core-periphery pattern for air passengers in ESPON space.

In the case of **migration** in the core of Europe, there are indeed mainly shorter distances. However, this is also true of the smaller countries of Central and Eastern Europe, such as Hungary and Slovakia, where migrations are carried out mainly at the national level, as in southern Sweden and Norway as well as the whole of Finland. In turn, the Baltic countries — especially Latvia, which ranks third in Europe, after Iceland and Cyprus, in terms of the average distance of the migration flow in the ESPON space — are characterized by particularly long distances. Some political borders very clearly mark the limits of shortening/extending the average length of flows. This is especially true for Germany's eastern and western borders. The explanation is above all the size of the NUTS 2 units (clearly smaller in Germany than in Poland and France).

For **labour mobility**, the situation is optimal in the European core, where average commuting distances are shortest. These distances lengthen as we move away from the European core, but the growth rate of average distances is faster in peripheral areas than around capitals. A difference between the periphery and the capital can be seen in, for example, Romania, Hungary, Czechia, and Austria. Although it is not the rule, then, we can speak of a domestic center-periphery system also for labour mobility. On the other hand, the group of regions where traditionally, regardless of flows, long distances dominate are Mediterranean islands: Sardinia, Sicily or the Balearic Islands.

In **tourism**, the core-periphery pattern in the context of the entire ESPON space is almost perfect, although very short distances are also visible in peripheral Slovakia. For the northern regions of Scandinavia, moreover, there are interesting differences between the average distance for tourism (long distances) and for air passengers (short distances). These differences may result from frequent business trips within countries and rare but long tourist trips, e.g. to the Mediterranean Sea.

The **synthetic matrix for the people basket** shows certain that clusters/hotspots of regions are characterized by short distances. One such cluster lies in northern Hungary, western Slovakia, eastern Austria, Slovenia and south-central England. Short journeys are also the domain of the Swiss. On the other hand, longer distances are less visible in northern Scandinavia (the effect of shorter domestic flights) but observed in Helsinki and Latvia. Longer flows are clearly visible in many metropolitan areas, while shorter flows are observed in their surroundings (dominance of migration and labour mobility to the nearest large city). Longer flows are also seen in coastal regions and Mediterranean islands (tourism and long-distance migration). In some of the larger countries there is also an internal tourism factor (coastal or mountainous regions away from big cities). This is evident in France, Poland, and Italy.

The **box-plot analysis** indicates significantly shorter distances in countries outside the European Union, and in the Alpine macro-region (in both cases, Switzerland is mainly responsible for this result). On the other hand, long distances are typical for less-developed regions, for the Baltic Sea and Adriatic-Ionian macroregions, as well as for the urban regions that form a network of people flows in the ESPON space.

Of all our analyzed baskets the **knowledge basket** presents the clearest core-periphery pattern in the ESPON space. In particular, the **patents** spatial pattern is nearly identical to the distribution of potential accessibility at the European level. The center of the system — between Belgium, Germany, France, and Switzerland — is clearly marked and is characterized by shorter distances. The spatial distribution of average distances for **H2020** and **Erasmus** is very similar. However, for individual regions, large differences can be noticeable. For example, for the Podlaskie voivodeship (northeastern Poland), very short distances for H2020 are accompanied by very long distances for the Erasmus program. Defined by the length of knowledge flows, the core area of Europe is at its most spatially restricted for patents and at its least restricted for Erasmus student flows.

The synthetic matrix for the knowledge basket reveals short distances for the European core, slightly shifted also to the east and clearly reaching the German-Polish and German-Czech borders. The longest distances are in Cyprus, Crete, Iceland, and the north of Norway and Finland, and, quite surprisingly, in the Podlaskie Voivodeship in northeastern Poland.

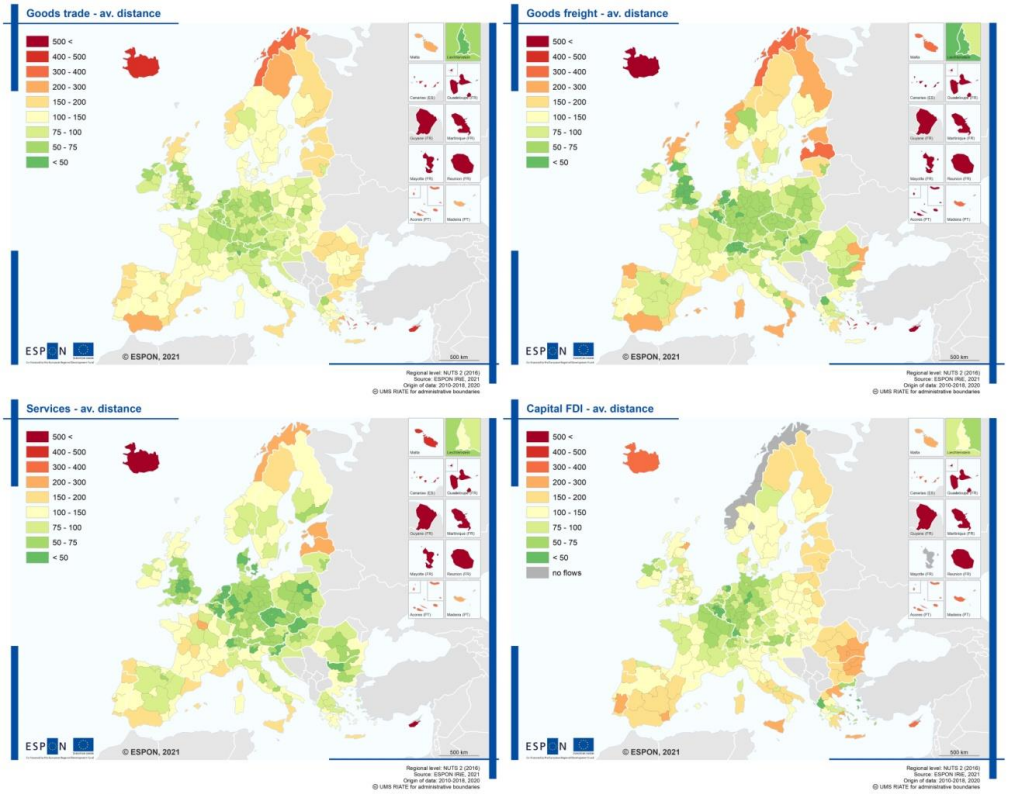
The **box-plot analysis** shows very large differences in distances between region groupings. For example, because of their peripheral location and relatively small network of knowledge, regions in countries that joined the EU in 2004-2013 indicate large distances in knowledge flows. Also, less-developed regions and rural regions are definitely characterized by long distances of knowledge flows. In turn, these types of flows are shortest in the Alpine macroregion.

A **synthetic matrix of 11 flows** shows the shortest distances in the metropolitan systems of Prague and Budapest (focus on flows to and from the two capitals), as well as in a relatively large number of regions in Belgium, the Netherlands, and the United Kingdom. On the other hand, the longest average distances are seen in Iceland and Cyprus, followed by northern Norway, Crete, and Athens, and in Andalusia, Algarve, and Lisbon. The pan-European picture shows a compact core area (dominance of low average flow distances) including Germany, Denmark, Benelux, northern France, Switzerland, Austria, Czechia, and Hungary, as well as England, northern Italy and western Poland. Within this area, several metropolitan areas, including Paris, Franfurt, Brussels, Berlin, Prague, and Budapest, are characterised by larger average relationship distances. Around this zone, the indicator of average distance increases significantly and then decreases again in the vicinity of some metropolises. We may assume that these metropolises balance the polycentric structure of the European settlement network. They take over some of the interactions for which

the EU core becomes too geographically distant. Madrid, Rome, Athens, Warsaw, and Bucharest play this role. In the most peripheral zone the increase in the distance of average flows is determined additionally by their attractiveness for migration and tourism.

Our **box-plot analysis** indicates shorter distances in countries outside the EU and in the Alpine macroregion. In both cases this is due primarily to the short distances in Switzerland. Longer distances, in turn, are characteristic of less-developed regions and the Adriatic-Ionian macroregion.

Figure 3.33: Goods/services/capital. Distance impact. Average distance index (total=inflow+outflow).



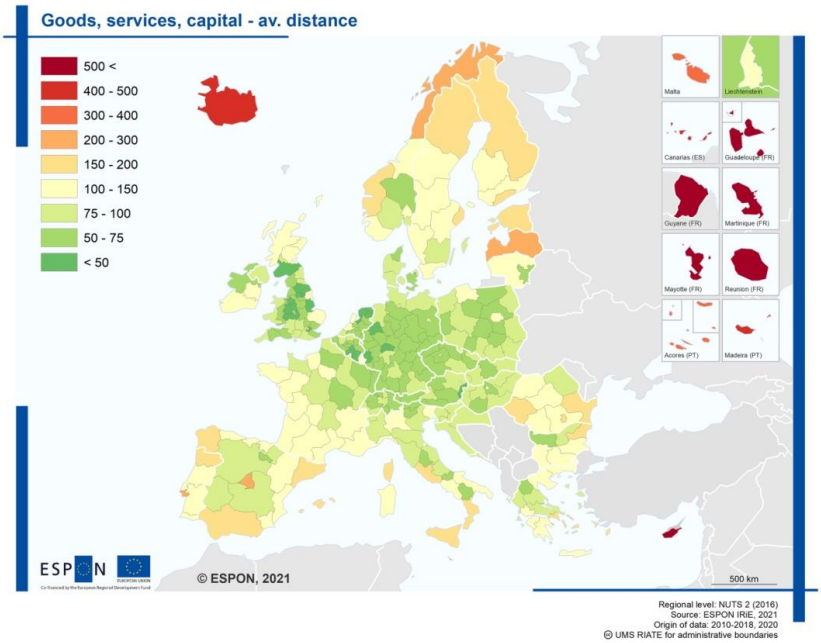


Figure 3.34: Goods/services/capital. Distance impact. Average distance index (total=inflow+outflow).

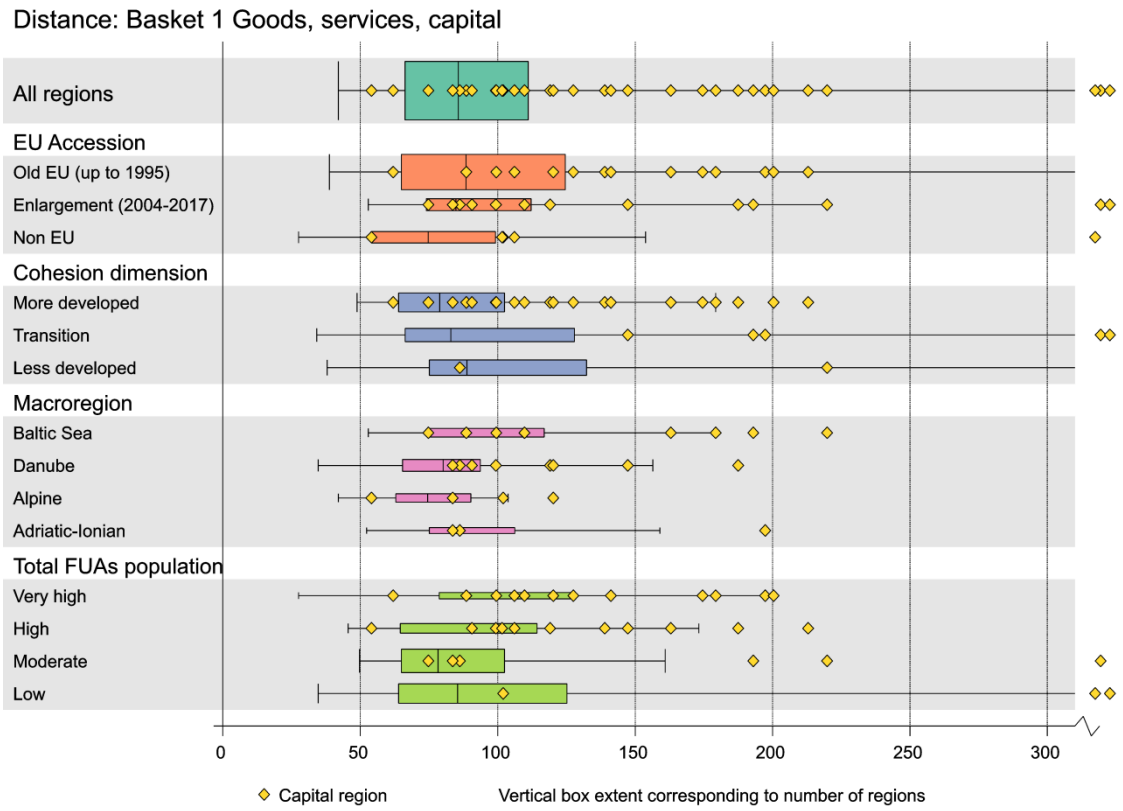


Figure 3.35: People. Distance impact. Average distance index (total=inflow+outflow).

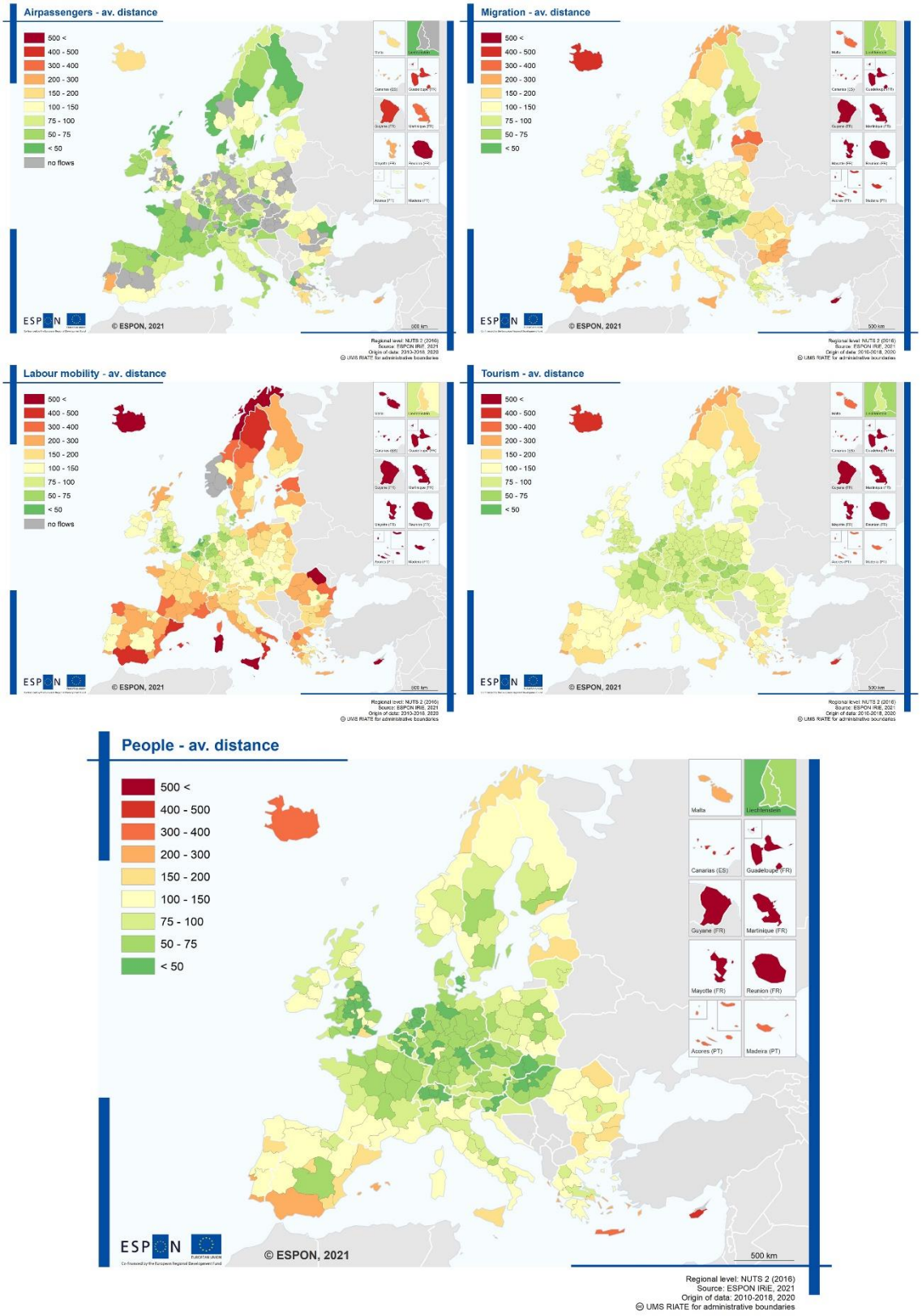


Figure 3.36: People. Distance impact. Average distance index (total=inflow+outflow).

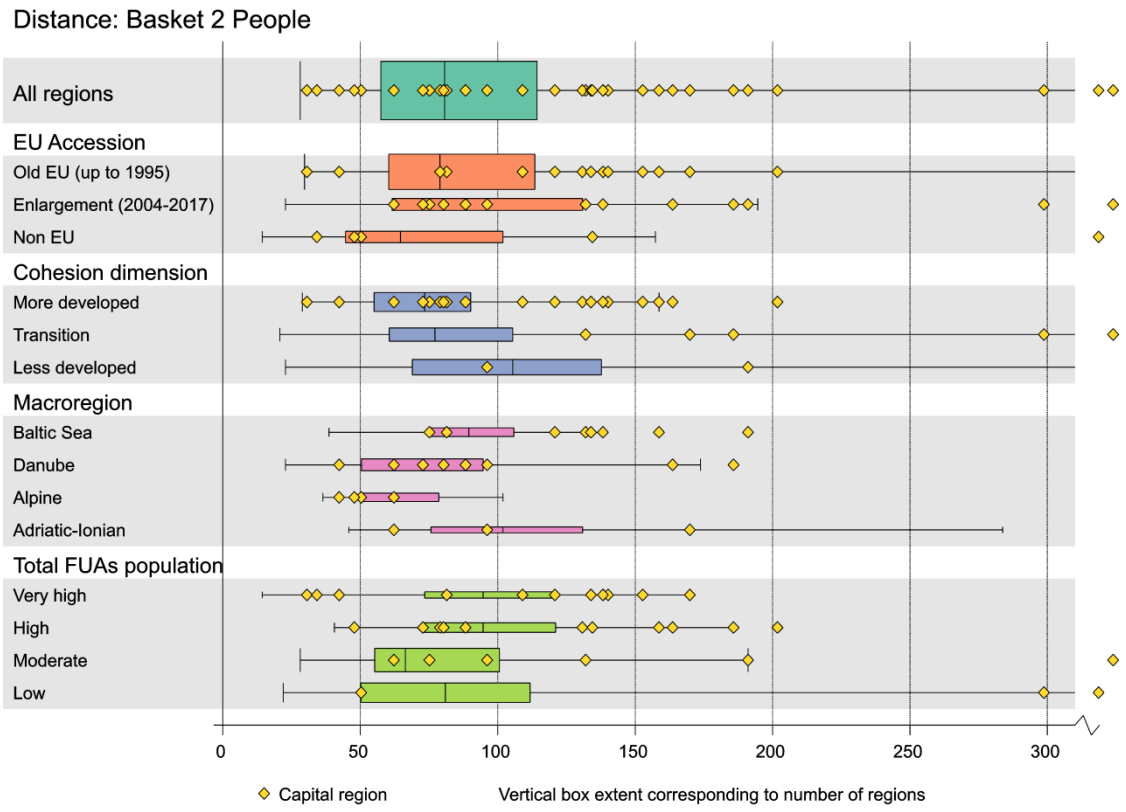


Figure 3.37: Knowledge. Distance impact. Average distance index (total=inflow+outflow).

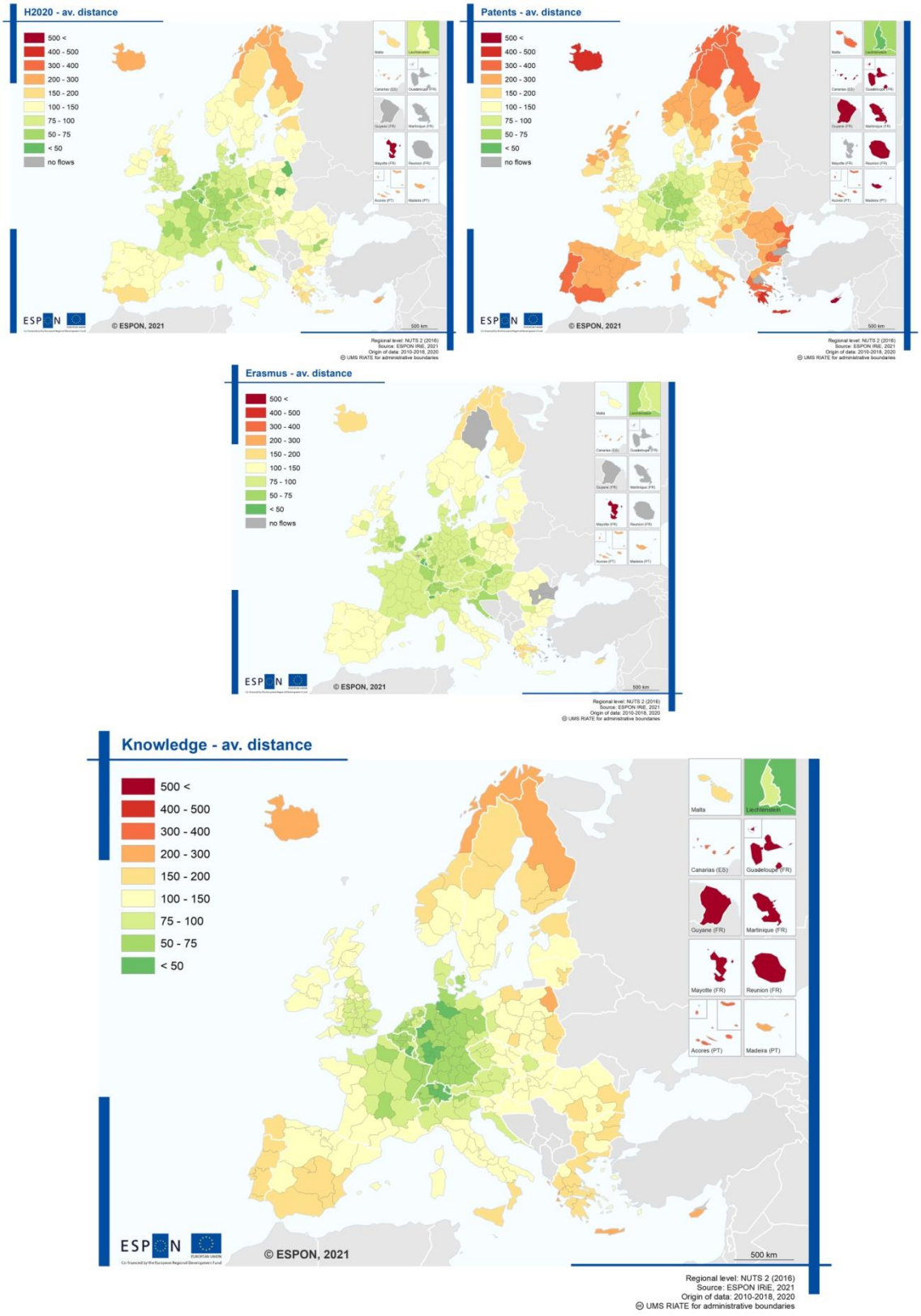


Figure 3.38: Knowledge. Distance impact. Average distance index (total=inflow+outflow).

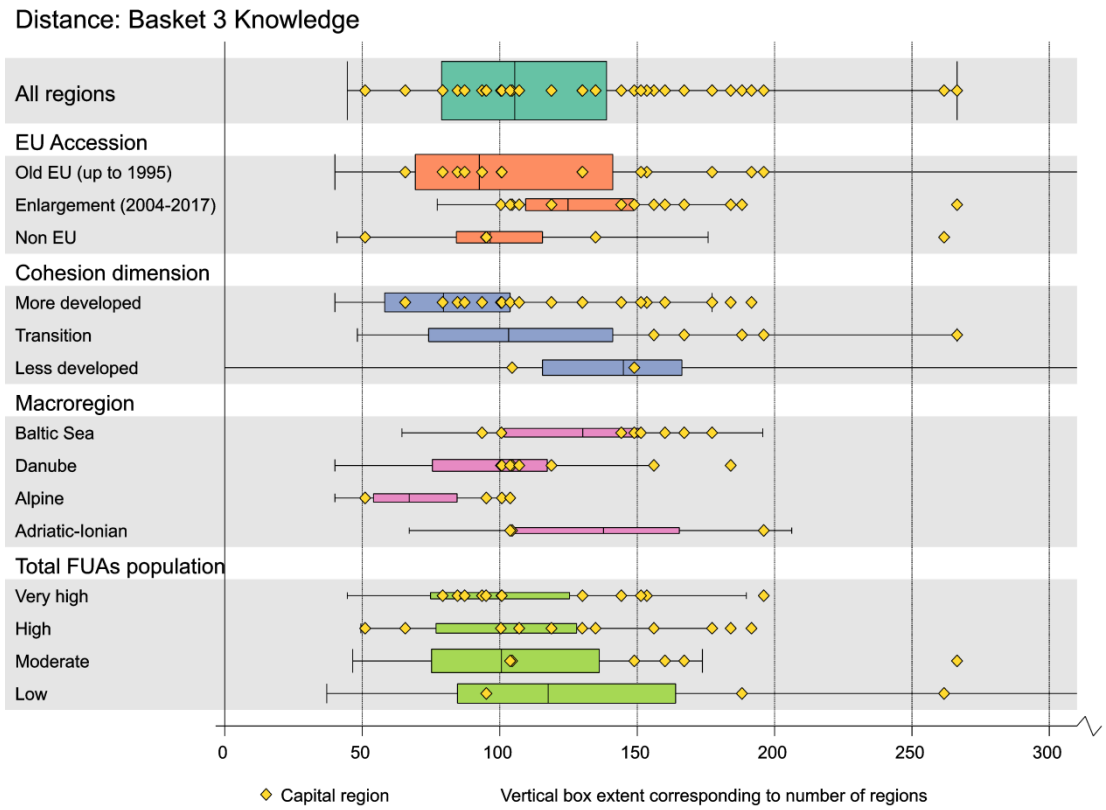


Figure 3.39: Synthetic indicator. Distance impact. Average distance index (total=inflow+outflow).

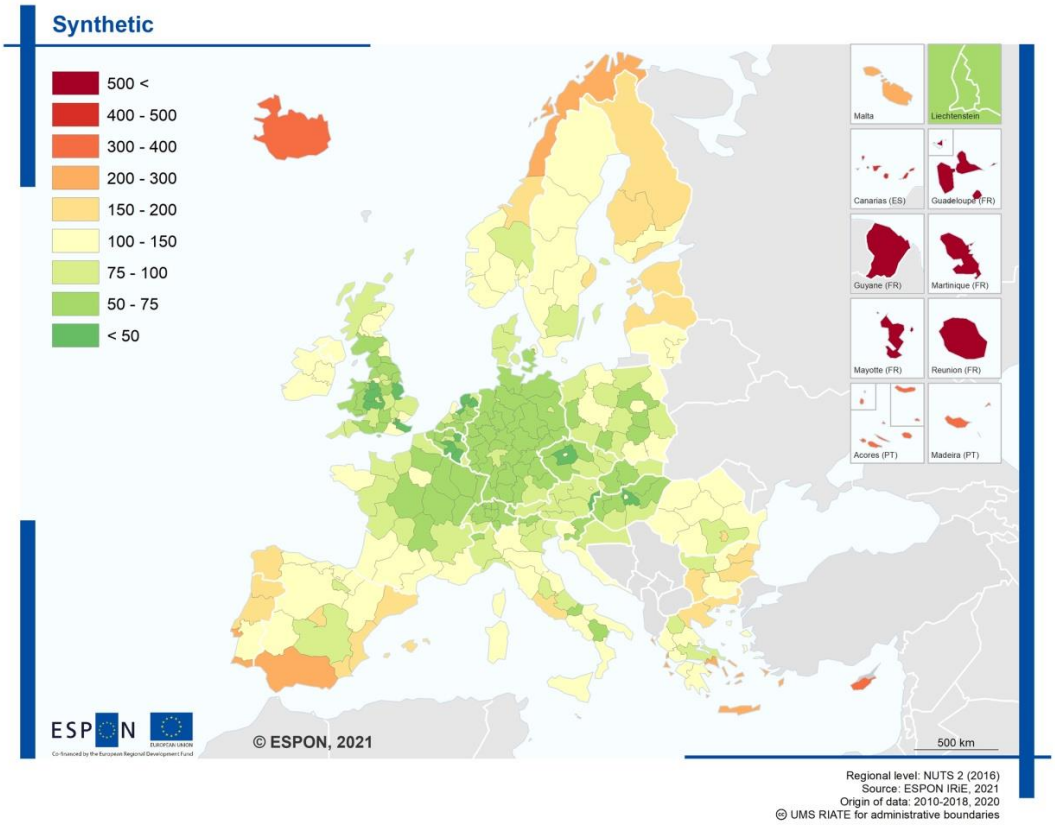
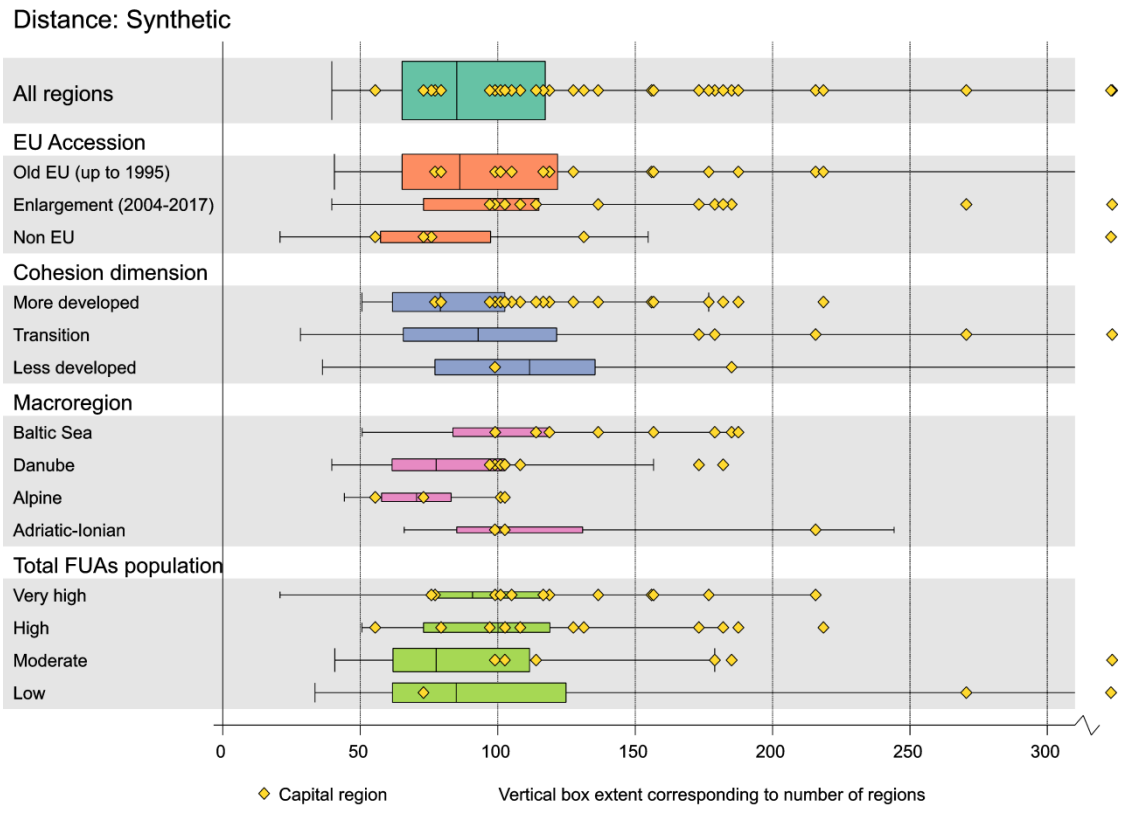


Figure 3.40: Synthetic indicator. Distance impact. Average distance index (total=inflow+outflow).



3.4.2 Border-effect index

The **border-effect index** shows the region's dependence on international relations. For our border-effect analysis, we abandoned the basket approach. The reasons are as follows: (1) a country's size and the number and density of its NUTS 2 regions have a decisive impact on the indicator, which distorts its universality and comparability for the entire ESPON space at the basket level; (2) for Erasmus student flows, intra-country flows do not exist, so our analysis looks at only two knowledge flows (H2020 and patents).

The obvious conclusion from the analysis is that small countries are more dependent on foreign flows than large countries. Moreover, border regions are usually subject to a greater exchange of international flows than central regions, the most remote from the border. Thus, it is particularly interesting to compare large countries in the ESPON space.

An analysis of flows of **goods trade** and **goods freight** shows that the key to internationalization of regions for trade is proximity to the European core. Regions that in a given country are located on the border with a country closer to the European core are more open to international trade within the ESPON space. This applies also to countries located in the European core, where a particularly large share of international trade is on the Franco-German border. The above conclusion, however, especially applies to countries such as Poland, Romania, and Hungary (although in the last case it is mainly the specificity of goods freight). Thus proximity to the European core tends to increase the share of international trade in the exchange of goods on a regional basis.

The situation is different in Scandinavia, where the northern parts of Sweden, Norway, and Finland, being particularly far from the European core, have relatively strong international trade ties (mainly with neighboring countries). In Spain, the region that belies the conclusions of our analysis is Andalusia, where, despite significant distances to other countries in the ESPON space, the share of international flows in the flows of goods traffic is particularly high, especially by tonnage (goods freight).

In the case of trade in goods and **services**, certain capitals and other large cities are clearly dominant. They are more dependent on international flows (compared with other units in their own countries). Such is the case of Madrid, Warsaw, Prague, and Vilnius. The same pattern is not so visible in goods transport, where the dominance of internal traffic is (especially in Poland and Spain) common. In the case of services, northern France is characterized by high internationalization, whereas in Germany, Spain, Italy, and the United Kingdom flows related to services show much greater concentration in internal flows.

Capital FDI flows take on much more of a mosaic pattern in the large countries of the ESPON space. However, there are compact areas of strong international capital flows. Northern Italy is more internationalized in this respect than southern Italy, and western Germany's international capital flows are similarly more international than eastern Germany's. The Central-Eastern Europe states, as well as Denmark and England, are internationalized to a greater extent than other countries of Western Europe, especially the large ones. It is astonishing that the level of internationalization of FDI flows in Ireland is low. While in the UK internationalisation is associated with investment links between UK companies, in Central and Eastern Europe this is the result of FDI inflows from other countries. Against this background, we should note that some of the most peripheral regions of these same countries remain more dependent on domestic capital (e.g. eastern Poland and eastern Romania).

The share of domestic **air-passenger** flows is by far highest in the north of Scandinavia, where most flights are internal to Scandinavia, with Oslo, Stockholm, and Helsinki as destinations. The situation is similar with certain Mediterranean islands, such as Sicily, Corsica, and Sardinia, as well as with Scotland and certain Spanish and French regions that are heavily dependent on national hubs. In smaller German airports, the dominance of connections to the main German hubs is much lower (with the exception of Saxony and Mecklenburg). In turn, in the countries that joined the European Union in 2004-2013, only single regions (like Ostrava) have strong national connections. For Central and Eastern European states, international connections are dominant; this relates to another flow: migration. The share of domestic flights is surprisingly high in France and Spain, which have well-developed high-speed railway networks. A much smaller share of domestic flights is seen in Italy (except for the islands and Calabria) and especially in Germany.

There are countries in the ESPON space where the share of internal **migrations** is particularly high. These are Great Britain and the Scandinavian countries, but also Greece and partly Hungary, Czechia, and the Netherlands. On the other hand, international migrations dominate in Poland, Romania, Bulgaria, Croatia, Slovakia, Portugal, and the Baltic states, and also (although in this case it is more receivers than senders)

in Switzerland, Ireland, and Iceland. In addition, in some countries there are large internal differences between regions. In Spain, for example, Extremadura has an especially high share of internal migrations, while Catalonia and Valencia are regions strongly focused on international migration. In several countries, internal migration patterns are visible, disrupting the dominance of foreign migration. This is particularly the case in Poland and Romania. The local metropolises of Warsaw and Bucharest are alternatives to foreign destinations. In Western European countries the situation is the opposite. Metropolises are characterised by a higher share of international migration, which results from the mobility of highly skilled workers. This is the case in Paris, Madrid, Berlin, and Stockholm.

In the case of **labour mobility**, it is difficult to generalize. Of course, there are areas with a high degree of daily labour mobility across national borders, such as the regions bordering Luxembourg, Scania (Malmo), and Copenhagen (ESPON METROBORDER, 2010). On the other hand, surprisingly high shares of foreign trips to work are recorded in regions farther away from national borders, such as Romania and Spanish Andalusia. In many cases, however, these are units where the overall volume of labour mobility outside the region is very small and part of the labour mobility is unregistered migration or teleworking.

In **tourism**, domestic flows are particularly important in large Western European countries and in Scandinavia (except Denmark).

The internationalization of knowledge flows related to the implementation of projects in the **H2020** program is often rather random, especially in the case of peripheral and more autarkic regions. Few projects in peripheral regions of Poland and Romania are implemented with national or international partners, which makes the spatial pattern resemble a mosaic. On the other hand, the smaller countries of the ESPON space and the Scandinavian countries are definitely more evenly focused on international cooperation in H2020 projects.

Patents present a completely different spatial pattern from that of other flows. The domination of Germany is visible also in the context of patent internationalization. The spatial pattern in ESPON space shows very strong internal ties between the regions of Germany, while in other countries there are strong international ties. Such is the case also in Switzerland and Austria, whose involvement in the flow of patents is equally strong. Such large differences between Germany and the rest of the ESPON space in the internationalization of patent flows require further methodological and database work.

Figure 3.41: Border effect for goods trade, goods freight, services, and capital FDI

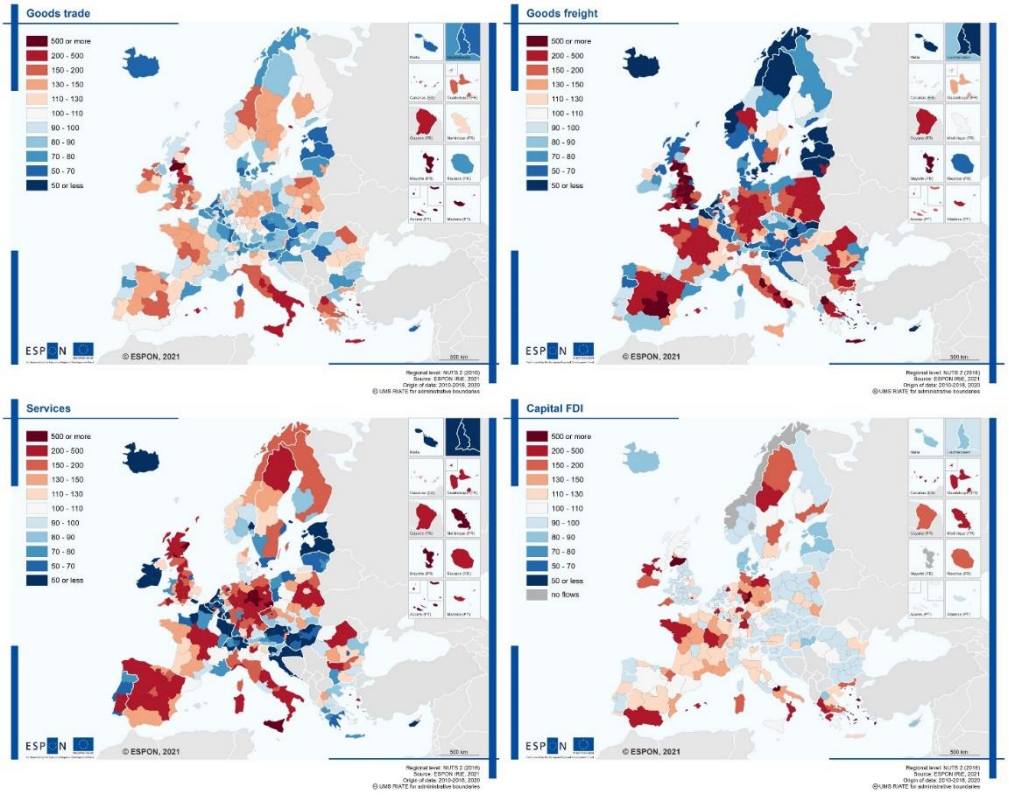


Figure 3.42: Border effect for air passengers, migration, labour mobility, and tourism

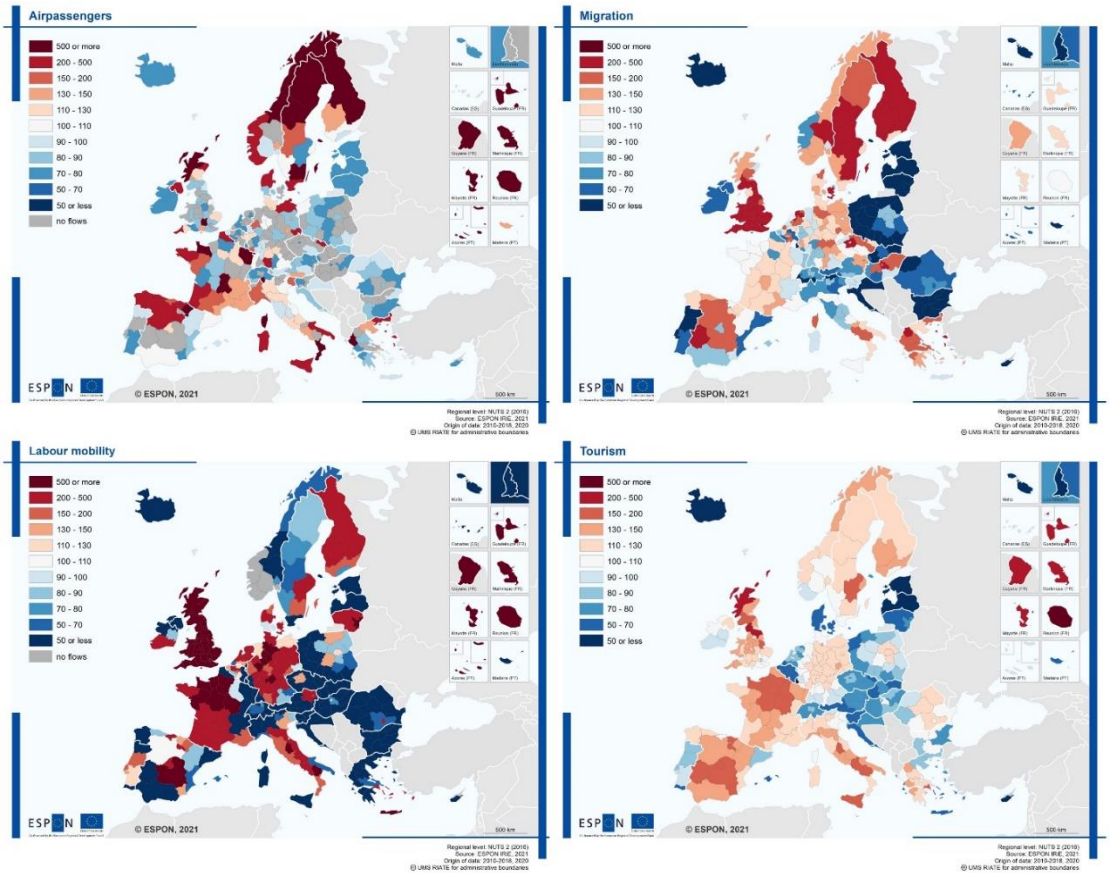
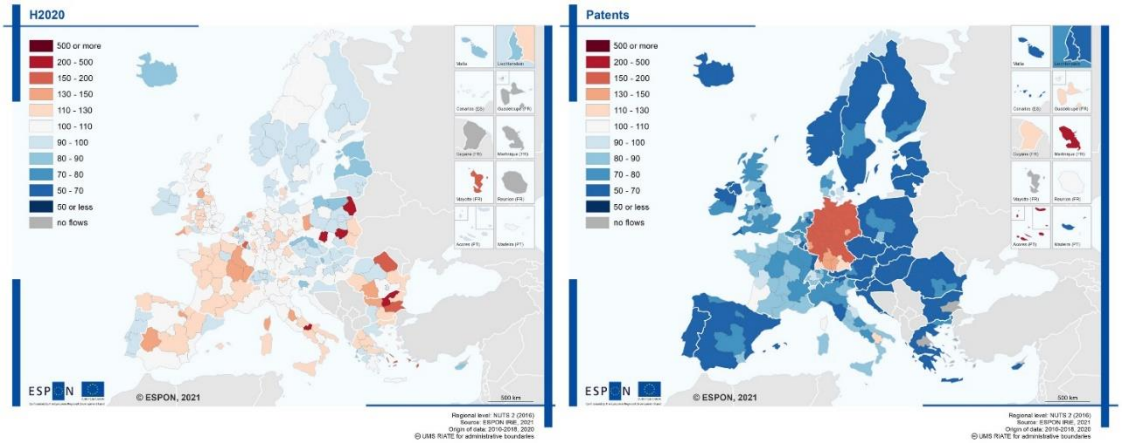


Figure 3.43: Border effect for H2020 and patents



3.5 Two-dimensional typology

3.5.1 Weighted intensity vs. balance

The spatial pattern for the typology of the relationship between weighted intensity and balance for the **goods/services/capital basket** resembles a mosaic. One can observe single areas with highly intensive senders in Scotland, northern Sweden and Norway, and the Randstad. On the other hand, there are single regions which are highly intensive receivers, such as Luxembourg. In general, peripheral areas in the east and south of the ESPON space are mostly non-intensive or moderately intensive senders. The position of metropolitan areas, including capitals, differs. Within the EU core, they are often non-intensive receivers (e.g. Paris, Frankfurt, Rome), while in the periphery they are moderately intensive senders (Warsaw, Bucharest, Prague). This may indicate an internal imbalance within the network of major European cities.

Two-dimensional weighted intensity-balance analysis for the **people basket** gives very interesting spatial results. The highly intensive receivers in the people basket are mainly tourist areas, i.e. islands in the Mediterranean, the Algarve in Portugal, the Dalmatian coast in Croatia, and the Alpine region in Austria and Switzerland. Most capitals and small urban regions also belong to highly intensive receivers, but what is quite surprising in this group is the absence of certain well-known strong tourist, migration, and labour-mobility attractors like Paris, Madrid, and Rome. Most of the highly intensive receivers are surrounded by highly intensive senders, as is natural, because the NUTS 2 regions surrounding strong centers are mainly the so-called migration and labour-mobility catchments. The typology confirmed the large role played by internal flows (migration and tourism). In this respect, countries closer to the EU core have flows of higher intensity than do peripheral countries in the east and south of ESPON space. However, in both cases there are strong internal balance differences. They testify to the high concentration of receivers within almost all European countries. It is also noticeable that regions of extremely different types are located next to each other. This is observed in the eastern German Länder, but also in the Alpine Macroregion and in the UK. This confirms the thesis that the distribution of flows of people differentiates the European space more strongly than traditional socio-economic indicators.

The two-dimensional intensity-balance typology for the **knowledge basket** shows a strong cluster of highly intensive receivers in the Nordic countries, although both Norway and Sweden also have highly intensive senders regions. In the case of Finland, this is mainly due to the enrollment of a very large number of students in the Erasmus program, especially in the sparsely populated north. Apart from Scandinavia, highly intensive receivers are also visible in the Central European capitals, from Budapest through Prague to Berlin. This group also includes Lisbon and Oslo. On the other hand, highly intensive senders for the knowledge basket include such other capitals as Paris, Madrid, Rome, Vilnius, and Bratislava. We can therefore conclude that the group of capitals and agglomerations is strongly dependent on flows of knowledge, but the direction of these flows is highly diversified. The typology confirms that while the intensity of knowledge flows fits the classic core-periphery pattern (especially in the west-east relationship), once the balance is taken into account the system becomes more territorially complex, and the north-south dimension becomes important.

The two-dimensional typology weighted for intensity vs. balance for the **synthetic matrix of 11 flows** indicates a strong group of highly intensive receivers in Switzerland and western Austria. It is the only compact group of regions among the highly intensive receivers. Apart from Switzerland and Austria, highly intensive receivers include individual metropolitan areas, such as Stockholm, Vilnius, Prague, Luxembourg, Copenhagen, and Hamburg. On the other hand, highly intensive senders are often regions located around metropolises, such as those around Vienna, Dublin, Brussels, Oslo, and (in the Netherlands) Randstad. Northern Norway and Sweden also belong to this type. The whole of Central and Eastern Europe (from Estonia to Greece) is characterised by a strong predominance of either non-intensive senders or non-intensive balanced types. Apart from the Greek islands, only a few regions in the whole area are characterised by medium- or high-intensity of flows (usually capitals), and a few others with low intensity have balanced flows or belong to receivers. These are areas with established international historical relations (Opolskie in Poland, Transylvania in Romania), or border areas with Western European countries (in both NUTS2 regions in Slovenia, Zachodniopomorskie in Poland).

Figure 3.44: Goods/services/capital. Weighted intensity vs. balance.

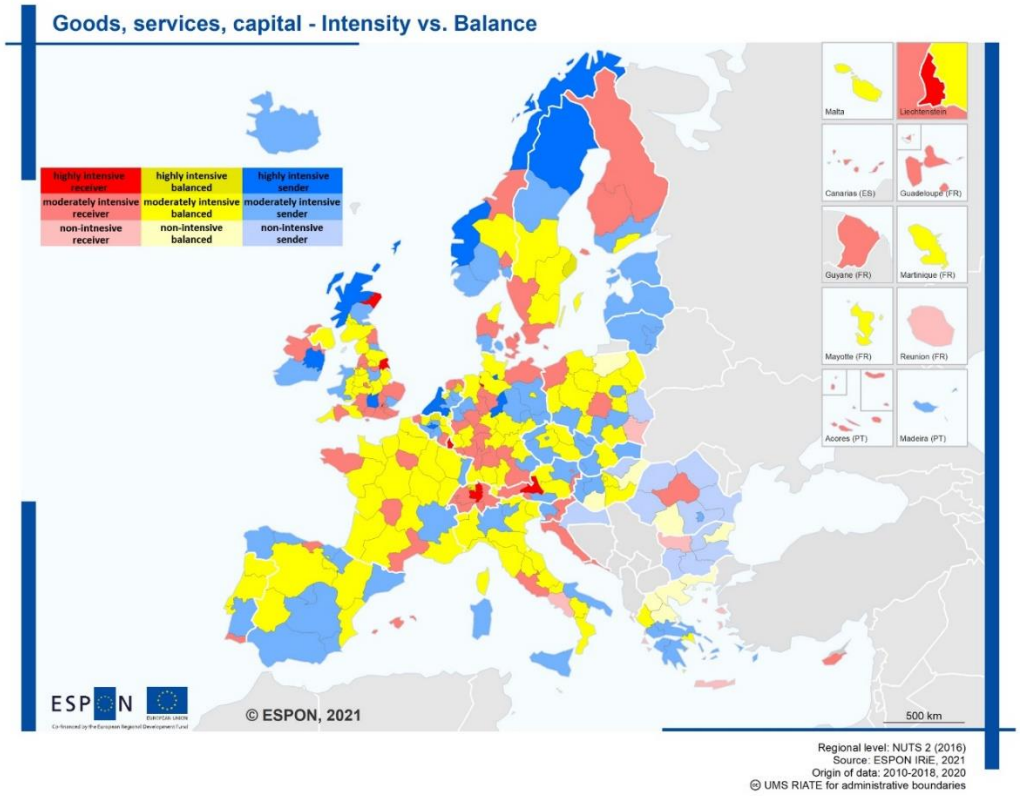


Figure 3.45: People. Weighted intensity vs. balance

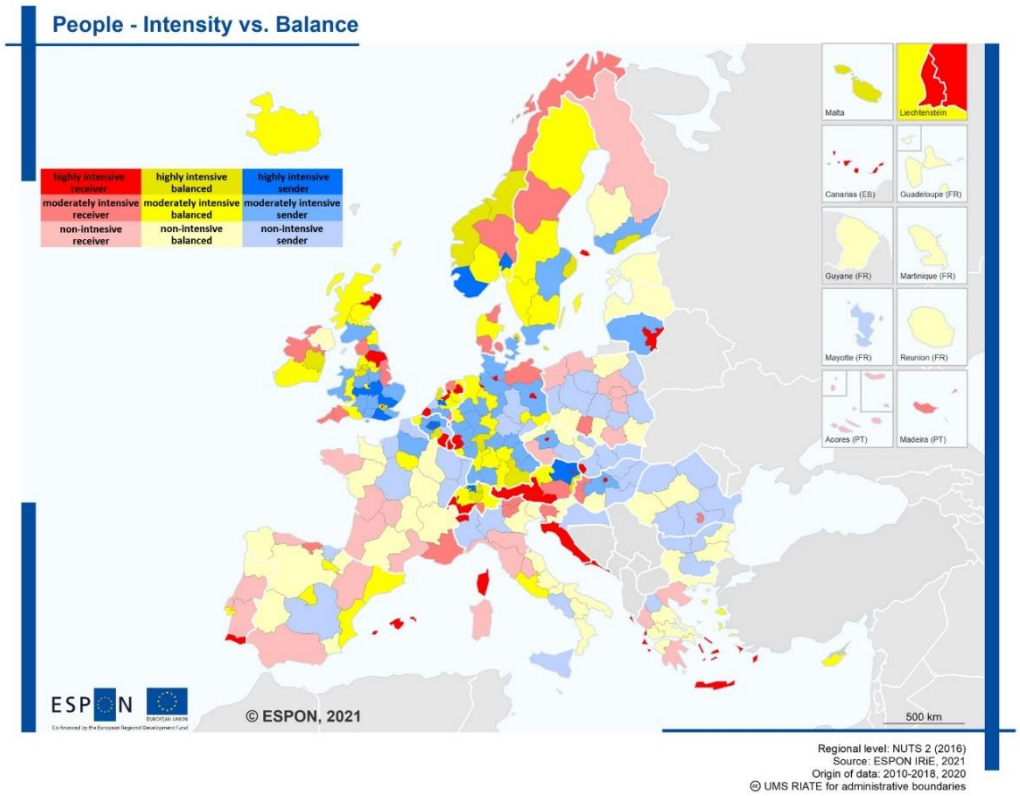


Figure 3.46: Knowledge. Weighted intensity vs. balance

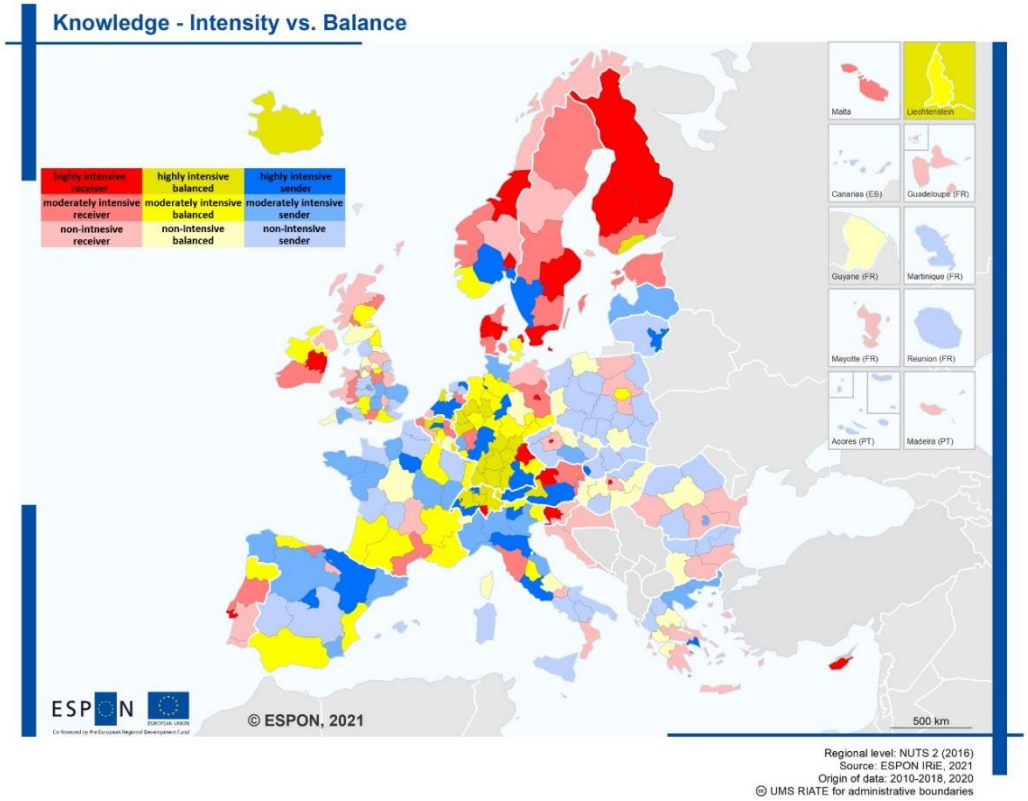
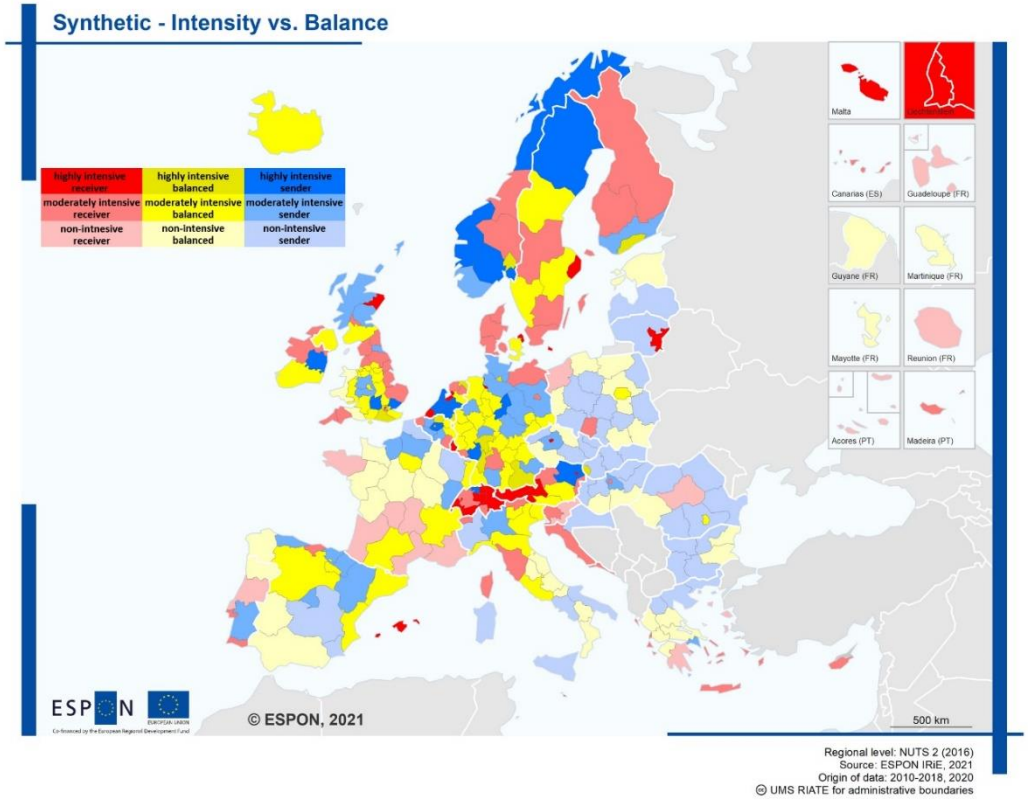


Figure 3.47: Synthetic. Weighted intensity vs. balance



3.5.2 Weighted intensity vs. concentration

Two-dimensional analysis of weighted intensity vs concentration for the **goods/services/capital basket** shows a compact group of highly intensive, strongly concentrated flows in the area of Scandinavia, Scotland, northern England, and Ireland. A very interesting example is the Netherlands, whose northeastern part has a high spatial concentration of flows, whereas its southwestern part has highly dispersed flows. We can assume that this is determined by port functions and the intensive transport of goods. Luxembourg also shows highly intensive dispersed flows. FDI flows are crucial in this case. A large spatially compact area in Western and Central Europe (from Spain through France, northern Italy, and Germany to Czechia and western Poland) includes regions classified as having moderately intensive and dispersed flows. This can be interpreted as a sign of successful European economic integration, in which even non-metropolitan regions are economically connected to many other places within the ESPON space. In this area there are "islands" in the form of regions with highly intense economic relations, often at the same time with greater dispersion (the aforementioned port cities, financial centers). Within the described belt, a slightly higher concentration of flows occurs in the eastern Länder of Germany and southern France. This can be interpreted as a retreat of the inner peripheries.

Two-dimensional typology of weighted intensity vs. concentration for the **people basket** points to highly intensive, strongly concentrated flows in the metropolises of northern Europe: Oslo, Stockholm, and Helsinki but also Vilnius, as well as some central European capitals, such as Bratislava and Budapest. In turn, highly intensive dispersed flows occur in tourist regions such as the Algarve in Portugal, the Balearic Islands, and the Dalmatian Coast in Croatia. This group also includes a group of regions in the Alpine parts of Austria, Switzerland, and Germany, as well as Luxembourg, Berlin, Dublin, and individual regions in the European core. In the peripheral zone, high concentration combined with low intensity of people flows characterizes the regions surrounding larger metropolises. In the metropolises themselves the intensity is still low or average, but the concentration is clearly lower.

Two-dimensional analysis of weighted intensity vs concentration for the **knowledge basket** leads us to very interesting conclusions. First, only the eastern part of Switzerland has highly intensive, strongly concentrated flows. This means that for the entire ESPON space, only in eastern Switzerland are knowledge flows both very important for the local community and strongly concentrated spatially. In other regions, the high significance of these flows is associated with relatively low spatial concentration, high dispersion, and networking. On the other hand, regions with a relatively low intensity of knowledge flows — e.g. peripheral and rural regions in Central and Eastern Europe — are usually characterized by a strong concentration of knowledge flows. The exceptions, however, are the capitals of these EU states (Warsaw, Bucharest, Athens, Prague, Budapest), where the intensity is higher and the concentration clearly weaker.

Two-dimensional weighted intensity vs concentration analysis for a **synthetic matrix of 11 flows** shows highly intense, strongly concentrated flows in regions of Norway and northern Sweden, Luxembourg, and eastern Switzerland. On the other hand, regions of highly intensive dispersed flows are located mainly in the European core, but this group also includes some capitals outside the core, such as Copenhagen, Prague, and Bratislava. However, the core of the EU is characterized by a broad diversity of region types. In Germany, Austria, Switzerland, and the Benelux countries there are regions with different concentrations and high or medium flow intensities. As we move eastward and southward the intensity decreases and the level of concentration increases. However, the most peripheral eastern regions (eastern Poland, Romania, Bulgaria) once again record a slightly lower concentration. This may indicate that low-intensity flows are to some extent random in their concentration. Moreover, migration outflows from these areas are often multi-directional.

Figure 3.48: Goods/services/capital. Weighted intensity vs concentration

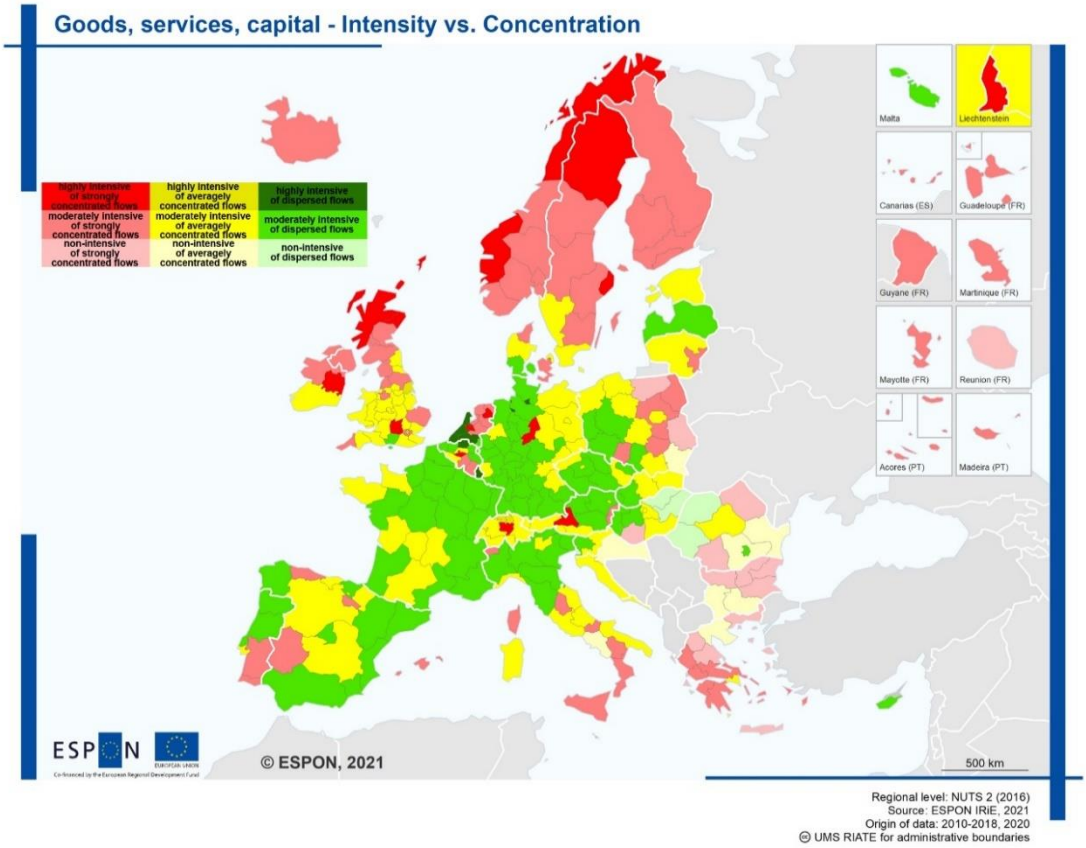


Figure 3.49: People. Weighted intensity vs concentration

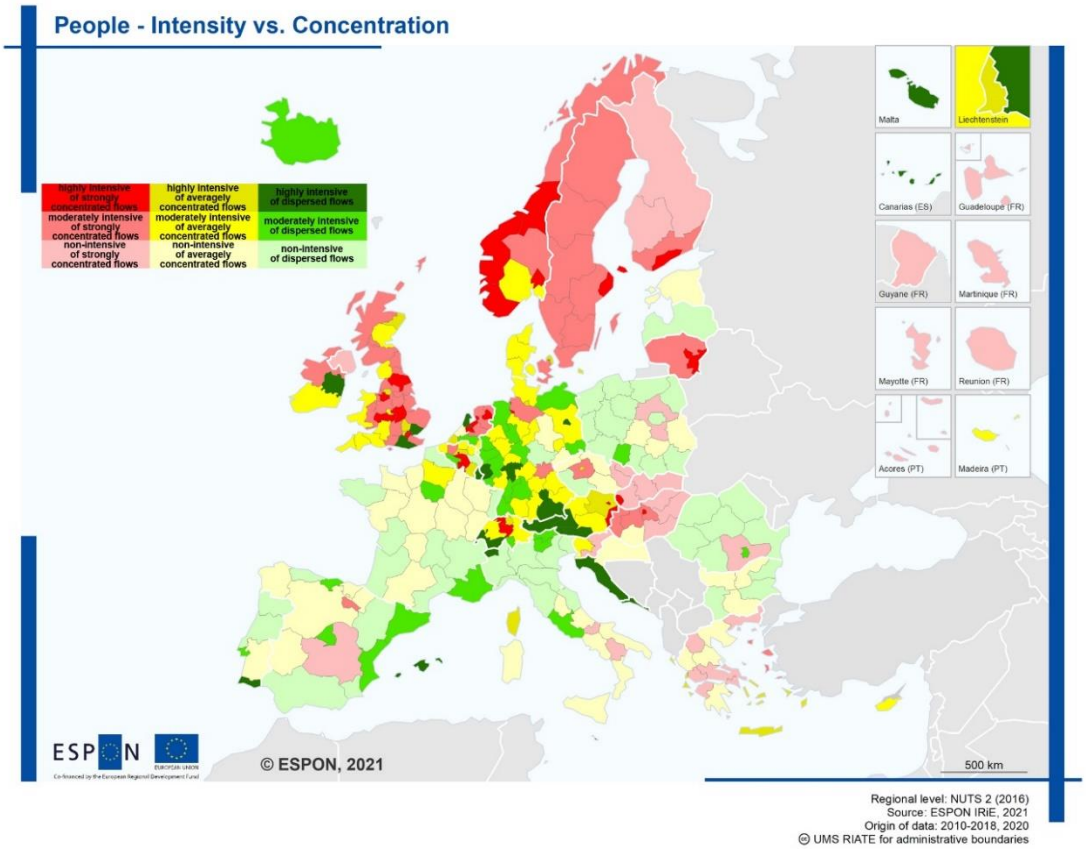


Figure 3.50: Knowledge. Weighted intensity vs concentration

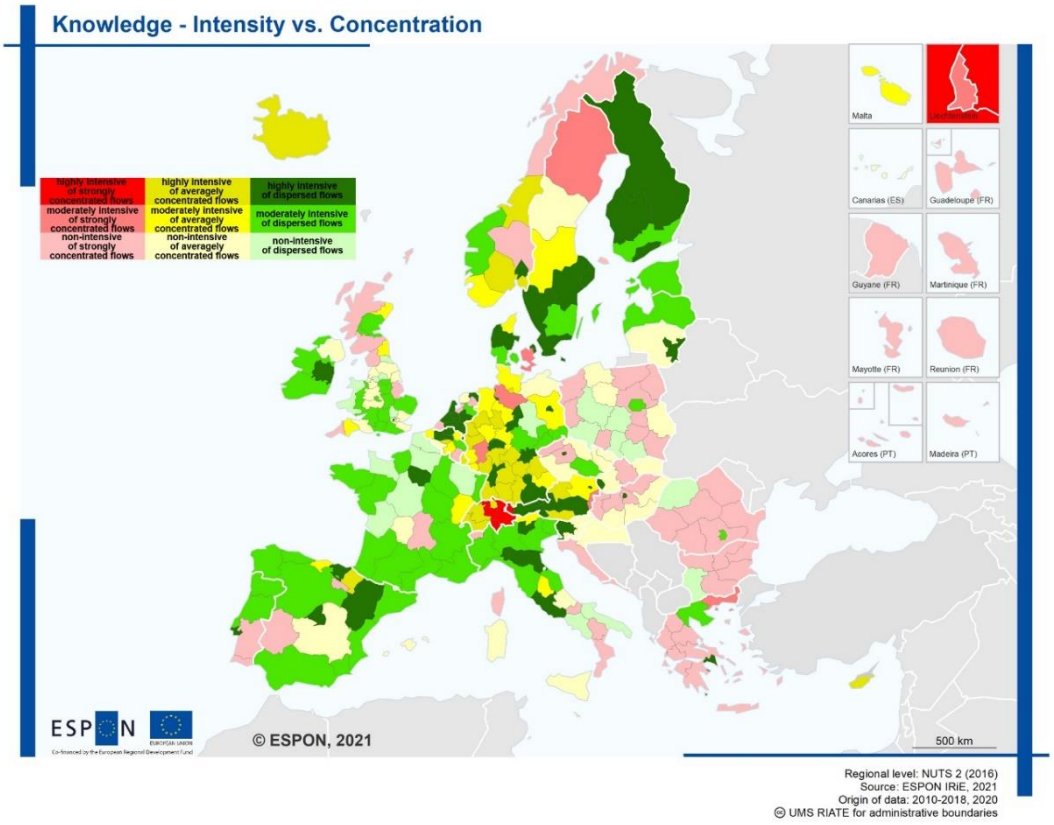
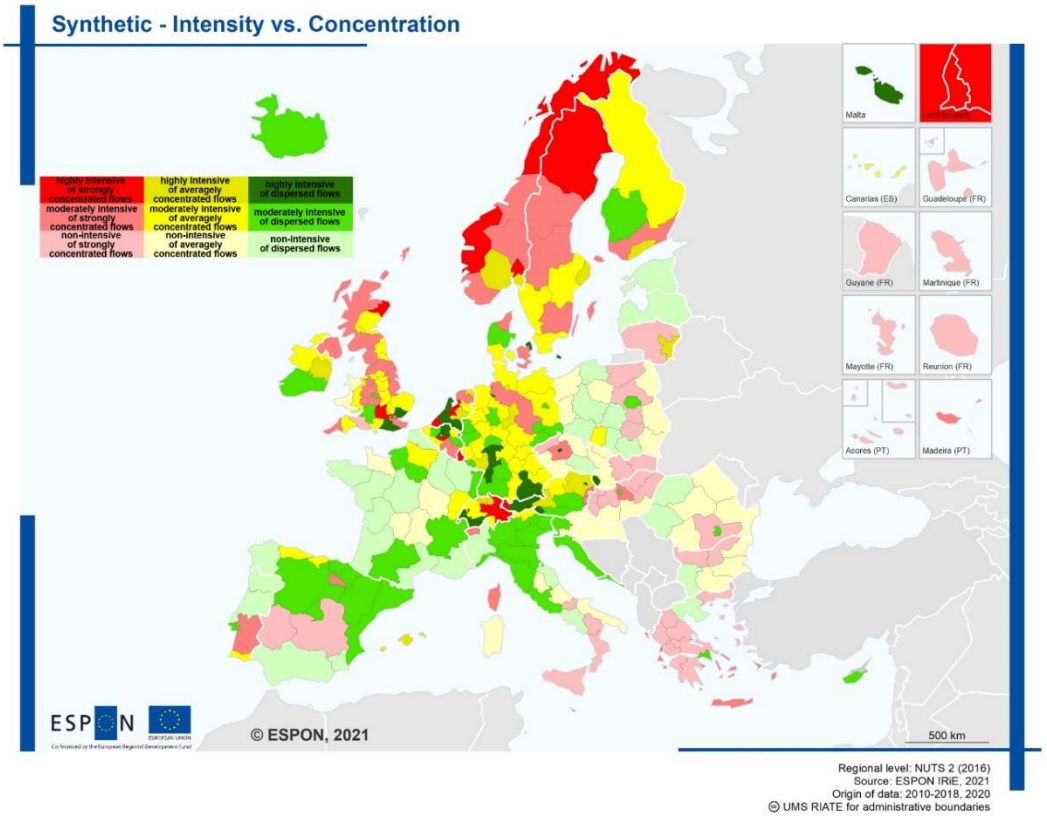


Figure 3.51: Synthetic. Weighted intensity vs concentration



3.5.3 Weighted intensity vs distance

Two-dimensional analysis of weighted intensity vs distance for the goods/services/capital basket indicates two highly intensive, long-range regions, which include Stockholm and Nord-Norge in Norway. On the other hand, in the light of the typology used, the regions of Brussels and Drenthe (Netherlands) were classified as highly intensive and short range. The vast majority of regions in ESPON space can be classified as medium-intensive, medium-range. This shows indirectly that for most regions distance is not a very important limit on the volume of economic flows. Moreover, the outermost regions in the north and south are not characterised by a particularly low intensity of flows. In the most peripheral eastern regions, average relationship lengths are still recorded with low intensity.

Two-dimensional typology analysis of weighted intensity vs distance for the people basket shows single highly intensive, long-range regions, which mainly include tourist areas on the Mediterranean (Algarve, Baleary, and Crete). In turn, among the highly intensive, short-range regions are many in the European core, but outside France and Italy. Most regions in large countries, such as Spain, France, Italy, Poland, and Romania (but not Germany), are of the non-intensive, medium-range type. This can be explained by the importance of internal relations in these countries.

Unlike for other baskets, our **two-dimensional weighted intensity vs average distance typology** shows for the knowledge basket two strong clusters of long- and short-range, highly intensive regions. The first cluster of long-range, highly intensive regions is located in Finland. There are also a few single regions of this type, including Iceland, Trøndelag (Norway), Cyprus, Lisbon, and Athens. The second highly intensive, short-range cluster is the German-Swiss patent “kingdom”, but there are also some other individual regions of this type in the Benelux and Austria. The rest of ESPON space is mostly of moderate (Western Europe) or non-intensive (Central and Eastern Europe) medium range.

Our **two-dimensional weighted intesity vs average distance typology** for 11 flows shows long-range, highly intensive regions in northern Norway, Helsinki, and the Balearic islands. In turn, highly intensive, short-range regions are located in Switzerland and northern Germany, with single ones in Belgium and the Netherlands. The French border is clearly marked, which proves that flows are relatively longer in France than in its northern and eastern neighbours. The overall picture shows a core-periphery system. The core is characterized by high to medium intensity, short-range flows. It includes mainly Germany, Switzerland, and some regions of Belgium, the Netherlands, and the United Kingdom. The core is surrounded by an extensive zone dominated by medium-range flows. To the north (Scandinavia) and south (Italy, Slovenia, northern Spain) the flows are more intense; towards the east, rather non-intensive. There are a few islands in this zone where local links are dominant (flows become short again). This is the case in the surroundings of certain metropolises or their groups, especially in the Budapest-Vienna-Bratislava triangle but also in the neighbourhood of Warsaw, Prague, and Copenhagen. Outside the zone of medium distances on the northern and southern edges of Europe there is a relatively small number of regions with dominant long-distance flows. For natural reasons, such flows dominate also in overseas regions. In both cases the average flow intensity is low, although it is medium or high in a few (mostly tourist) regions.

Figure 3.52: Goods/services/capital. Weighted intensity vs distance

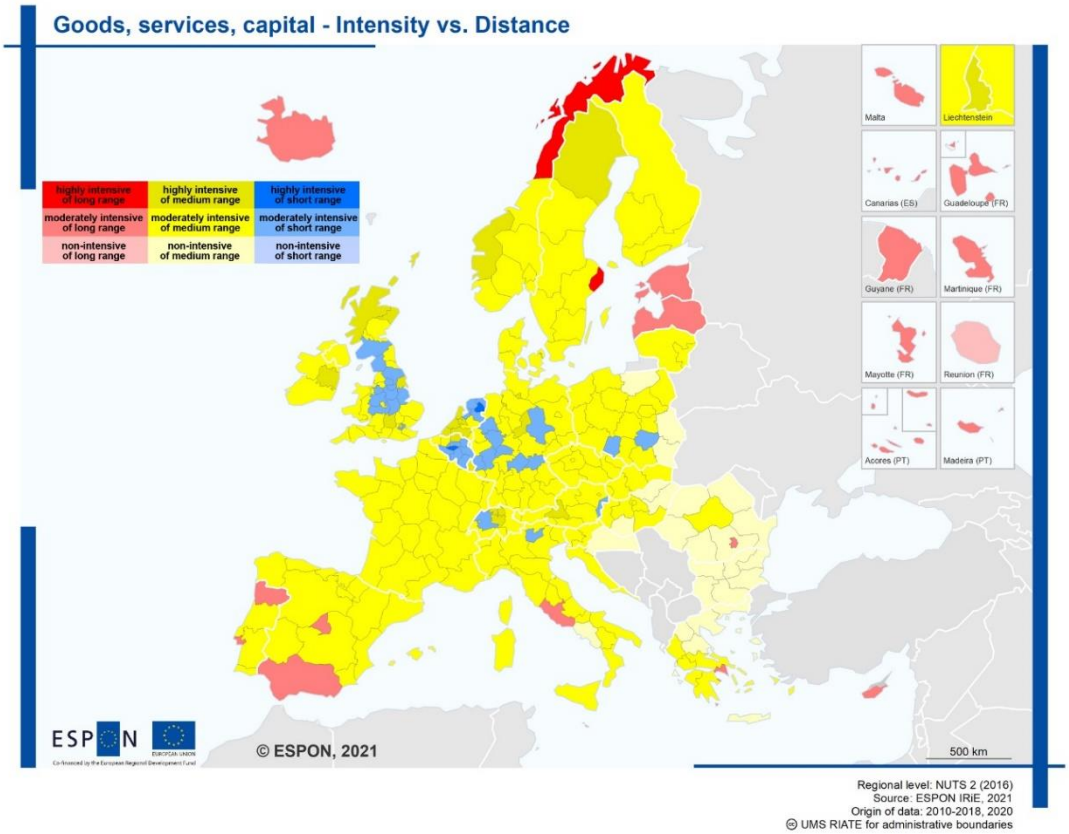


Figure 3.53: People. Weighted intensity vs distance

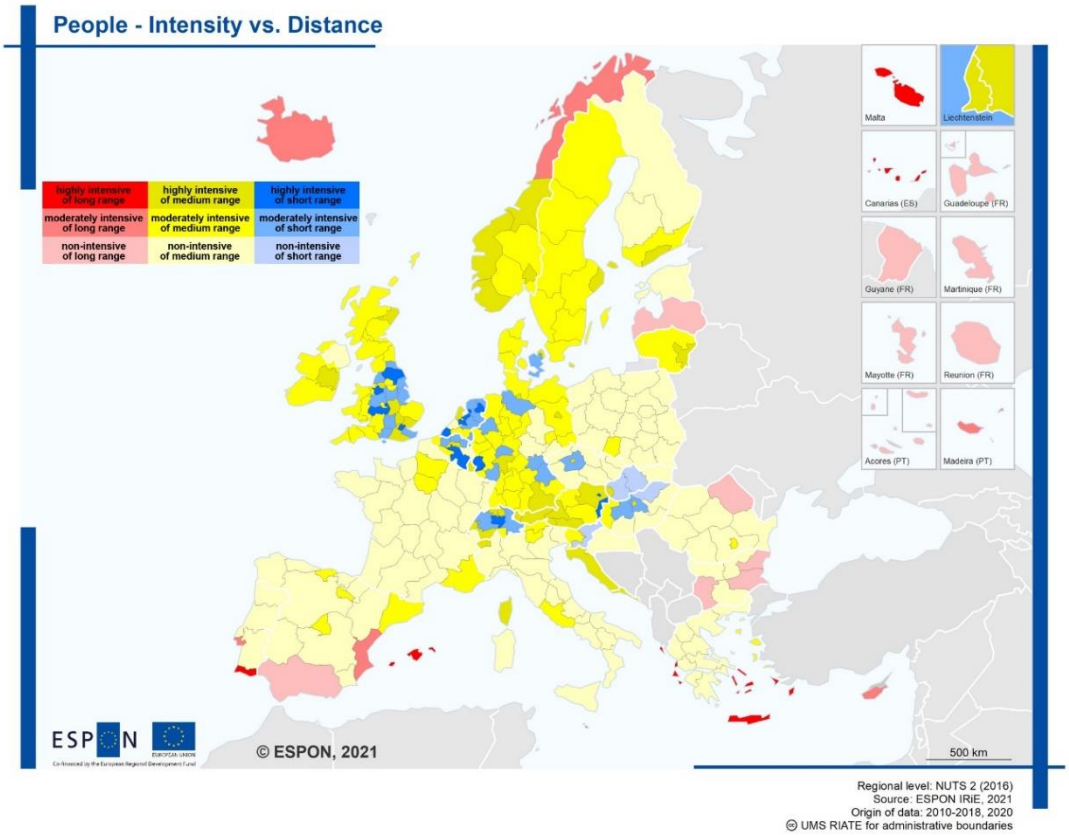


Figure 3.54: Knowledge. Weighted intensity vs distance

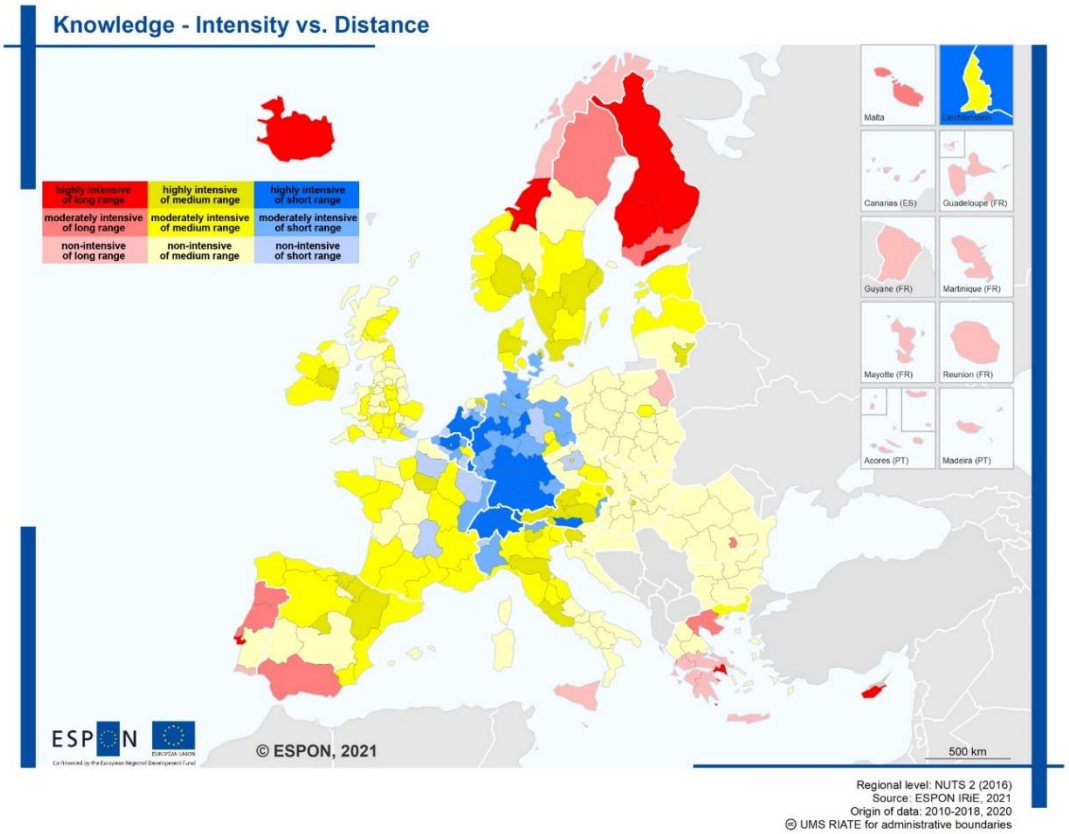
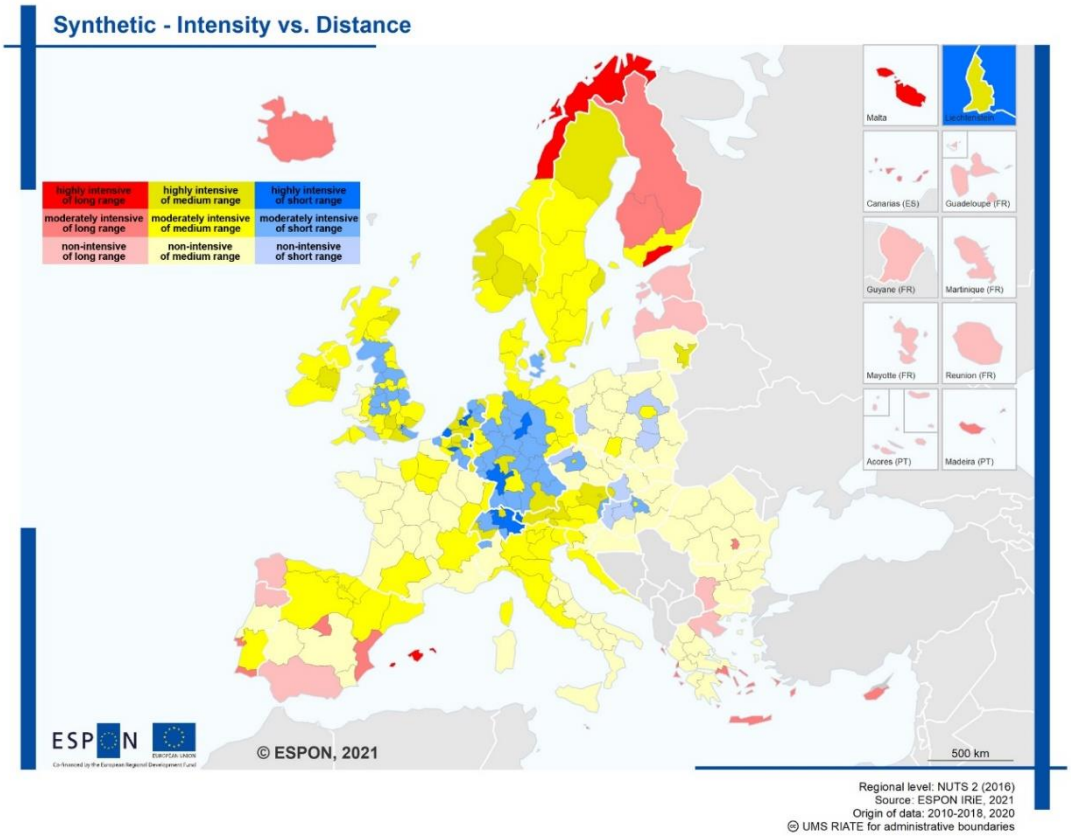


Figure 3.55: Syntethic. Weighted intensity vs distance



3.6 Histograms

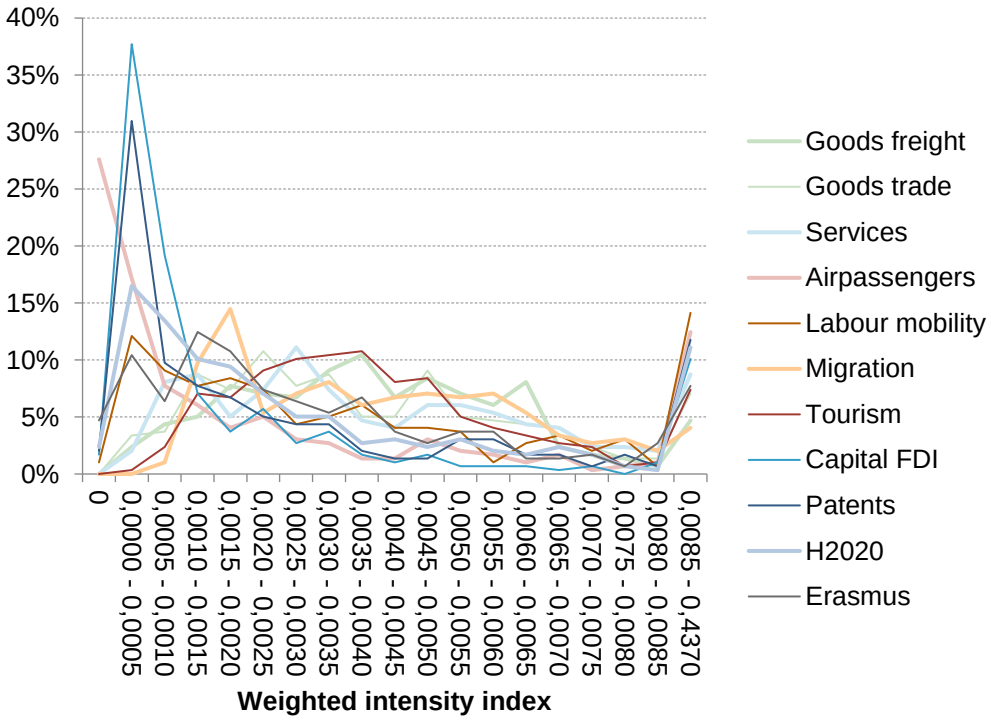
With histograms, selected flows can be compared by distribution of individual indicators, which makes it possible to determine for a given flow which indicators generate either a dominant (low, medium, or high) or an indistinct value.

Histograms were presented for four dimensions, for the following indicators: (1) weighted intensity, (2) balance index, (3) concentration per population, (4) distance index.

3.6.1 Weighted intensity

Many regions do not have an airport. For this reason, **air passengers** is the only flow with a dominant value for an index value of zero. For the other two flows, **FDI capital** and **patents**, the dominant value is sharp, with low indicator values. This means that very many units (regions) are characterized by a lack of major capital or patent flows. The dominant low values, although not as sharp as with the aforementioned flows, are characteristic also for participation in the **H2020** project network and for **labour mobility**. For the remaining flows, the distribution of weighted intensity values is definitely more even, without distinct dominant values. Even if a dominant value appears, it does not exceed 15% of the regions of the ESPON space in the given ranges.

Figure 3.56: Weighted intensity index. Histograms

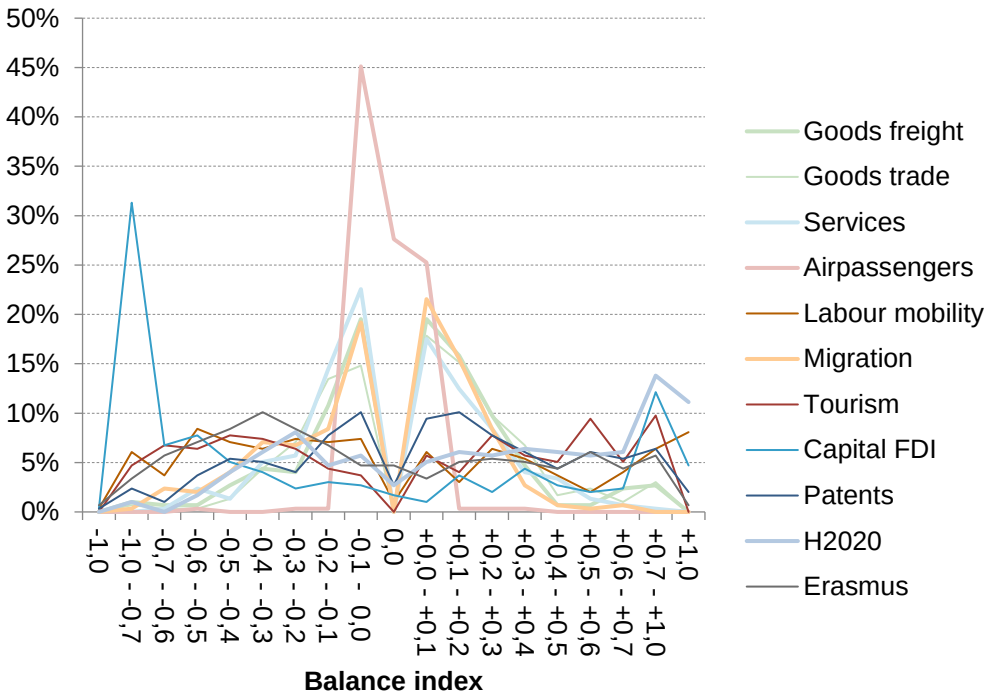


3.6.2 Balance

In the balance index, flows can be divided into groups by the position of the dominant value in the histogram. The first group may comprise regions whose flow is balanced. Air passengers is certainly one of the most balanced flows. The number of passengers in the departures and arrivals halls is the same or similar at most airports. Balanced flows also include services, migration, goods freight, and goods trade.

For the remaining flows, we observe small or large deviations from the balance of flows in many regions. Capital FDI (dominance of senders) and H2020 (dominance of receivers) show the greatest deviations from the equilibrium.

Figure 3.57: Balance index. Histograms

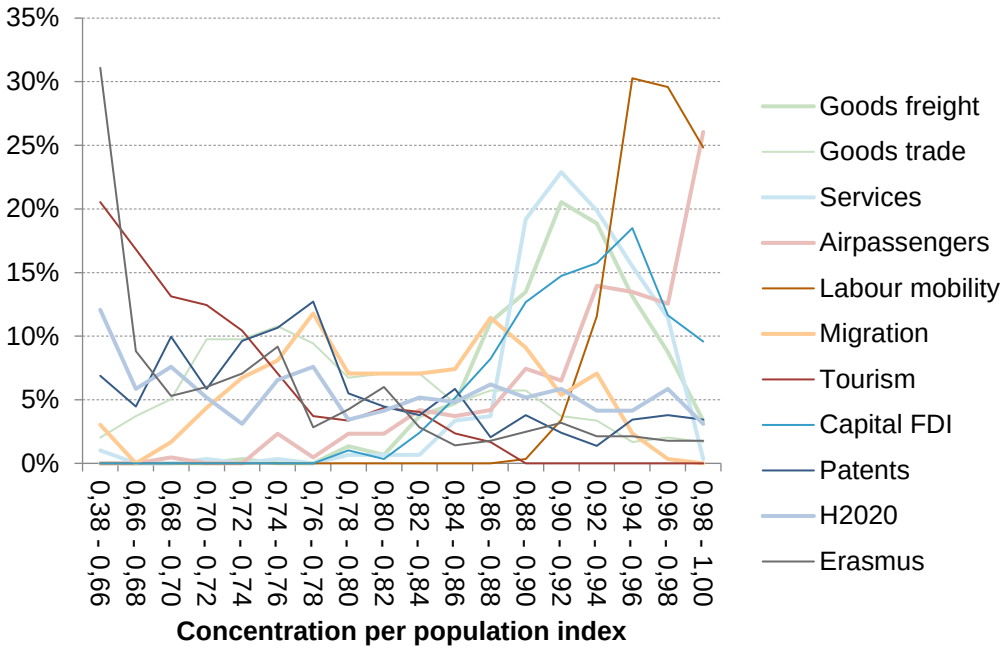


3.6.3 Concentration

Concentration is one type of indicator for which it is possible to distinguish clearly between flows of high and low spatial concentration. The first group (high spatial concentration) includes **labour mobility** (metropolitan systems), **air passengers** (a network of the largest hubs), and **capital FDI** (large financial centers). In turn, the low spatial concentration of flows is typical of student flows in the **Erasmus** program and in **tourism**. For trade flows, **goods freight** is much more concentrated than **goods trade**. We can conclude that trade is more spatially fragmented in value than in tonnage.

Interestingly, only in **migratory flows** does the distribution of spatial concentration approach the normal distribution. There are relatively few regions for which migration flows are very dispersed, but also relatively few regions for which migration flows are highly spatially concentrated.

Figure 3.58: Concentration index. Histograms

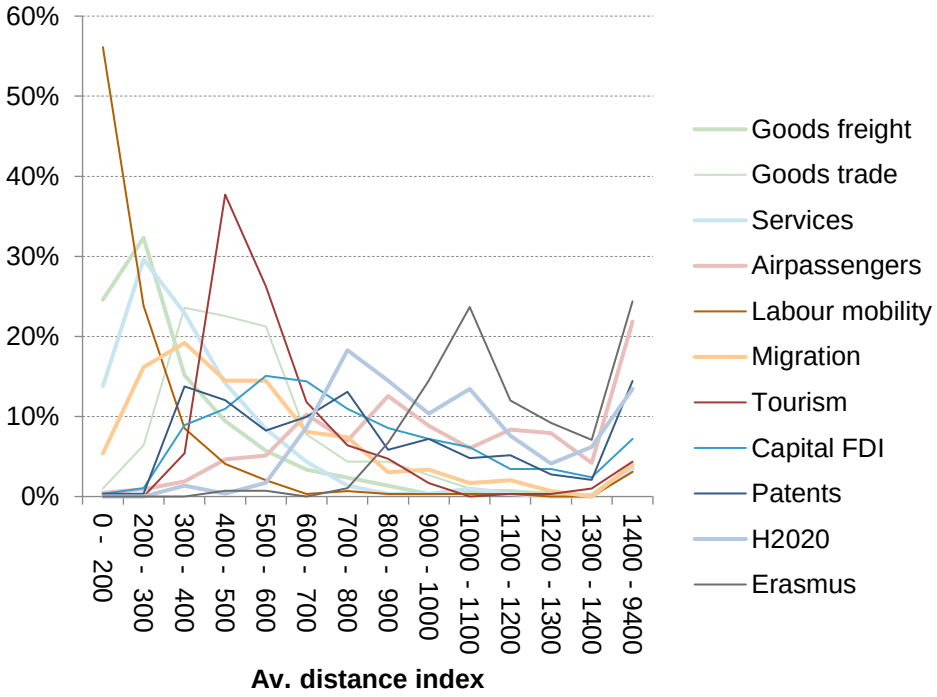


3.6.4 Distance

In terms of average distance, flows can be grouped by dominance of short, medium, and long distance. Short flows comprise primarily **labour mobility**, but also **goods freight**, **services**, and (surprisingly) **migration**.

In turn, the longest distances are characteristic of **Erasmus** and **air-passenger** flows.

Figure 3.59:: Distance index. Histograms



3.7 Crossreferencing. Econometrical analysis. Size dimension

3.7.1 Motivation

In this section we provide complementary analysis about the relationship between some key bilateral flows estimated in T1, which have been combined in this T2 document for the generation of typologies. The analysis is based on basic correlations and regressions, with no intent to identify causality or deal with problems of simultaneity.

We focus on the models most clearly covered in the literature (Burchardi et al., 2019; Bahar & Rapoport, 2018), namely:

- **Model M1: Trade of goods as endogenous variable.** The motivation of this analysis rests on the wide literature on trade of goods, the best-known and most-globalized aspects of the economy. Our analysis focuses on trade flows of goods measured in monetary values rather than on transport flows in tons, since the former subsumes the latter. Moreover, they are coherent with official production and trade flows, whereas freight flows are not. We thus avoid, to some extent, the problems of double counting due to multimodality.
- **Model M2: Trade of services as endogenous variable.** Trade flows of services are expressed in monetary values and subsume all passenger flows plus other indicators (labour mobility, freight, etc.). They are coherent with official production and trade flows, whereas passenger flows are not. They avoid, to some extent, the double counting due to multimodality; passenger flows do not.
- **Model M3: Migration flows as endogenous variable.** Migration flows are the most complex and permanent flows of people covered in the IRIE Project. Aware of the long literature connecting the migration with other flows (trade, FDI, etc.), we seek with this model to shed new light on the relationship using novel interregional European flows.
- **Model M4: FDI flows as endogenous variable.** There is also an extensive literature analysing the link between FDI and trade and migration. Here, to complement the previous analysis, we focus on FDI flows, also expressed in euros, which are survey based. These comprise stocks related to the flows of goods and services, as well as migration. Flows related to capital and rents (loans and remittances) are less robust and incomplete.
- **Model M5: Knowledge as endogenous (H2020) variable.** Finally, we use H2020 as a proxy for knowledge flows, given the former's novel nature and its clarity as an instrument of the European Commission to promote basic research within the EU27.

We conclude with a brief analysis of the relationship between all these flows and certain variables of interest for the DG Regio: those relating to the ageing population.

3.7.2 Empirical analysis. Correlations

Table 3.1: Correlations

	goods	freight	services	airpassengers	labour mobility	migration	tourism	fdi	patents	H2020	erasmus
goods	1										
freight	0.831	1									
services	0.588	0.632	1								
airpassengers	0.093	0.055	0.329	1							
labour mobility	0.369	0.471	0.370	0.015	1						
migration	0.501	0.608	0.540	0.130	0.660	1					
tourism	0.578	0.550	0.558	0.248	0.294	0.508	1				
fdi	0.051	0.030	0.039	0.077	0.017	0.035	0.063	1			
patents	0.400	0.389	0.334	0.090	0.317	0.403	0.340	0.049	1		
H2020	0.172	0.121	0.173	0.298	0.064	0.151	0.270	0.193	0.180	1	
erasmus	0.042	-0.005	-0.012	0.222	-0.013	-0.001	0.039	0.108	0.051	0.480	1

The previous matrix corresponds to the Pearson correlation coefficient between all the flows included in this analysis. The following results are worth mentioning:

- The largest coefficients are obtained between trade of goods and freight (0.831). This is reasonable because our estimation of the trade of goods uses freight statistics as one of its main data inputs.
- Other highly positive coefficients are obtained between trade of goods and services (0.588), goods and migration (0.501), goods and tourism (0.578), migration and labour mobility (0.660), and tourism and migration (0.508). All of these numbers are reasonable and corroborate the existing literature, indicating that the trade of goods and services is aligned, as are flows of goods with all kinds of flows of people. This could create enhanced trade channels, mainly through the reduction of trade costs (information) and the spillovers of common consumer preferences (flavour). The positive and high correlation between the three flows of people (migration, tourism, and labour) is also interesting, because the mobility of people is affected by moving costs (transportation and information costs), and because migration decisions can often be explained by the same people's previous trips of certain types (tourism and labour mobility), or by the trips of relatives and friends.
- The lowest coefficients are obtained for FDI flows, which can be associated with the greatest sparsity (number of zeros) of data. Moreover, the literature also points to the presence of a bi-polar relationship between trade and investments; it is possible to find enhancing (positive) or competing (negative) relationships, depending on the type of FDI flows and trade shipments under consideration (horizontal vs. vertical FDI; final goods vs. intermediates; more homogeneous vs. more heterogeneous markets; etc.).
- Knowledge flows display the greatest heterogeneity. On the one hand, patent citations show the highest and clearest positive relations with trade and migration flows, reaching the highest coefficient for trade of goods (0.4) and migration (0.403). The variable H2020 also reaches positive coefficients with all the other variables, but its levels are lower than those of patent citations. Finally, the Erasmus variable reaches very low coefficients, being negative with freight, services, and labour mobility. The only high coefficient for Erasmus is with H2020; this suggests that university linkages for student mobility are somehow aligned with linkages for joint collaborations in H2020 projects.
- The three variables included at the end of the correlation matrix correspond to three variables related to ageing in each region of the ESPON space:
    - Age_i: the average age of the inhabitants of each flow's region of origin.
    - Age_j: the average age of the inhabitants of each flow's region of destination.

- Diff_Age_ij: the difference between the average age of the inhabitants of the region of origin and the average age of the inhabitants of the regions of destination for each inter-regional *i-j* pair for which flows are computed.

- Note that for these three variables the correlation coefficient with the flows is very low, indicating that, in principle, these three variables are not very relevant drivers/obstacles to any of the five types of interregional flows considered as endogenous variables in M1-M5.

3.7.3 Empirical analysis. Econometric analysis using the gravity equation

In this section we provide a basic econometric analysis using the gravity equation (Head and Mayer, 2014). This is complementary to the analyses provided in each report corresponding to each flow (T1), while including the other flows as additional explanatory factors.

The preferred specification is the Pseudo Poisson Maximum estimator (PPML), in line with the state of the art in trade modelling with the gravity equation in the presence of large numbers of zero flows. This estimation also has the virtue of producing unbiased estimates that solve potential heteroskedasticity problems, in contrast to the classical OLS with logs on trade flows. Moreover, when fixed effects are added, the PPML estimation is consistent with the equilibrium constraints imposed by structural approaches, such as outward and inward multilateral resistance and equilibrium constraints. Accordingly, we define this new specification of the model with the following equation:

$$Flow_{ij}^{eu} = \exp\left[\beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{jt} + \gamma' OTHER\_FLOWS_{ij}^{eu} + \beta_3 INTER_{ij} + \beta_4 CONTIG_{ij} + \beta_5 DIST_{ij} + \beta_6 X_{ij} + \mu_i + \mu_j\right] + \varepsilon_{ij}$$

where the dependent variable $Flow_{ij}^{eu}$ refers to the outflow of a given category (goods, services, etc.) from region *i* to region *j* in year *t*. Note that in this analysis each endogenous variable has been standardized and includes only inter-regional flows (intra-regional flows have been eliminated). Moreover, the flows correspond to average figures for the period 2010-2018. The standardization of flows is described in previous sections of this document.

In our dataset, the origin is always an ESPON NUTS 2 region. GDP_i denotes the GDP of the exporter region in period *t*, and GDP_i denotes the GDP of the importing region in period *t*.

The inter-regional dummy ($INTER_{ij}$) indicates whether the exporting region *i* and the importing region *j* are different (*i≠j*) but belong to the same country (*e=u*). Because these two dummy variables are included, we must interpret the coefficient results in comparison with the excluding category: i.e. international trade (*i≠j* and *e≠u*).

The dummy $CONTIG_{ij}$ takes the value of one if the exporter NUTS 2 region and the importer NUTS 2 region are contiguous and zero otherwise. The classical distance between origin and destination ($DIST_{ij}$, measured in log km) is included as a proxy for trade cost.

The terms μ_i, μ_j represent multilateral resistance. They are expected to capture the general relation of each trading region *i* and *j* to all other possible partners, and how this relation can hamper (hence the resistance) each bilateral flow. In accordance with the literature (Head and Mayer, 2014), these variables are proxied by origin-time fixed effects and destination-time fixed effects.

We add a set of origin-destination variables (X_{ij}) to categorize the different trade flows, as summarized in Table 3.2.

Table 3.2: Explanatory variables considered in the R2R econometric analysis.

Variable	Definition	Source
Ln(GDPi)	Log of gross domestic product of the origin NUTS 2 region.	Eurostat and CEPII

Ln(GDPj)	Log of gross domestic product of the destination NUTS 2 region.	Eurostat and CEPII
Inter	Inter-regional trade dummy.	Own elaboration
LnDist	Log of distance (in km).	JRC and CEPII.
Contig	Contiguity dummy variable. Takes value 1 if the partners are adjacent NUTS 2 regions.	Own elaboration
Contig_c	Contiguity dummy variable. Takes value 1 if the partners belong to adjacent countries.	CEPII
ComLang	Common language dummy variable. Takes value 1 if the partners use the same language.	CEPII and own elaboration
EU	European Union dummy variable. Takes value 1 if both partners are EU members.	Own elaboration
EUM	Euro dummy variable. Takes value 1 if the euro is the official currency for both partners.	Own elaboration
Island	Island dummy variable. Takes value 1 if the region of origin or destination is an island.	Own elaboration
Coast	Dummy variable. Takes value 1 if the NUTS 2 region of origin or destination has a coast.	Own elaboration
Inst	Difference in the quality of institutions for both NUTS 2 partners.	European quality of government index (Charron et al., 2014).
Out	Dummy variable. Takes value 1 if the region of origin or destination is an outermost region.	Own elaboration
Island_c	Island dummy variable. Takes value 1 if the origin or destination country is an island.	CEPII and own elaboration
Nocoast_c	Dummy variable. Takes value 1 if the origin or destination country is an inland country.	CEPII and own elaboration
Age_i:	Average age of the inhabitants of each flow's region of origin.	Own elaboration based on Eurostat data
Age_j:	Average age of the inhabitants of each flow's region of destination.	Own elaboration based on Eurostat data
Diff_Age_ij:	Difference between the average age of the inhabitants of the region of origin and the average age of the inhabitants of the region of destination for each interregional *i-j* pair for which flows are computed.	Own elaboration based on Eurostat data

For brevity, we use a single matrix $\gamma' OTHER\_FLOWS_{ij}^{eu}$ to denote a set of column vectors with other bilateral flows alternative to the one used as an endogenous variable. More specifically, the relations tested are summarized in 3.3.

Table 3.3: Flows (endogenous variable) and OTHER_FLOWS (explanatory variables) by models

Model	Flow (dependent variable)	OTHER FLOWS (explanatory factors)
M1	Trade of goods (€) The variable is standardized	• Trade of services (€) • Flows of migration (people) • Flows of FDI (€) • Flows of knowledge (Erasmus)

		• Flows of knowledge (H2020) • Flows of knowledge (patents) All these variables are standardized
M2	Trade of services (€) The variable is standardized	• Flows of migration (people) • Flows of FDI (€) • Flows of knowledge (Erasmus) • Flows of knowledge (H2020) • Flows of knowledge (patents) All these variables are standardized
M3	Flows of migration (people) The variable is standardized	• Trade of goods (€) • Trade of services (€) • Flows of FDI (€) • Flows of knowledge (Erasmus) • Flows of knowledge (H2020) • Flows of knowledge (patents) All these variables are standardized
M4	Flows of FDI (€) The variable is standardized	• Trade of goods (€) • Trade of services (€) • Flows of migration (people) • Flows of knowledge (Erasmus) • Flows of knowledge (H2020) • Flows of knowledge (patents) All these variables are standardized
M5	Flows of knowledge (H2020) The variable is standardized	• Trade of goods (€) • Trade of services (€) • Flows of migration (people) • Flows of FDI (€) All these variables are standardized

3.7.4 Results from the econometric analysis

Table 3.4 shows the main results of the econometric analysis. The first column for each model with a different dependent variable (M1, M3, M5, M7, and M9) shows the results for a classical OLS estimation. The other columns represent the results with a PPML estimation. We show the estimations with regional fixed effects.

The GDP variables are not significant enough in most estimations, because of the introduction of regional fixed effects and the inclusion of the other bilateral flows as explanatory variables. There are some exceptions for knowledge estimations (M9), with positive and significant coefficients for GDP and trade flows of goods (M1) with a negative and significant coefficient in the GDP of the origin region. Note also that while the flows are standardized, the GDPs are not.

The distance variable shows a negative and significant coefficient for all estimations, consistently with the literature. The exception is M3 for services, where the negative coefficient is not significant. The inter-regional dummy variable shows heterogeneity with respect to the dependent variable selected. The coefficient is positive and significant for all services (M3 and M4) and migration (M5 and M6) estimations, indicating that inter-regional flows within each country are clearly larger than with other countries. For trade and knowledge, the coefficient is negative and significant in the OLS estimation (M1 and M9) but positive and significant for the PPML estimations (M2 and M10). In the case of FDI, the coefficient is negative and significant in the OLS estimation (M7) but not significant enough in the PPML estimation (M8).

Regarding the key variables exchanged through the estimations, it is possible to observe the positive influence of trade on migration, FDI, and knowledge. Services flows show positive and significant coefficients in trade, migration, and knowledge estimations. In the case of migration, the variable seems to be positively related with knowledge flows and negatively with FDI. The effect of migration flows on trade and services differs by the econometric method used. In both estimations, the coefficient of migration is positive and significant in the OLS estimation but turns negative in the PPML. FDI doesn't appear very significant in most estimations but shows positive and significant coefficients in migration and knowledge estimations.

Erasmus flows show a positive and significant coefficient as a driver of trade flows of goods and services, as well as of migration, with the PPML. However, the coefficient turns negative and significant in services and migration estimations with the OLS. The variable doesn't show significance in the FDI estimation.

Results for H2020 and patent citations are very homogeneous. The variable shows a positive and significant relation with services and FDI. The variable also shows a positive and significant relation with trade of goods

and migration but only in the OLS estimation. In the PPML estimations the coefficient turns negative or not significant.

Regarding the rest of the explanatory variables, the contiguity of the regions, the use of a common language, membership in the EU, the use of the euro as the official currency, and the insularity of the country have a clear positive and significant effect on trade flows of goods (M1 and M2). On the other hand, the contiguity of the countries, the insularity of the region and possession of a coastline present negative and significant coefficients. Finally, the coefficients for the quality of institutions, outermost region location, and inland country location are positive and significant in the OLS estimation (M1) but negative and significant in the PPML (M2).

With trade of services as the dependent variable, the contiguity of the regions, the contiguity of countries, the use of a common language, the insularity of the region, possession of a coastline, and the insularity of the country generate a positive and significant coefficient. On the other hand, the difference in the quality of institutions and outermost region location seems to be negatively related with the bilateral average flow of services. Membership in the EU, the use of the euro as the official currency, and inland country location present inconsistent results. Use of the euro as the official currency generates a negative sign in the OLS estimation (M3) but a positive sign in the PPML (M4). On the other hand, the two other variables present positive and significant results in the OLS estimation (M3) but turn negative in the PPML (M4).

With respect to the models that use migration as an endogenous variable, average flows are positively affected by the contiguity of the region, the insularity of the region, the difference in the quality of institutions, and outermost region location. On the other hand, the use of the euro as the official currency and location within an island or inland country seem to be negatively related with those migration flows. The rest of the variables (contiguity of countries, use of common language, membership in the EU) present negative and significant coefficients in the OLS estimation (M5) but positive coefficients in the PPML (M6). Finally, possession of a coastline presents a positive coefficient in the OLS estimation (M5) but a negative one in the PPML (M6).

In the case of FDI flows, the variables don't turn out to be very significant. The only significant results are for the contiguity of regions and countries (negative in the OLS estimation: M7), the insularity of regions, possession of a coastline, and the quality of institutions (negative in the PPML estimation: M8), and outermost region location (positive in the OLS estimation: M7).

Finally, bilateral knowledge flows seem to be positively affected because of the use of a common language, membership in the EU, the use of euro as the official currency, and inclusion within an island country. On contrary, the insularity of the region, possession of a coastline, the quality of institutions, outermost region location, and inclusion within an inland country present negative and significant results in the estimations. Finally, the results for the contiguity variable are not very robust, being negative and significant in the OLS estimation (M9) but positive in the PPML (M10).

Table 3.4: Econometric analysis suing OLS and PPML gravity equations. Average flows for the period 2010-18. Flows are standardized.

Dep. variable	Trade		Services		Migration		FDI		Knowledge H2020	
	OLS	PPML	OLS	PPML	OLS	PPML	OLS	PPML	OLS	PPML
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
lngdp_i	-0.283**		0.074		0.090		0.125		3.507***	
	(0.112)		(0.311)		(0.126)		(0.892)		(0.338)	
lngdp_j	0.080		0.428		0.198		1.218*		2.707***	
	(0.113)		(0.328)		(0.121)		(0.735)		(0.327)	
goods					0.127***	-0.003***	0.086*	0.003	0.060***	-0.001

					(0.029)	(0.001)	(0.046)	(0.002)	(0.014)	(0.001)
services	0.241***	0.003***			0.211***	0.003***	-0.009	0.002	0.046***	0.000
	(0.027)	(0.000)			(0.024)	(0.001)	(0.015)	(0.003)	(0.013)	(0.001)
migration	0.069***	-0.004***	0.402***	-0.002***			-0.002	-0.014*	0.036***	-0.000
	(0.014)	(0.001)	(0.045)	(0.001)			(0.020)	(0.007)	(0.007)	(0.001)
fdi	0.002	0.000	0.001	-0.000	-0.000	0.0005**			0.030***	0.000
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.0002)			(0.009)	(0.000)
erasmus	0.004	0.006***	-0.146***	0.009***	-0.058***	0.005***	0.171	0.0028		
	(0.008)	(0.001)	(0.017)	(0.001)	(0.008)	(0.001)	(0.131)	(0.003)		
H2020	0.032***	-0.000	0.175***	0.002	0.053***	-0.002	0.767***	0.008***		
	(0.012)	(0.001)	(0.027)	(0.001)	(0.011)	(0.001)	(0.164)	(0.003)		
patents	0.104***	-0.002***	0.127***	0.001*	0.187***	-0.001***	0.027	0.004*		
	(0.011)	(0.000)	(0.033)	(0.001)	(0.027)	(0.001)	(0.023)	(0.002)		
inter	-1.203***	0.333***	8.146***	3.671***	2.614***	2.337***	-1.919**	-0.251	-0.672***	0.123**
	(0.270)	(0.055)	(0.368)	(0.108)	(0.289)	(0.067)	(0.849)	(0.418)	(0.151)	(0.053)
lndist	-1.118***	-1.246***	-0.122	-0.467***	-1.230***	-0.857***	-1.207***	-0.748***	-0.220***	-0.273***
	(0.072)	(0.021)	(0.107)	(0.048)	(0.128)	(0.021)	(0.295)	(0.104)	(0.049)	(0.019)
contig_c	9.923***	0.405***	3.807***	0.464***	11.07***	0.751***	-2.752***	-0.441	-1.380***	0.187***
	(0.470)	(0.029)	(0.783)	(0.045)	(0.778)	(0.035)	(0.631)	(0.277)	(0.221)	(0.060)
Contig_r	-0.158***	-0.0236	-0.060	0.446***	-0.802***	0.084**	-0.679*	-0.196	0.084	-0.027
	(0.0468)	(0.0262)	(0.071)	(0.059)	(0.081)	(0.041)	(0.367)	(0.171)	(0.067)	(0.027)
comlang_off	0.268***	0.252***	0.0170	0.742***	-0.640***	0.306***	0.379	0.119	0.309***	0.189***
	(0.0825)	(0.0417)	(0.097)	(0.064)	(0.084)	(0.050)	(0.709)	(0.181)	(0.100)	(0.037)
EU	3.152***	1.033***	3.893***	-0.460***	-1.208**	1.070***	-0.398	0.559	-0.350	0.323**
	(0.718)	(0.122)	(0.970)	(0.110)	(0.587)	(0.089)	(0.918)	(0.843)	(0.218)	(0.128)
UEM	0.0815**	0.172***	-0.110***	0.294***	-0.132***	-1.264***	-0.125	-0.254	0.342***	0.133***
	(0.033)	(0.058)	(0.040)	(0.058)	(0.036)	(0.045)	(0.240)	(0.285)	(0.045)	(0.032)
island	-1.100**	-0.167	-0.732	0.840***	0.651***	0.449***	-0.240	-1.077**	-0.219**	-0.609***
	(0.489)	(0.223)	(0.595)	(0.193)	(0.161)	(0.156)	(0.578)	(0.483)	(0.093)	(0.109)
coast	-0.290***	-0.651***	0.199***	-0.072	0.164***	-0.226***	-0.0401	-0.350*	0.060	-0.092***
	(0.044)	(0.031)	(0.076)	(0.064)	(0.052)	(0.030)	(0.268)	(0.206)	(0.054)	(0.025)
inst	0.090***	-0.094***	-0.061	-0.213***	0.409***	0.428***	-0.149	-0.436***	-0.059**	-0.117***
	(0.023)	(0.017)	(0.039)	(0.040)	(0.036)	(0.018)	(0.142)	(0.083)	(0.023)	(0.012)
outermost	2.918***	-1.122**	-0.135	-2.206***	2.710***	0.737**	2.075***	0.956	-0.386**	-3.531***
	(0.617)	(0.568)	(1.255)	(0.383)	(0.525)	(0.312)	(0.593)	(0.731)	(0.191)	(0.355)
island_c	1.233***	0.556***	2.569***	1.501***	-2.652***	-1.029***	0.718	0.385	0.519***	0.255***
	(0.228)	(0.091)	(0.465)	(0.084)	(0.349)	(0.055)	(0.559)	(0.384)	(0.109)	(0.053)
nocoast_c	0.201*	-0.146***	0.440*	-0.250***	-0.233	-1.085***	-0.020	-0.565	0.003	-0.239***
	(0.121)	(0.052)	(0.226)	(0.075)	(0.296)	(0.051)	(1.636)	(0.440)	(0.088)	(0.076)
Age_i	0.476*		-0.300		-0.025		-1.603		-7.821***	
	(0.267)		(0.763)		(0.333)		(2.008)		(0.775)	
Age_j	-0.323		-1.090		-0.279		-4.020**		-6.062***	
	(0.275)		(0.790)		(0.322)		(1.796)		(0.758)	
Dif_age	-0.014	0.071***	-0.123**	-0.111***	0.127***	0.154***	-0.546***	-0.217**	0.006	0.020
	(0.025)	(0.015)	(0.053)	(0.031)	(0.043)	(0.018)	(0.194)	(0.089)	(0.028)	(0.013)
Constant	1.949	7.963***	4.031	1.469***	12.33***	4.541***	37.84***	8.860***	83.89***	3.502***
	(2.836)	(0.163)	(7.706)	(0.323)	(3.544)	(0.160)	(13.24)	(1.088)	(6.308)	(0.178)
Observations	87,912	87,912	87,912	87,912	87,912	87,912	87,912	80,621	87,912	74,273
R2 / Pseudo R2	0.534	0.672	0.400	0.824	0.482	0.758	0.081	0.735	0.339	0.686
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. Note: *** p<0.01, ** p<0.05, * p<0.1

3.7.5 Interregional interaction and ageing: a focus

Following the recommendations of the SAG of the IRIE Project, where we noted the interest of confronting all the interregional categories of flows with the regional situation in terms of ageing, this short section comments on the variables included to this end in Table 3.4, as well as some additional visualizations. In relation to the econometric results (Table 3.4), the following results are worth mentioning:

Age_i: Note that the average age of the region of origin *i* is reported only for the OLS estimation, while it is subsumed by the fixed effects in the PPML. For trade of goods (M1), the coefficient is positive and significant, indicating that, on average, the regions with the oldest population are also intense exporters of goods. This is perhaps because the average population in certain highly industrialized or ruralized regions, specialized in industrial or agricultural products, is higher than in regions more specialized in complex services, such as business services (accounting, consulting, public sector, etc). Similarly, M9 found a negative and significant relation between a region's knowledge flows and the average age of its population. Again, regions specialized in R&D are often more directly associated with high levels of labour mobility among young white-collar employees, who usually appear around the capital city of each country, close to the headquarters of big multinationals, reputed universities, and other research institutions linked to the public sector. Thus the regions most attractive for young talented employees will become the main exporters of knowledge to other regions. The coefficients for the rest of the flows/models are non-significant.

Age_j: The coefficients in the results for the average age of the regions of destination *j* are non-significant for all flows except knowledge, where, as with the previous variable, the regions with the highest inflows of knowledge have the youngest population on average. This is reasonable for this kind of flow, where the network of knowledge represents the interconnection between very few, very competitive regions in each country (mainly capital cities and regions with attractive R&D and entrepreneurial clusters), with few interconnections with the other regions. While in the case of goods and services, all regions depend on supply from the most industrialized/rural regions. Here the average age has little effect on knowledge. Only the most competitive and innovative regions in Europe are involved in the knowledge network, while others, older in their demographic structure, do not necessarily participate in the creation and absorption of knowledge. Note that the proxy here is H2020 projects, which, like patents, can be described as the "superleague" of knowledge creation-diffusion in the EU.

Dif_Age$_{ij}$: Results for the difference in average age are even more illustrative. In this case we report them for the OLS and the PPML estimations.

- For M2 (goods) and M6 (migration) the coefficient is positive and significant, indicating that the greater the difference in age between the exporting and importing region, the more intense the flows of goods and migration. When the population of region *i* is older than that of *j*, we tend to see higher exports of goods and migration from *i* to *j*. With goods, this is coherent with the aforementioned rationale, in which regions specialized in agriculture and manufacturing are net exporters of goods to regions specialized in services (i.e. capital cities and other highly urbanized regions). For migration, the rationale could be associated with the phenomena of *brain-drain* and *rural exodus*, in which young people leave regions specialized in manufacturing and agriculture for more urbanized-servitized regions (capital cities and the coast), which end up being younger thanks in part to this permanent inflow of younger employees, with their capacity to establish new families.
- On the flipside, M4 (services) and M8 (FDI) generated negative and significant coefficients for *Dif_Age*$_{ij}$. If the youngest regions are the most vibrant and specialized in services, where the multinationals and leading public institutions are settled (i.e., capital cities), the *Dif-Age*$_{ij}$ variable will be smaller for regions exporting services and capital.
- Also remarkable is the non-significant result obtained for knowledge flows (H2020), which again confirms that the *i-j* pairs in this network of knowledge creation-diffusion serve as a "elite club", with regions of similar demographic structure. Note that if regions *i* and *j* have the same average, the difference will tend to zero. In these cases, the most equal and youngest regions, which are the most attractive for highly mobile researchers and technicians, are the ones that exchange knowledge and, indeed, the employees who produce/use it.

We now turn to briefly comment on the figures in the rest of the document, which basically confirm the most robust conclusions of the econometric analysis:

- Figures 4.1-4.5 (Annex) show the total outflows and average ages of the regions of origin. Only in Figure 4.1 (Annex) (goods) is the relationship is slightly negative, while in Figure 4.5 (Annex) (knowledge) it is slightly positive. It is in all cases blurry, but in Figures 4.2, 4.3, and 4.4 (Annex) it is very hard to detect a pattern.
- Figures 4.6-4.10 (Annex) show a clearer pattern, although the first impression is always biased by zero flows. In Figures 4.6 and 4.8 (Annex), we found the clearest negative relation between intensity of flows and difference in regional average age. Note that in these two cases, even for the regions with higher differences, there are non-zero flows, while in the case of services and FDI, almost all flows are zero when the demographic structures of the trading regions are very different. For H2020, the relation is blurrier.

To close this section we would like to note that our visual analysis does not include the extreme cases of the French outermost regions, whose average age clearly diverges from that of the rest of Europe (which is below 30 years) and was considered an outlier that would bias the rest of the relationships.

3.8 Multiflow maps. Size dimension

3.8.1 Dominant flow

There are many maps showing stereotypes about Europeans from different parts of the continent. So far, however, there has been no map showing the dominance of individual flows. It turns out that the map of the dominant flow, out of the 11 selected for analysis, provides an interesting new look at European reality. From among the 11 matrices, we selected the dominant flow, i.e. the one for which the standardized value of the weighted intensity index is the highest among the analyzed matrices.

In spatial terms, the picture resembles a mosaic. However, in metropolitan areas containing airports air passengers is usually the dominant flow. **Air passengers** dominate also in tourist regions in southern Europe and in Iceland.

Capital FDI competes with airports for dominance in metropolises and prevails over them — in, among other cities, Luxembourg, Paris, Stockholm, Dublin, and Randstad.

Labour mobility is the domain of densely urbanized regions, including the so-called European core, in particular the Franco-Belgian border as well as central and northern England, but also some regions in Central and Eastern Europe, in particular Lithuania and Slovakia as well as regions surrounding Prague and Budapest, where this type of flow stands out against the generally low values of other indices.

The areas dominated by flows under the **Erasmus** program (2010-2014) look extremely interesting. Apart from unequivocal exceptions, this is not the dominant flow in the European core. On the other hand, Erasmus is dominant in Finland, Estonia, and Latvia, as well as in Portugal, Spain, and individual regions of Italy and France. Quite surprisingly, it is also the dominant flow in most Central and Eastern European capitals, i.e. Berlin, Warsaw, Prague, Bratislava, and Budapest.

Goods freight flows definitely dominate in most regions in Poland, which seems to specialize in this type of flow within ESPON. In other countries, goods freight is the dominant flow only for individual regions, and these are very different regions by specificity, so this topic offers great research opportunities for the future.

Goods trade differs from goods freight in that it is calculated in money, not tonnage. Regions where this flow is dominant lie in northern Italy and northeastern France, but also in Belgian Flanders and in the western parts of Czechia, Slovakia, and Hungary. It is surprising that Western Germany, which has traditionally been strong on trade, is so "dominated" by patents; only in the Saarland does goods trade dominate.

Participation in **H2020** projects (2015-2018) is the domain of capitals such as Helsinki, Rome, Athens, Vienna, and Ljubjana, as well as highly developed regions such as Navarre and the Basque Country in Spain.

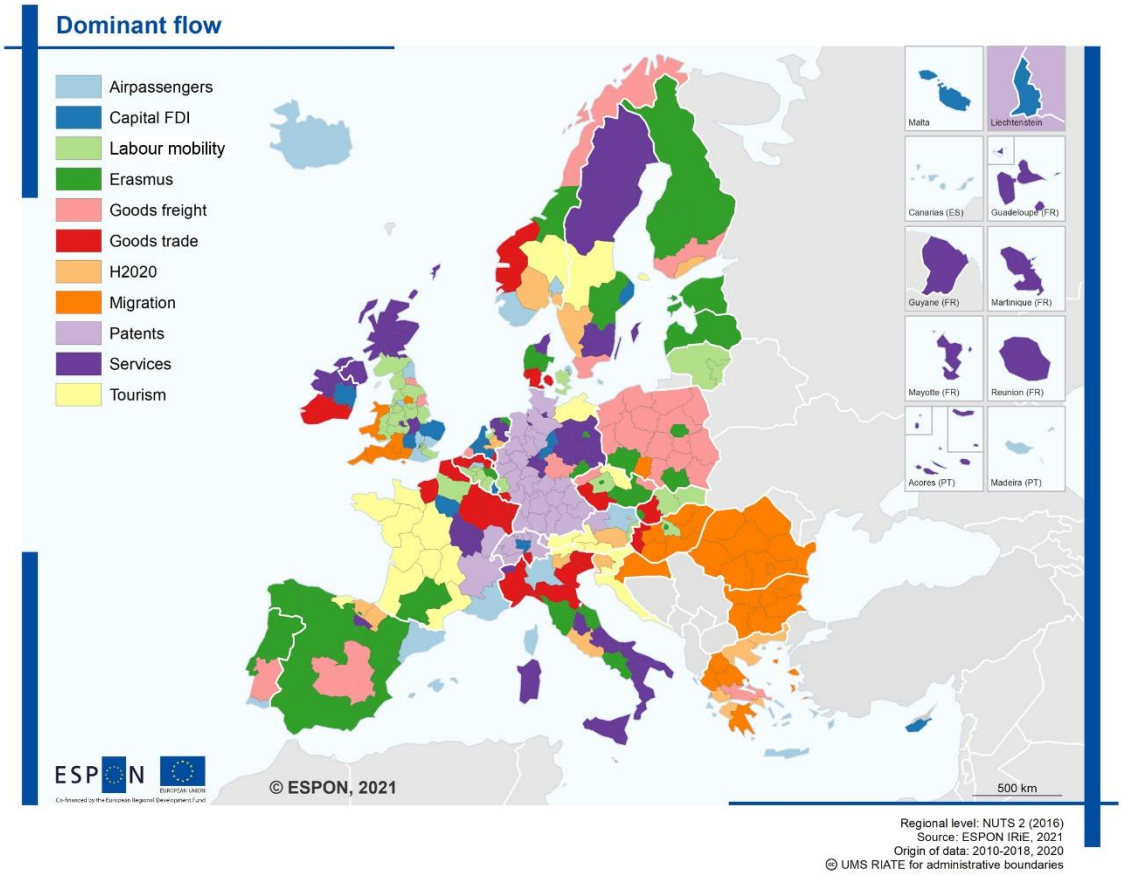
Migrations dominated the southeastern part of the ESPON space, from Hungary and Croatia through Romania and Bulgaria to Greece. It is surprising that this flow also dominates in Wales and the southwest of England. In Poland, migrations dominate in the Opolskie Voivodeship, thanks to the area's traditionally strong migration ties with Germany.

As mentioned earlier, the "kingdom of **patents**" is West Germany and Switzerland, but also, although because of the weakness of other flows, regions of France bordering on Switzerland.

Services is a fairly puzzling flow that dominates regions as diverse as Scotland and Northern Ireland, as well as southern Italy, including Sicily and Sardinia. Services also dominates, among other places, in Hamburg, Brandenburg, and northern Sweden.

Last but not least, **tourism** is quite surprisingly dominant in the compact area of western France, in Mecklenburg (Germany), and on the Norwegian-Swedish border, but also, less surprisingly, in the Alpine regions of the Italian-Austrian border, on the Dalmatian coast of Croatia, and in Cantabria (Spain).

Figure 3.60: Weighted intensity. Dominant flow



3.8.2 Concentration of dependencies on individual flows

Each of the regions has a dominant flow. However, regions differ in the concentration of their dependencies on individual flows by comparison with other flows. In this report, we use two measures of flow concentration: (1) **coefficient of variation** and (2) **gini index**. As they are highly correlated, their description is common.

Luxembourg definitely has the group's highest concentration of analyzed flows in the ESPON space, as befits its unique position in the field of **capital FDI flows**. Central Switzerland is also highly concentrated in FDI capital.

A very high concentration is also characteristic of some of the regions where **migration** is the dominant flow: mainly in Romania and southern Hungary (Southern Transdanubia), but also in Greece and the Opolskie Voivodeship in Poland.

Another example is the focus on **goods freight**, which takes place primarily in peripheral and sparsely populated regions, such as northeastern and western Poland and northern Norway.

Another coherent group comprises regions with a high concentration — we could also say specialization — in **tourist flows** and related **air passengers**. This group includes regions around the Mediterranean basin that are strongly concentrated on the abovementioned flows, especially such islands as the Balearics, Sardinia, and Crete, but also the Algarve in Portugal and the Dalmatian coast in Croatia. The Åland Islands in Finland are also heavily focused on tourist flows. It is also worth emphasizing the air-passengers flow's high concentration in regions near London, where the largest airports are located. However, this is an exception to the rule, as NUTS 2 regions with large air hubs are usually located in agglomerations and are therefore not very dependent on single flows. Labour mobility, for example, is also strong in these areas.

On the other hand, the regions that are least concentrated on single flows are also worth our attention. They are, in a sense, the least vulnerable to single-flow crises, because they are "involved" in the whole spectrum of flows. They are resilient regions, capable of responding to shocks and stresses from particular flows. They certainly include northern Italy, especially Lombardy, and some regions in Sweden (south Sweden and east-middle Sweden). We may generally conclude that metropolises, including state capitals, have a much greater dispersion in their involvement in particular flows, while low-population, peripheral areas are more exposed to a single flow's high concentration. We may also conclude that in general the risk of concentration on individual flows increases as we move away from the European core, while flow portfolios in the core tend to be diversified (except for the high concentration on FDI flows in Luxembourg and central Switzerland).

We recommend further research on this topic, and suggest that it take into account a larger number of flows, as well as the basket approach (flows of goods, people or knowledge), with a possible weighting of flows by their importance in individual baskets. Only such comprehensive analysis could paint a comprehensive picture of the vulnerability and resilience of regions to crises in particular flows.

Figure 3.61: Concentration of dependencies on individual flows. Coefficient of variation

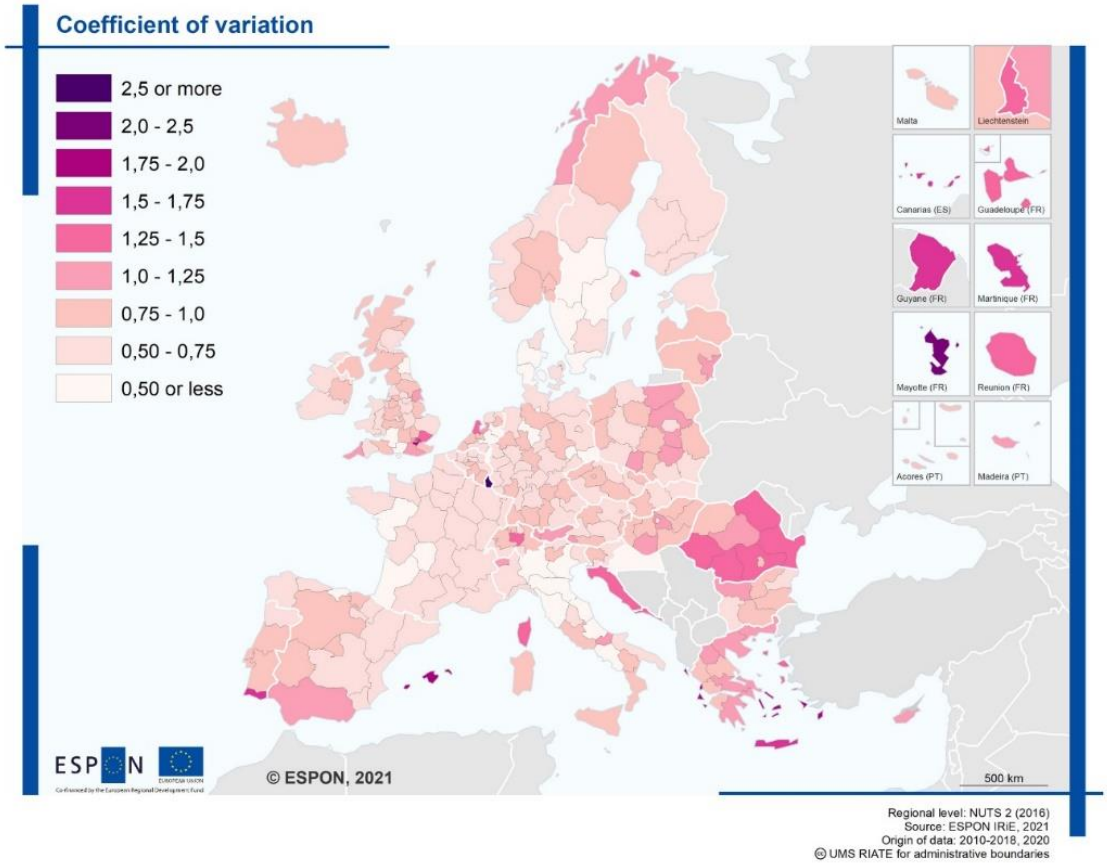
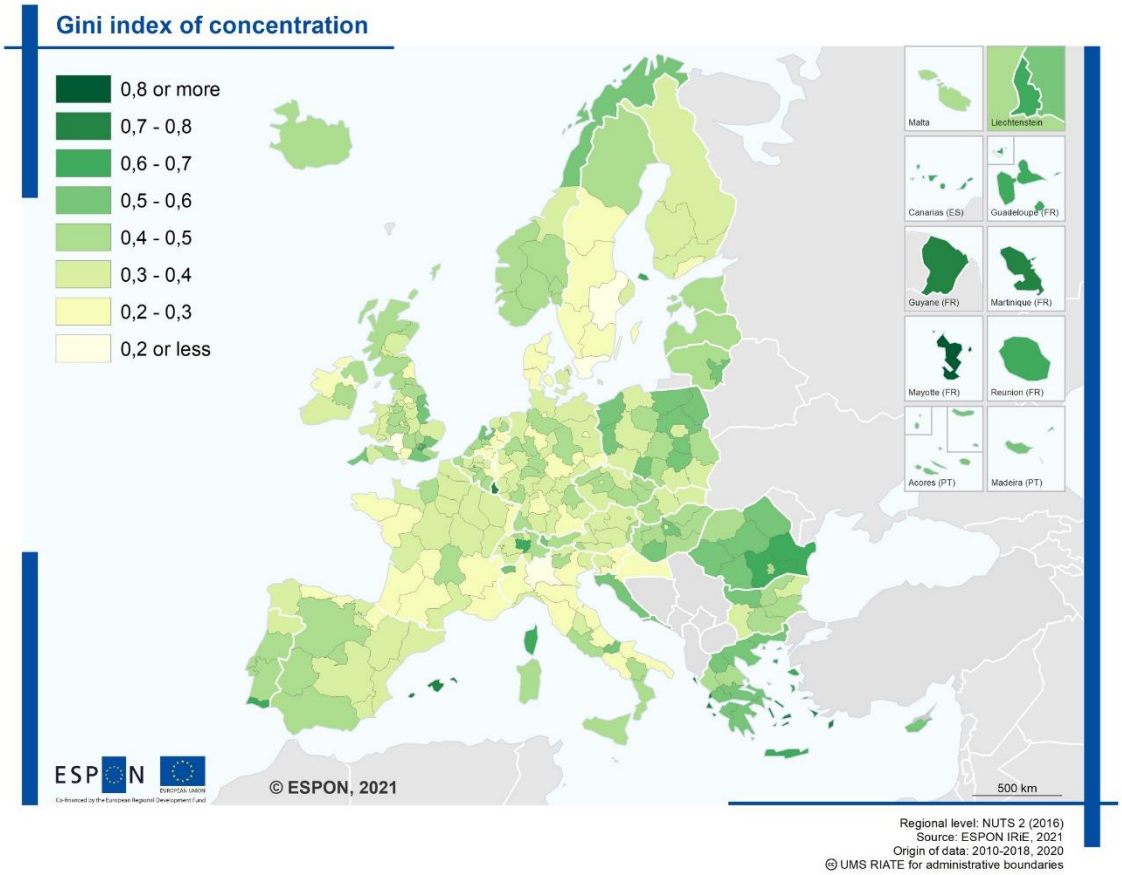


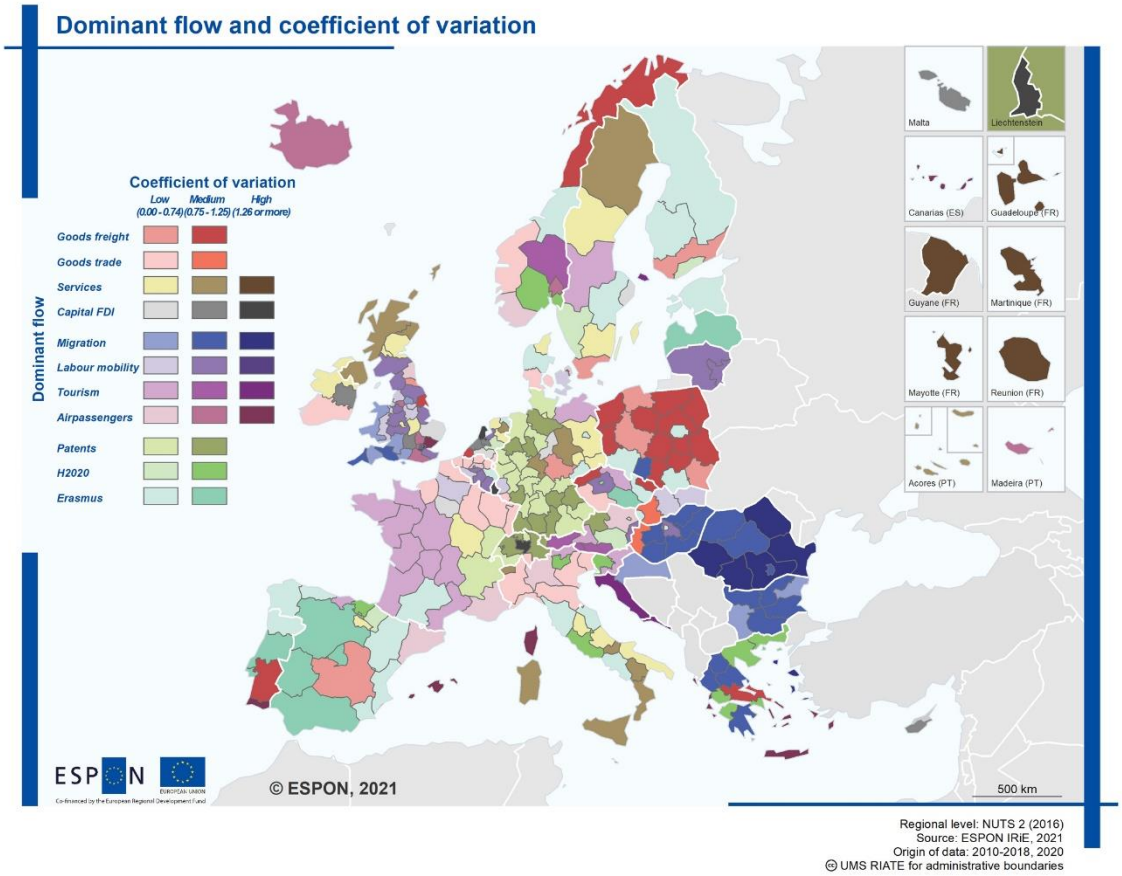
Figure 3.62: Concentration of dependencies on individual flows. Gini index



Combining the results of the dominant flow with the coefficient of variation yields interesting information on, first of all, regions with high concentration on the selected dominant flow. This could serve as an analogue to resilience.

We define 'resilience' as a region's capacity to recover quickly from a crisis connected with particular flows. Therefore, we consider that a region's exposure to interregional dynamics or resilience depends on the diversity of its external relations. By this approach, regions with a balanced composition of flows, instead of a concentration on one, are less exposed to external shocks or policy decisions affecting one flow in particular. In general, metropolises, including state capitals, have a much greater dispersion in their involvement in particular flows, while low-population, peripheral areas are likely to have a high concentration on one flow. In Figure 3.63 we can identify strongly dominant flows, like migration in Romania and FDI in Luxembourg. Because of its strong reliance on FDI flows, Luxembourg is probably less resilient to shocks in its dominant flow than other regions. The same goes for the peripheral regions of Romania that focus on migration flows.

Figure 3.63: Concentration of dependencies on individual flows. Dominant flow and coefficient of variation



Clustering

We performed a clustering analysis of 11 flows as a supplement to indicate whether the regions are clustered for two indices, i.e. weighted intensity and balance. The answer turned out to be positive and very interesting, especially in the context of weighted intensity, perhaps a premise for further research under ESPON, concerning, among other things, a new or extended typology of regions that takes interregional flows into account.

To determine the optimal number of clusters we used the WSS and Silhouette methods. To present the results, we used not just a cartographic study and a table with average values for each cluster for the 11 flows, but also two-dimensional plots to visualize how the regions are distributed and how the clusters are concentrated, spread out, or what have you.

3.8.3 Weighted intensity

Through our research procedure, which included determination algorithms, we distinguished six clusters for the weighted intensity index.

Geographically, in the ESPON space there is a clear distinction between clusters 2 and 3 and the rest. Clusters 2 and 3 are geographically compact, large areas and mathematically quite concentrated around their mean. Other clusters are rather small in number, and geographically there are single regions with common features.

Cluster 3 is clearly narrowed down to the German language space (Germany, Switzerland, and Austria), the Benelux countries, and most of the regions in Ireland and Great Britain and the southern part of Scandinavia. Apart from the relatively compact area, only single regions were qualified for cluster 3, i.e. Opolskie Voivodeship in Poland, strongly connected by migrations with Germany, three Alpine regions in Italy, Liguria, and two autonomous regions: the German-speaking autonomous region of Trentino-South Tyrol and the

French-speaking region of the Aosta Valley. The most distant region from the compact area of northern and central Europe is La Rioja in Spain. Explaining its presence in this cluster will require further research. The weighted intensity indices for regions in cluster 3 take on high average value, which means that these regions participate actively in the flow space. The particularly high values of the index are the result of the very high position of the German linguistic area in patent flows. This cluster can be characterized as the core of Europe (in terms of flows), in which highly intense economic (trade, freight) and social relations (migration, tourism) are accompanied by high indicators for such flows as labour mobility (intense in Germany and around its territory) and knowledge (especially patents).

Cluster 2 includes most of the regions from the countries that joined the European Union in 2004 (with some exceptions, mainly capitals). It also includes all regions of France and most regions from the rest of the Mediterranean, as well as Northern Ireland, some regions of Great Britain, and two regions of northern and central Finland. The regions in cluster 2 usually have lower values in the weighted intensity index, are less involved in the flow space, and can be described as peripheral to those which are more cross-linked.

Cluster 1 includes mainly capital city regions. This group of regions includes Madrid and Lisbon, Berlin and Vienna, Stockholm and Helsinki, Dublin, and Brussels, as well as a compact group of capitals of the countries that joined the European Union in 2004, i.e. Vilnius, Prague, Bratislava, Budapest, and Ljubljana. In addition, this group includes the Dutch Utrecht and Groningen and — though it is quite interesting and difficult to explain — Iceland and the Norwegian Trøndelag. Despite these exceptions, clusters can be defined as groups of capital units in countries outside the European core. They are "islands" of highly intense flows and at the same time gateways between peripheral areas and the core.

Cluster 4 includes in particular port-city regions in northwestern Europe and northern Scandinavia. These include Hamburg, Bremen, and Antwerp. Regions in cluster 4 specialize primarily in trade flows, and the weighted intensity indicator is much higher for trade here than in other clusters. The position of these regions in terms of service flows is also relatively high. Liechtenstein, although not a port, has also been assigned to cluster 4.

Cluster 5 is Luxembourg, which appears as an outlier, a cluster of its own! Luxembourg has an extremely high index value for FDI capital and very high values also for participation in H2020, labour mobility, and services.

Cluster 6 is dominated by regions with strong air-passenger and tourism flows. This cluster includes a group of NUTS 2 regions around Greater London, Greater Manchester, North Holland (Schiphol airport) in the Netherlands, and Olso in Norway, as well as a number of island regions in the Mediterranean, plus the Algarve in Portugal and Canarias.

Figure 3.64: Weighted intensity. Multiflow comparison. Cluster plot

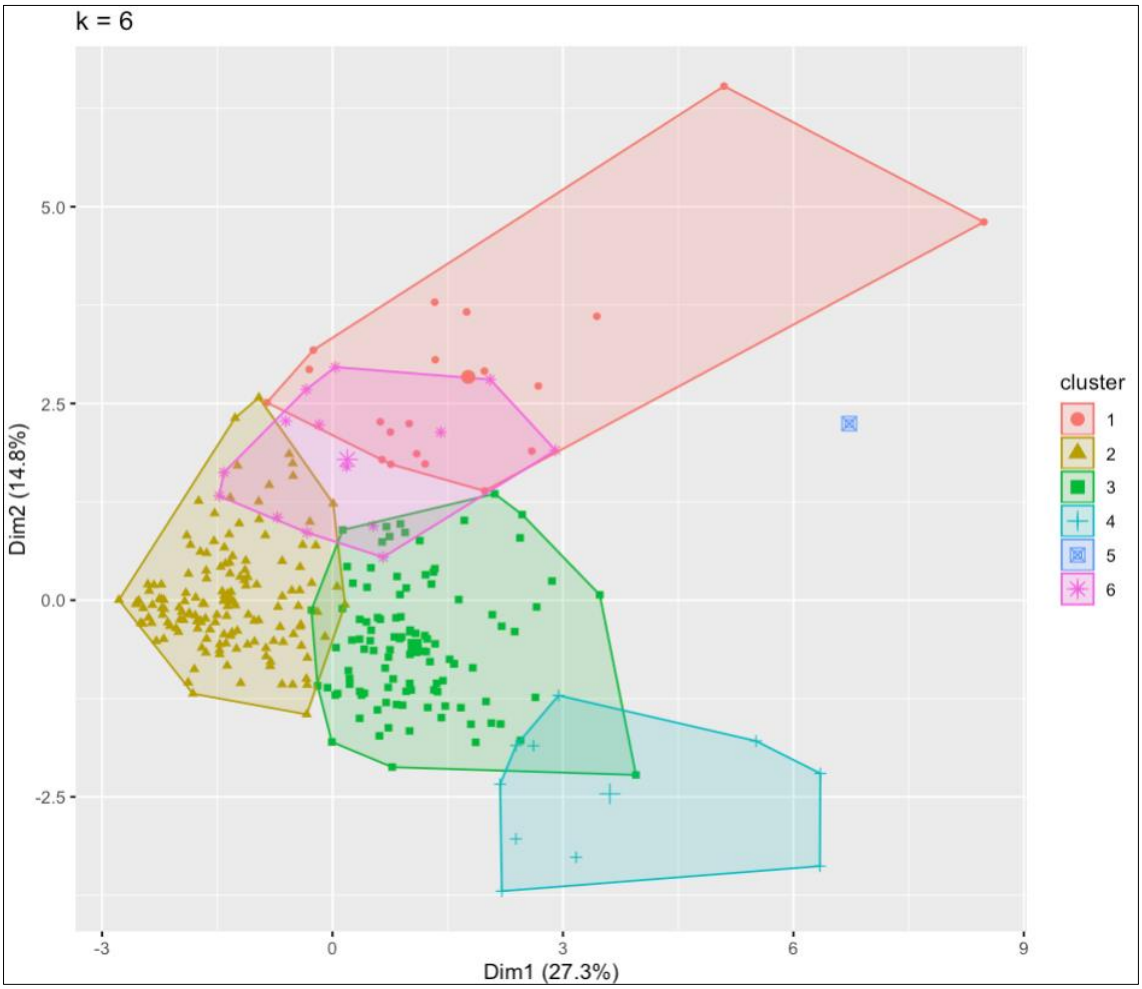
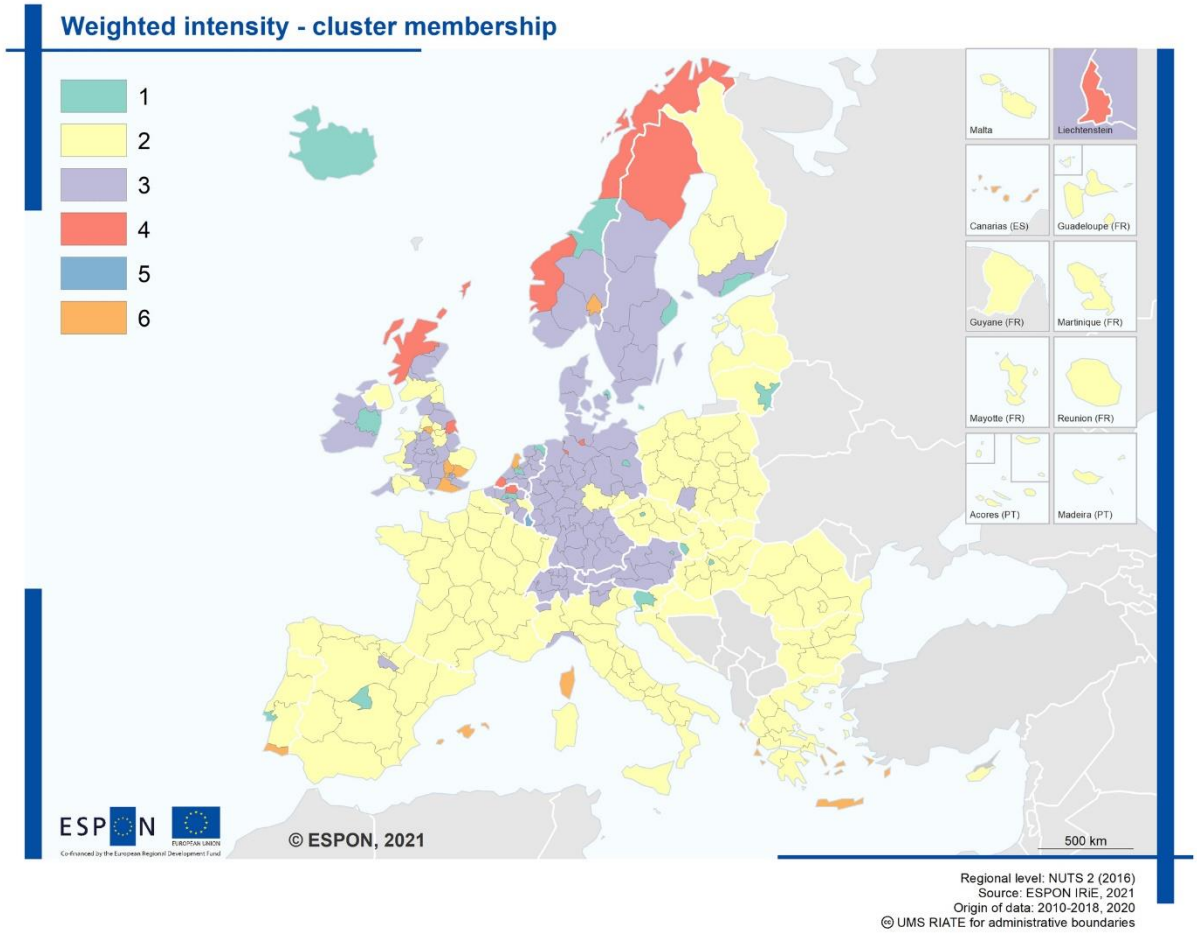


Table 3.5: Cluster means for 11 flows. Weighted intensity

	Goods freight	Goods trade	Services	Capital FDI	Airpassengers	Labour mobility	Migration	Tourism	Patents	H2020
1	-0,267472	-0,186676	0,06229958	0,29715528	0,6713027	0,79681041	0,612068	0,3683396	0,0354745	2,08883
2	-0,4466545	-0,4131701	-0,58598268	-0,13546015	-0,2592877	-0,461348	-0,5803683	-0,4945664	-0,4807774	-0,30458
3	0,4101977	0,3590702	0,5084315	-0,04543712	-0,245463	0,38563168	0,5451192	0,4430399	0,69219795	0,021015
4	3,4432694	3,1552325	1,82445126	0,16692776	0,1617824	0,732878	0,502696	0,5557518	-0,0050625	0,079804
5	0,8891233	1,0413234	2,99379635	16,39106637	0,464923	1,13134865	0,6704662	0,6787796	0,4719892	1,324914
6	-0,7111064	-0,5816579	0,49904317	0,02928722	3,4527599	0,02782518	0,482955	0,6975834	-0,4754492	-0,16496

Figure 3.65: Weighted intensity. Multiflow comparison. Cluster membership



3.8.4 Balance

Our clusters are closer in size for balance than for weighted intensity, and no major outliers appear for the three defined clusters.

Cluster 1 includes mainly peripheral areas that really belong to senders, in particular for flows such as migration, labour mobility, participation in the Erasmus program, and FDI capital. Nevertheless, this cluster covers most of the ESPON-space regions, including both the periphery and many units central to the traditional core (e.g. Germany, northern France). So by taking into account balance (and not just intensity), we narrow down the group of units constituting the core of European space (in terms of flows).

More-developed or metropolitan areas usually belong to clusters 2 and 3. The difference between them is that **cluster 2** "specializes" in being attractive to Erasmus students and FDI capital, and the regions belonging to it have a negative balance in tourism and trade flows. Spatially cluster 2 crosses the ESPON space from the northwestern part of the continent (Iceland, southern Scandinavia, Ireland, and Great Britain) through the European core to individual regions in southern Italy and Greece. We may assume that cluster 2 corresponds most closely to the quantitatively reduced group of core units. Seen in this way, the core includes all of Great Britain and Ireland as well as extensive areas in northern Italy and Scandinavia.

Meanwhile **cluster 3** (smaller) seems to include places — mainly capital regions — that rank distinctively in certain economic dimensions (goods, services, labour mobility). Cluster 3 covers most of the strong economic areas in peripheral zones. These include the capital cities of southern and central-eastern Europe, as well as some industrial areas (Czech Silesia) and tourist regions (on the Mediterranean and overseas). Cluster 3 again groups "islands" that could serve as the basis of a European polycentric system.

Figure 3.66: Balance. Multiflow comparison. Cluster plot

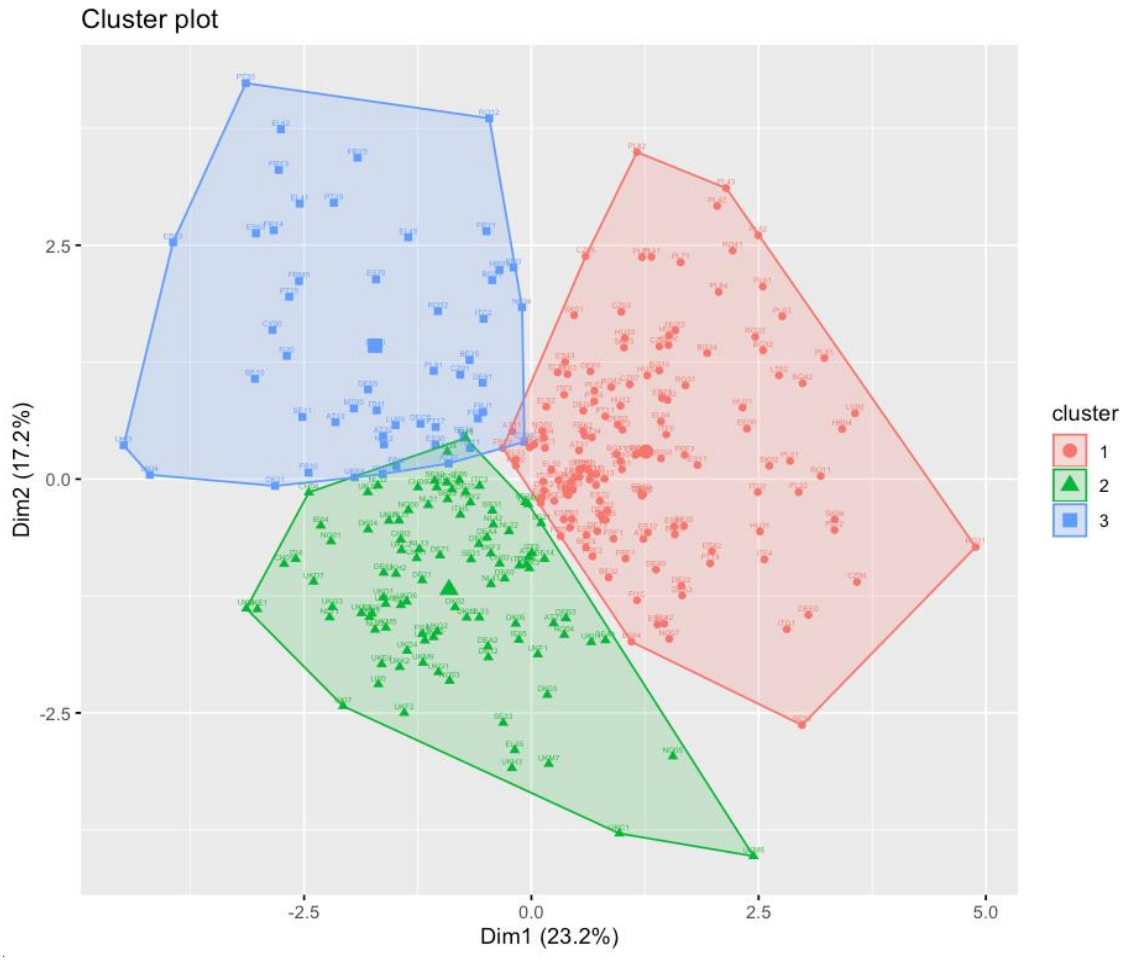
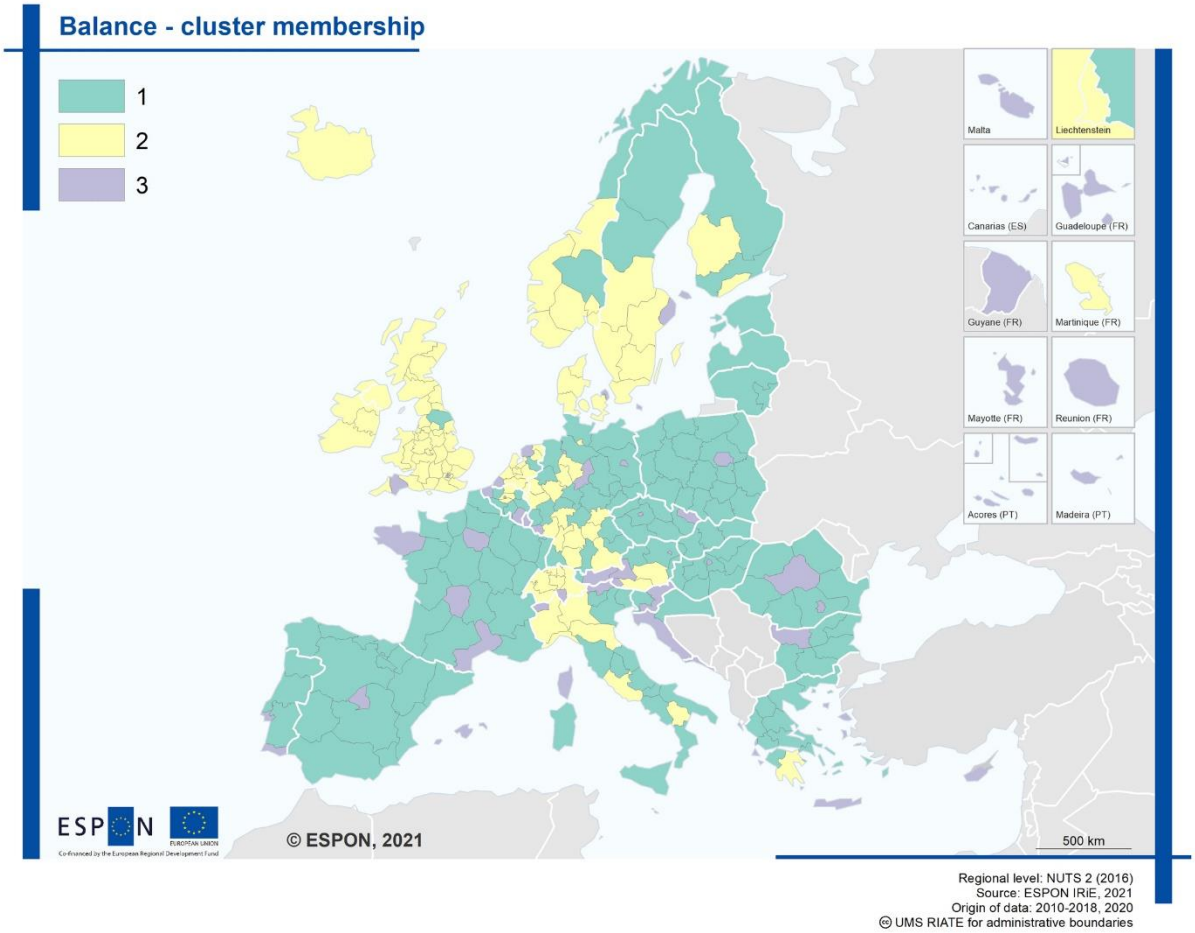


Table 3.6: Cluster means for 11 flows. Balance

	Goods freight	Goods trade	Services	Capital FDI	Airpassengers	Labour mobility	Migration	Tourism	Patents	H202
1	-0,43552967	-0,3647862	-0,247526786	-0,44844072	-0,16774239	-0,40857436	-0,4335988	0,2109938	0,51209242	0,3
2	-0,08452378	-0,1682487	0,008130168	0,66375126	0,05931754	0,07076252	0,4825988	-0,4906649	-0,7157517	-0,4
3	1,34280474	1,3085677	0,657185668	-0,03395591	0,34383301	0,97657462	0,2675158	0,3525166	-0,04087055	0,0

Figure 3.67: Balance. Multiflow comparison. Cluster membership



3.9 Dynamic approach

To simplify the analysis, we assumed that the sum of all r2r flows in a given matrix for a given flow equals 100 in the starting year, i.e. for 2010. For flows occurring under the Erasmus program we limited our analysis to 2010-2014, and for H2020 to the years 2015-2018 (here the value of 100 was taken as the base year, i.e. 2015).

The analysis of 11 flows in dynamic terms shows high stability for the sum of r2r flows in the analyzed period of 2010-2018. Most of the flows increase in 2010-2018 at a stable annual pace of several percent, while the cumulative increase for 2010-2018 is approximately 20% to 50%. However, a few outliers bear closer inspection.

A particular increase in the pre-pandemic period was observed for **FDI capital**, whose cumulative growth for 2010-2018 exceeded 60%. On the other hand, total **goods-freight** tonnage did not change in the analyzed period, which allows us to conclude that the transport intensity of the r2r-flows economy decreased in the analyzed period. Most interesting and dynamically different from the rest of the flows is **patents**, for which there is a systematic decrease in the sum of flows in the matrix, mainly in the early years of the decade.

When we take into account only the international flows (c2c dynamics; Fig. 3.69), the following differences from the r2r approach are noticeable:

- more than twice as high average annual increases in international flows (compared to r2r flows) for services, migrations and commuting;

- no differences, which is natural for Erasmus related flows;

- very smilar dynamics of c2c and r2r for capital FDI, H2020 and patents.

In the scatterplot of relationships between the time-dependence index and the dynamics index (for r2r flows), three groupings (clusters) of flows are clearly visible. The first, comprising the largest number of flows, shows quite clearly that the dynamics are highly dependent on the passage of time, with a positive growth rate. The second, i.e. the H2020 and patents cluster, consists of flows whose dependence on time is high, with a simultaneous constant decrease from year to year in total flows (negative dynamics values). The flow of goods freight is unique, because of its very low dependence on time and large fluctuations, small increases, and decreases in the index value over time.

The dynamics of change in the overall intensity of flows lead to some general conclusions. These require further detailed analysis, but they are potentially important for the future integrity of the EU (and the ESPON space as a whole) and for the objectives of several sectoral policies. Some of them are not optimistic. They are as follows:

- Highly dynamic FDI flows coupled with less-intense knowledge flows may indicate that integration in the R&D sector is not keeping pace with economic integration. In combination with the different spatial distributions of the two types of flows, this may imply that knowledge will polarize territorially if most of the economic system's regions integrate fully.

- Highly dynamic FDI flows relative to trade and services can be interpreted in two ways. On the one hand, they may indicate greenfield investment ahead of trade intensification; on the other, they may result from the increasing dominance of financial flows unrelated to real production.

- An increase in air-traffic dynamics (passenger traffic) above the level recorded for tourism indicates the growing importance of air transport to intra-European travel (at least until 2018, i.e. before the COVID-19 pandemic). This goes against the emissions-reducing objective of a proportional increase in the use of rail for medium-haul travel (up to 1,000 km).

- Decreasing migration dynamics may imply a levelling off of differences in living standards between parts of Europe.

Table 3.7: Dynamics of sum values for r2r matices for 11 flows

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Time dependency index	Dynar index
Goods freight	6410	6450	6181	6197	6257	6384	6396	6564	6526	0,224	
Goods trade	4451	4864	4834	4818	4877	4948	4889	5164	5381	0,761	
Services	8507	8737	8981	9381	9703	10319	10068	10753	10963	0,972	
Capital FDI	270462956	285417265	300399978	310598862	321488501	351275705	361258099	377264735	446296143	0,951	
Airpassengers	633944	676771	675853	683886	716291	763239	827738	886416	918682	0,944	
Migrations	8635	8915	9257	9436	9893	10126	10252	10373	10437	0,952	
Tourism	988380	1042457	1091100	1122329	1166944	1228182	1289375	1360373	1412778	0,996	
Labour mobility	16	17	17	19	19	18	19	19	20	0,847	
Patents	61	45	43	41	40	40	37	34	34	0,809	-
H2020						15	14	14	12	0,906	-
Erasmus	167	176	189	194	198					0,951	

Figure 3.68: Dynamics of sum values for r2r matices for 11 flows (base year of 100)

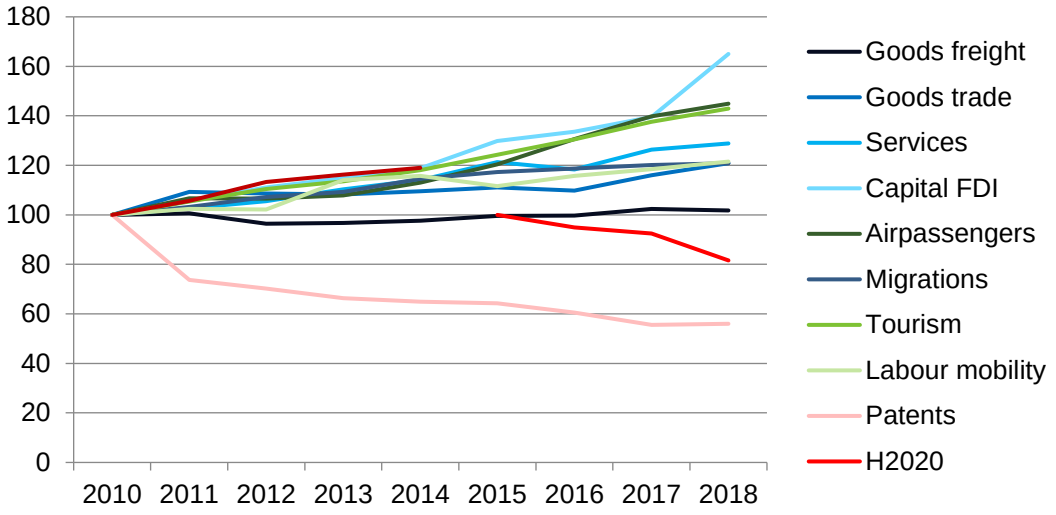


Figure 3.69: Dynamics of sum values for c2c matices for 11 flows (base year of 100)

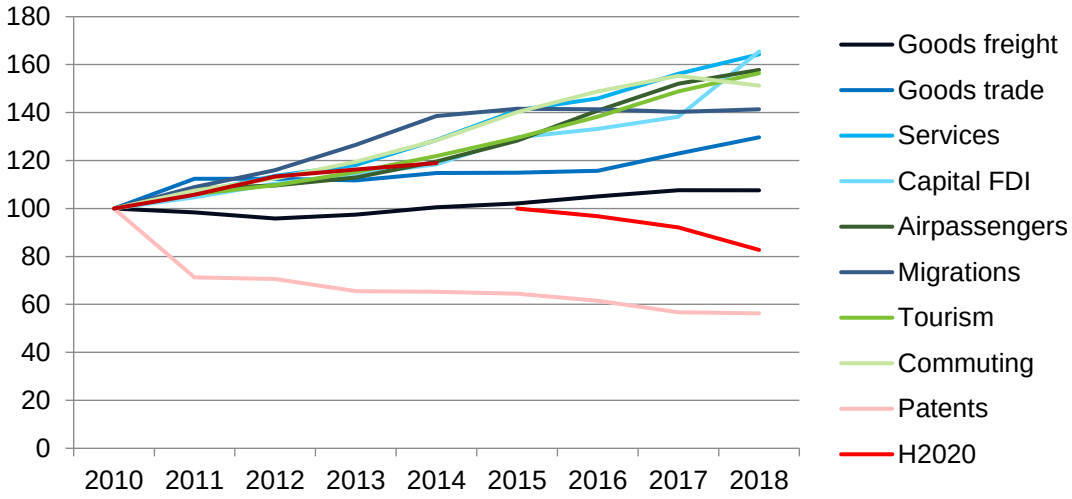
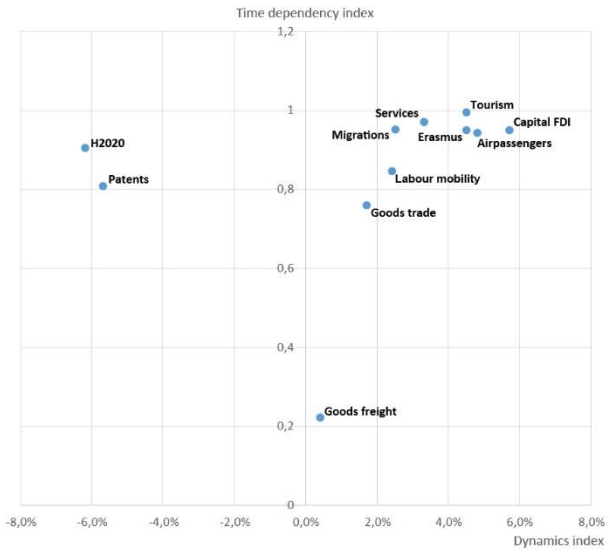


Figure 3.70: Scatterplot: Dynamics index vs time dependency index



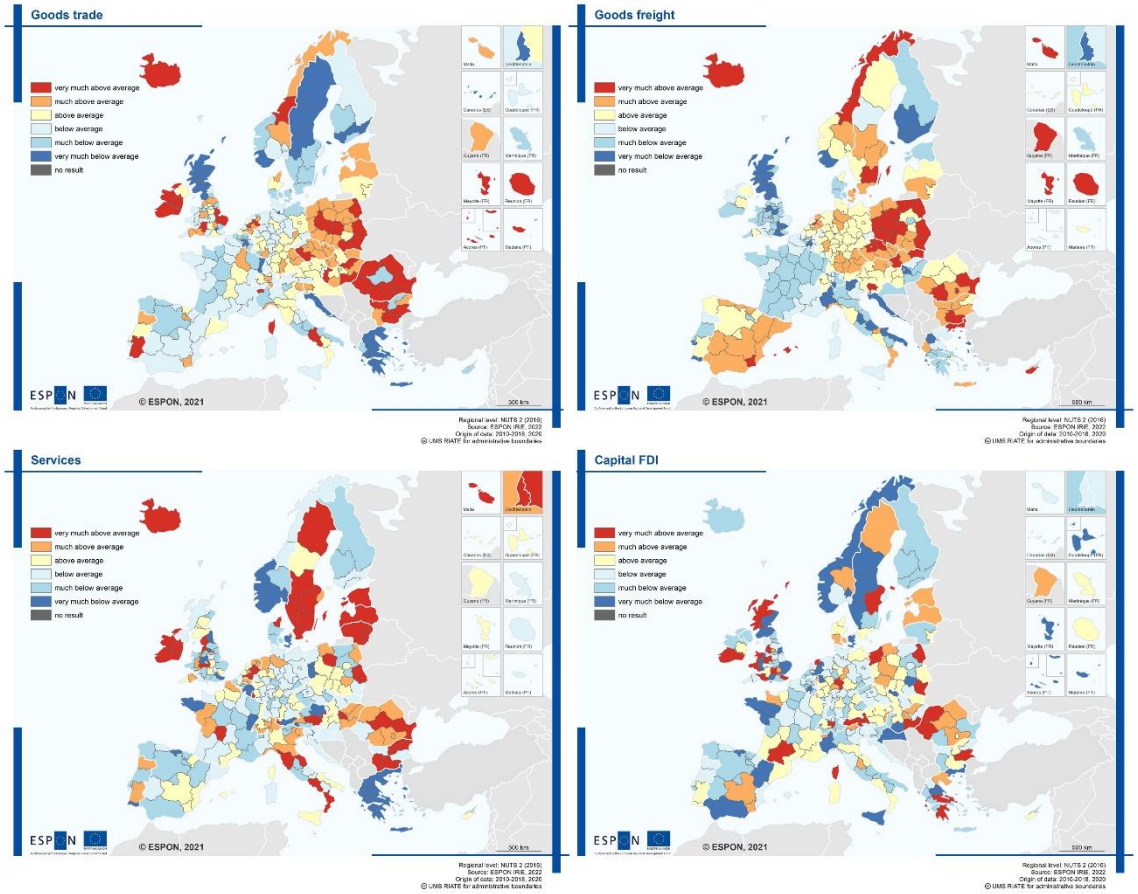
Each of indexes has been defined as dynamics of region's exponential trendline to identify differences between regions. Regions without any flow evidenced (total intensity is 0) appeared in case of some flows (e.g. airpassengers). In such cases, value 0 has been assigned to the regions without any flow during the entire considered period, while category of "no result" has been assigned to the regions with the flow evidenced, but not in every Year (exponential trend can not be identified). At further step, values has been classified within the framework of three levels above and three levels below total dynamics of exponential trendline for entire flow. The thresholds were determined by statistical distribution of empirical data set, where the equal representation is assumed in case of normal distribution (thus +/- 0,967 * st. dev. and +/- 0,431 * st. dev. from the mean). Such solution does not imply equal representation of each of three index classes in practice, but returns the added cognitive value of distribution's skewness display.

Taking into account the regional differences in dynamics, the following conclusions can be drawn:

- in synthetic terms, flow convergence is clearly visible; the annual increases of flows are clearly very much above the average in less developed regions, peripheral to the center of Europe, especially in the countries that joined the European Union since 2004; these regions have so far participated to a lesser extent in the space of flows, but are catching up quickly and are increasingly becoming networked;

- however, there are a few exceptions to the "flow convergence rule"; these exceptions include, for example, the increasing role of Ireland and Luxembourg characterized by high flow intensity; It is also worth noting that the dynamics of individual flows may differ significantly and, for example, in Poland, Lithuania and Latvia, migration flows are significantly below the average for the analyzed period because the peak of migration flows occurred there before 2010.

Figure 3.71: Goods, services, capital. Dynamics of region's exponential trendline of total (outflow and inflow) flow's intensity



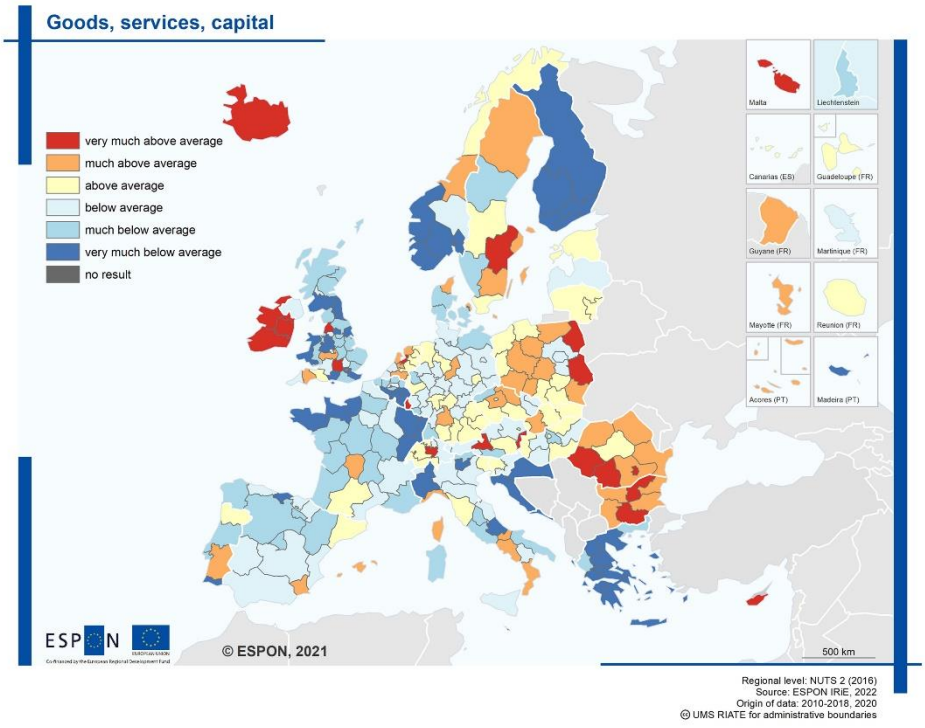


Figure 3.72: People. Dynamics of region's exponential trendline of total (outflow and inflow) flow's intensity

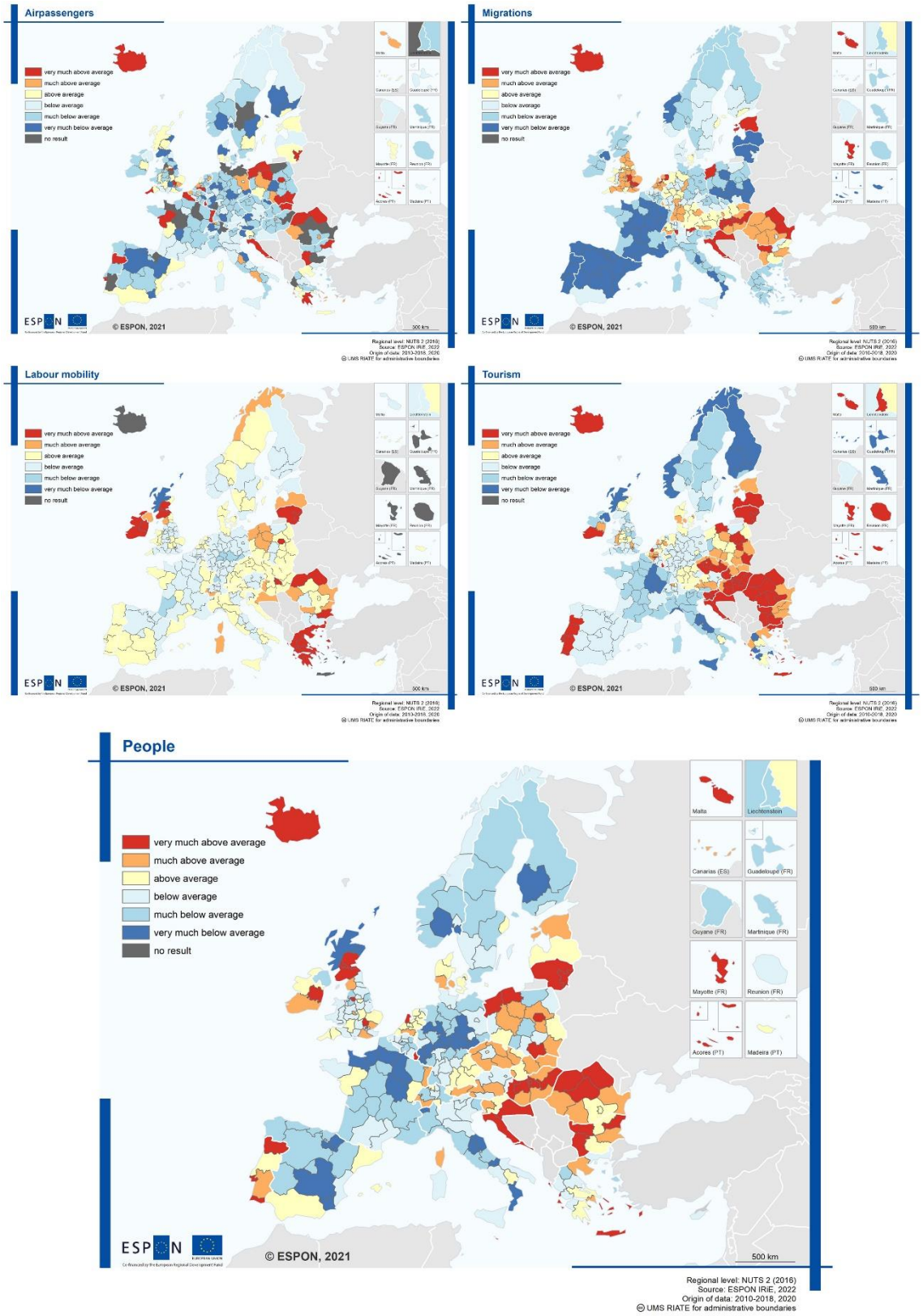
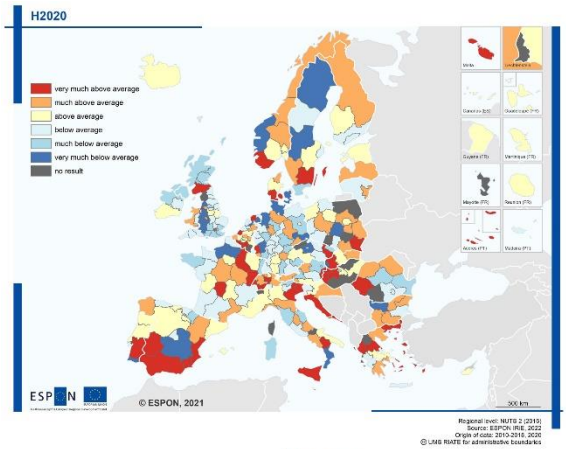
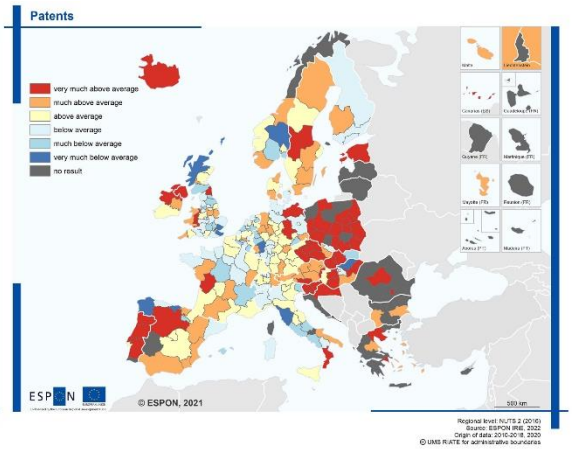


Figure 3.73: Knowledge. Dynamics of region's exponential trendline of total (outflow and inflow) flow's intensity


H2020
very much above average
much above average
above average
below average
much below average
very much below average
no result
ESPON
© ESPON, 2021


Patents
very much above average
much above average
above average
below average
much below average
very much below average
no result
ESPON
© ESPON, 2021

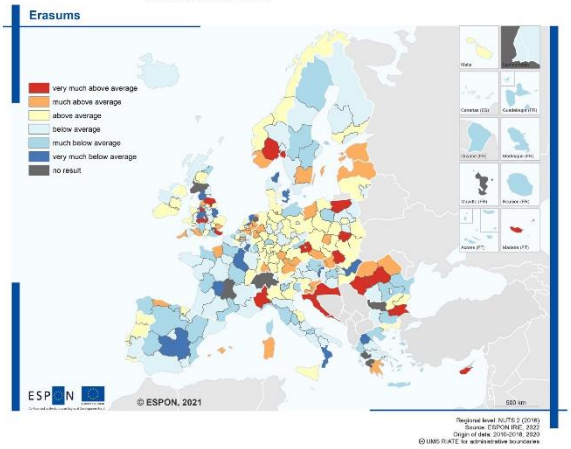
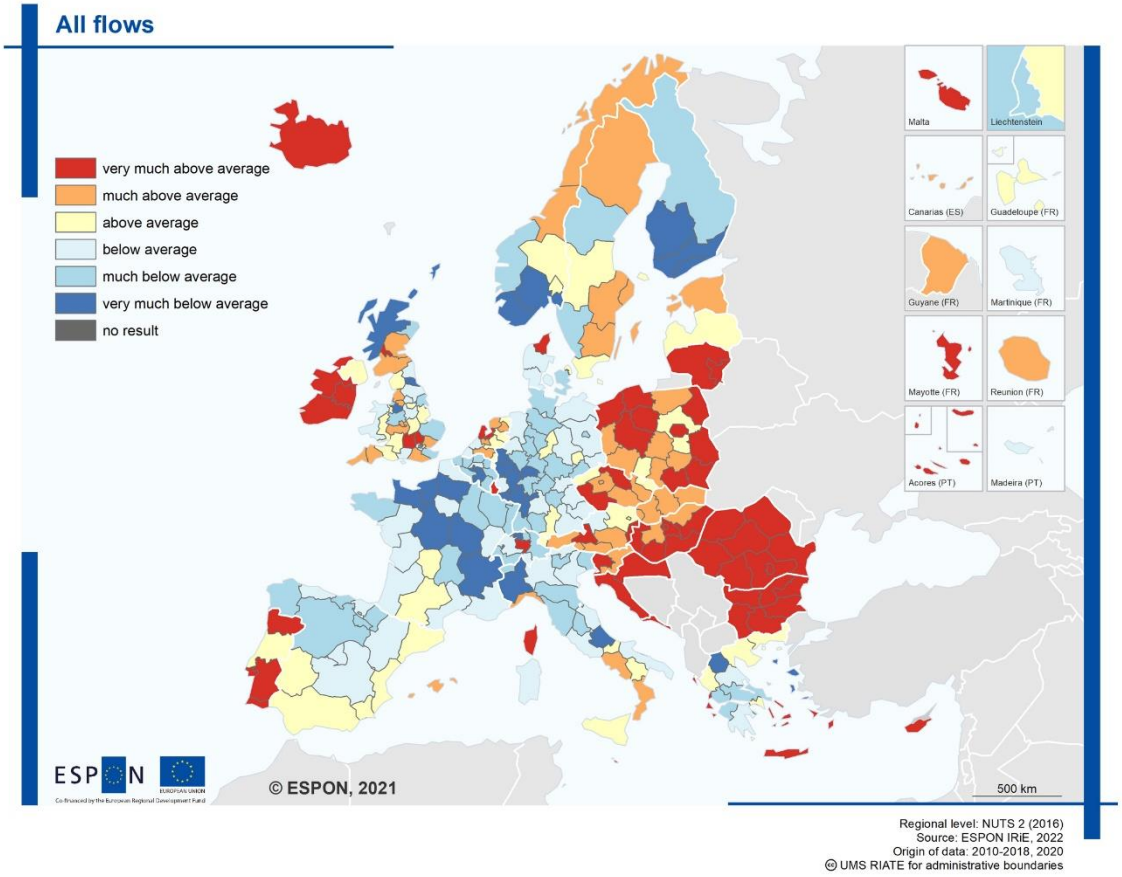

Erasums
very much above average
much above average
above average
below average
much below average
very much below average
no result
ESPON
© ESPON, 2021

Figure 3.74: All (nine) flows. Dynamics of region's exponential trendline of total (outflow and inflow) flow's intensity



4 Conclusions

The most important conclusions from the report have been presented analogically to the structure of the report, broken down into spatial, structural, and dynamic approaches.

Spatial approach.

Conclusions from the spatial approach relate primarily to the seven indicators described in Table 2.1: (1) intensity index, (2) weighted-intensity index, (3) balance index, (4) concentration-per-population index, (5) UK-dependency index, (6) average-distance index, and (7) border-effect index. Regardless of the detailed conclusions, it is possible to formulate helpful theses of broader significance, especially for sectoral-policy recommendations. They are based on our two-dimensional typologies, among other things.

Intensity index. In our analysis, we identify a network of metropolises that concentrate the strongest flows, mainly in Western and Northern Europe, and mostly near the European core. These metropolises anchor the flows in Europe. The **synthetic index of the Super League of flows** allows us to list the nodes that concentrate the strongest flows (of the 11 analysed). These are: London, Paris, Luxembourg, Amsterdam, Frankfurt, Munich, Hamburg, Berlin, Madrid, Rome, Milan, and Stockholm. The dense network of relations between EU member states that joined the EU before 2004 stands in contrast to the weak relations — with single exceptions — between new EU countries (2004, 2007 and 2013 enlargements). In many countries, the most intense flows occur between capital cities and regions in their immediate vicinity. This is the result of several elements, such as transport hubs, commuting distance, and suburbanization.

The synthetic index for the **goods/services/capital** basket illustrates the most important relations within the ESPON space, where flows within the network of metropolises (Luxembourg, London, the Benelux states, and Switzerland) dominate the European core, followed by domestic networks of goods/services/capital in countries that joined the EU before 2004. The synthetic index for the **people** basket underscores the crucial role of links between the capitals of the largest European countries and the largest cities in these countries. Because tourism and its numerous passenger flights are so important, relations with tourist centers on the Canary Islands, the Balearic Islands, and Sicily are visible. The synthetic index for the **knowledge** basket lacks dominant relations of the kind we see in other baskets. The network of metropolises is observed between the most important academic centers of western and southern Europe.

Weighted-intensity index. The weighted-intensity indicator is the index with the most possibilities, and was used in the report in many ways (dominant flow, clustering, etc.). The **synthetic weighted-intensity indicator** shows that most flow-oriented regions are located in the European core, from the London area, through the Benelux countries and West Germany and on to Switzerland and Austria. Outside the European core, important flows are visible also in Ireland, Scotland, and Scandinavia. Moreover, flows of relatively great importance can be observed in all capitals, which leads us to conclude that there are two levels of flow peripherality, including also the extreme periphery. In addition, regions with seaports, financial centers, and such are themselves large centers for economic flows. The lowest flows, meanwhile, are in the peripheral regions on the ESPON space, affected by their distance from the European core. Regions in countries that joined the European Union after 2004 (in particular Poland, Slovakia, Hungary, Romania, Bulgaria, and Croatia) usually show a lower value of flows. When we weight by population, interestingly, other peripheral regions emerge in the “game of flows”, e.g. Navarre and the Basque Country in Spain, Scotland in UK, and Iceland.

The value of the synthetic weighted indicator for the **goods/services/capital** basket is highest in the Netherlands, Luxembourg, and Switzerland. The regions with the highest values are either financial centers (such as Luxembourg, Zurich, London) or logistical hubs. On the other hand, the most flow-independent regions are located in southeastern Europe. The synthetic indicator’s pattern for the **people** basket is surprisingly similar to the one for the goods/serices/capital basket. Western European metropolises clearly dominate in both baskets. Scandinavia and Scotland are also strong. In the people basket, there is also a strong flow within areas attractive to tourists, i.e. Austria, Croatia, Portugal’s Algarve, and the islands of the Mediterranean Sea. The synthetic indicator for the **knowledge** basket shows that the core of Europe is southern Germany and Switzerland, followed by the entire belt from central Italy through Germany, the Benelux countries, Denmark, Sweden, and Finland. Box-plot analysis highlights the differentiation of knowledge flows between old and new EU member states. Urban regions, especially academic centers, are far more important to knowledge flows than rural areas.

In sum, we find strong similarities in the space of flows between regions at a similar level of economic development and between regions in countries that joined the European Union after 2004, although the latter participate less in the space of flows. In any case, regions of low development have a small share in the space of flows, as shown in the box-plot (the coloured bar shows 50% of regions around the most usual value). On the other hand, it is difficult to draw similar conclusions for functional urban areas except in the case of knowledge flows, for which they are of great importance. The more a region's population lives in a functional urban area, the more the region participates in the exchange of knowledge. Urban regions, especially academic centers, are far more important players in knowledge flows than rural areas. The concentration of knowledge flows is natural. It is important for individual countries (or macro-regions) to have regions specialised in research and development. This is an important dimension of the European settlement network's polycentric arrangement (postulated since the ESDP). The countries where knowledge-flow regions predominate (Erasmus flows excluded) comprise not only Germany, Switzerland, the Netherlands, Italy, and France, but also the Scandinavian countries, Spain, and Greece. Such regions do not exist in countries that joined the EU after 2004 (except Slovenia). Support from the European Union and its member states should be directed towards the creation of such centres in other countries as well.

Balance index. The **synthetic matrix for 11 flows** shows that in general the spatial distribution indicates that a strongly peripheral location can determine the negative balance of flows. However, this principle does not apply to regions with high tourism potential and settlement attractiveness (Mediterranean). The senders group includes mainly states that joined the EU in 2004-2013. The results of the synthetic balance index for the **goods/services/capital basket** are a derivative of the results in four flows belonging to the basket. There are few regions where inflow or outflow clearly dominates. Most countries are dominated by a spatial mosaic of inflow regions adjacent to those where outflow dominates. In some countries there are internal differences. Inflow is higher in the western parts of both Germany and Poland. Furthermore, the capital cities of the peripheral countries of southern and Central-Eastern Europe tend to have a strongly negative balance. The same cities mostly have an inflow surplus for trade and service linkages. However, this is more than compensated by FDI flows (strongly negative balance). In case of the synthetic matrix for the **people basket** the total balance of flows in agglomerations is usually close to zero, because large cities are senders in tourism and receivers in labour mobility and migrations. On the other hand, the balance is somewhat even also in peripheral areas that migration trips have made attractive to tourists. The high positive balance is nevertheless noticeable on the Italian-Austrian border and the Dalmatian coast in Croatia. The negative balance, in turn, consists mainly of regions with emigration flows located in Central and Eastern Europe. The synthetic matrix for the **knowledge basket** paints a more balanced picture, with single regions that are strong senders or strong receivers. Strong receivers are located mainly in Scandinavia and southeast Romania and Greece.

Concentration-per-population index. The more partners a region interacts with, the more resilient the region tends to be. Regions with a strong spatial concentration are mainly peripheral to the core of the ESPON space. The exceptions are financial centers, for which flows are usually also strongly spatially concentrated. On the other hand, many of the more peripheral regions are overexposed to external shocks, such as industry collapse (e.g. tourism during the COVID-19 pandemic) and restrictions on certain destinations (e.g. Brexit). The spatial pattern of the **synthetic relationship matrix for 11 flows** resembles a mosaic for the concentration-per-population indicator. A clearly higher concentration is characteristic of northern Europe, Great Britain, Ireland, Switzerland, Hungary, Slovakia, and Greece, as well as rural and peripheral centers, while metropolises, including capitals, are usually characterized by great spatial diversification of flows and networks of flows. The synthetic matrix of the **goods/services/capital** basket shows the culmination of spatial concentration for the Scandinavian countries and Greece. On the other hand, the most spatially diversified flows within the goods/services/capital basket are a feature of regions in a fairly compact spatial cluster, from Catalonia to the European core. The core-periphery system is visible but overlaid by national structures. In many countries the concentration is noticeably lower in capitals and other large metropolitan areas. This means that metropolitan regions there have a much more geographically diverse structure of economic partners. They are also probably the international economic "gateways" of their countries. It was confirmed that poorly urbanised peripheral regions are oriented towards relations with a limited number of regions. This may result from both economic (sectoral) specialisation and the need to use "intermediaries" in international relations. The synthetic picture for the **people** category shows a clear concentration of flows in Scandinavia, the British Isles, the Benelux countries, Lithuania, Slovakia, Hungary, and Greece. On the other hand, dispersed flows in the people basket are the domain of Latvia, Catalonia, and Valencia, as well as central and northern Italy. Low concentrations are also found in parts of Central and Eastern Europe, especially in western Poland and northern Romania. Clearly higher dispersion of flows is observed in the

capital regions and less in the immediate surrounding regions. More urbanized regions create networks of connections to a greater extent and are not so dependent on connections with individual regions. The synthetic matrix of flows within the **knowledge** basket indicates a large differentiation in the concentration of flows between neighboring countries and regions. This leads to the conclusion that knowledge flows are to a large extent based on a limited number of nodes (university cities, research-and-development centres, and regions). It is with them that most other regions are linked. They are often dominated by relations with one region: the node. As a result, the level of concentration of knowledge flows is high.

UK dependency index. In general, regions with by far the highest importance of flows to and from the UK (up to 50% of all total relations) include Ireland, the western Netherlands (with Amsterdam), the Portuguese Algarve, Malta, and Cyprus. The UK (and arguably London in particular) are key destinations for various types of flows from regions including many European capitals (Paris, Rome, Berlin, Stockholm, Warsaw, Madrid, Copenhagen, Bucharest). The value of synthetic shares decreases as we move east away from the UK (despite migration relations with Central and Eastern Europe). This confirms the thesis that Germany represents an important intermediate opportunity for the region's economic contacts with other Western European countries, including the UK. The synthetic picture of the UK's role in the external economic interrelations (**goods/services/capital**) of regions is the result of a coherent distribution of trade, services, and goods transport flows, on the one hand, and financial flows associated with FDI, on the other. The following factors determine the spatial distribution of the importance of economic interdependence with the UK: a) land neighbourhood (Ireland), b) geographical proximity of the regions of continental Europe, c) locations of large sea ports, d) attractiveness for tourism and settlement (Mediterranean Europe), e) locations of national capitals and other financial centres, f) low fiscal burdens (Luxembourg, Ireland), g) attractive investment locations in peripheral areas (Central and Eastern Europe). A synthetic picture shows that, unlike with economic flows, geographical distance does not play the most important role in **people** flows. Many regions remote from the UK have strong social ties to it. This is due to migration, the pattern of traditional tourist destinations, and even colonial dependencies (Cyprus, Malta). It is complemented by flows that are secondary to economic linkages. These include the migration of highly skilled professionals and business trips (included in tourism). Such flows in relation to the UK are of above-average importance in many EU capitals and certain other economically strong and/or financial-services regions. Regions with the highest synthetic share of **knowledge** flows with the UK are most often those where university cooperation translates into both joint H2020 projects and ERASMUS student exchanges. These include: a) central and southern France and Catalonia, b) southern Scandinavia, and c) the Netherlands. Relatively smaller but still significant shares of flows to and from the UK are recorded in Germany, Italy, and Greece.

Distance index. In general the pan-European picture shows a compact core with a dominance of low-average flow distances, including Germany, Denmark, Benelux, northern France, Switzerland, Austria, Czechia, and Hungary as well as England, the northern regions of Italy, and western Poland. Within this area, several metropolitan areas are characterised by greater-than-average relationship distances. Around this zone, the indicator for average distance increases significantly and then decreases again in the vicinity of certain metropolises. We can assume that these metropolises balance the polycentric structure of the European settlement network. They take over some of the interactions for which the EU core is becoming too distant. In the most peripheral zone the increase in the distance of average flows is additionally determined by their migration and tourism attractiveness. The synthetic picture of average distances for the **goods/services/capital** basket points, however, to the center-periphery pattern for ESPON space, with a few exceptions. Below-average distances are also characteristic of selected peripheral areas, such as Castile in Spain, the northern part of Greece, and the Romanian-Bulgarian border. On the other hand, above-average distances also occur in the European core, in particular for regions/countries that have numerous networks of commercial and financial links. These include Luxembourg and Liechtenstein. The distribution of the indicator shows indirectly the spheres of influence of certain economically strong metropolises. These are separated by belts with higher index values, a kind of European inner periphery. Regions with very high total FUA populations are also characterised by significantly higher flow distances. This confirms the thesis that they operate in a pan-European network system where distance is less important. In other regions, however, distance remains dominant. The **synthetic picture for people flows** shows clusters/hotspots of regions characterized by short flow distances. One such cluster comprises northern Hungary, eastern Austria, Switzerland, Slovenia and south-central England. On the other hand, longer distances are less visible in northern Scandinavia but observed in Helsinki and Latvia. Clearly longer flows are visible in many metropolitan areas, and shorter flows in their surroundings (dominance of migration and labour mobility to the nearest large city). Longer flows are also seen in coastal regions and Mediterranean islands (tourism and long-distance migration). The **synthetic matrix for the knowledge basket** reveals short distances for the European core,

slightly shifted also to the east and clearly reaching the German-Polish and German-Czech borders. The longest distances are in Cyprus, Crete, Iceland, northern Norway, and Finland.

Border effect. An analysis of the flows for **goods trade** and **goods freight** shows that the key to the internationalization of regions for trade is proximity to the European core. Regions that in a given country are located on the border with a country closer to the European core are more open to international trade within the ESPON space. This applies also to countries in the European core, where a particularly large share of international trade is on the Franco-German border. The above conclusion, however, applies especially to countries such as Poland, Romania, and Hungary. Thus, proximity to the European core is conducive to increasing the share of international trade in the exchange of goods on a regional basis. The situation is different in Scandinavia, where, for example, northern Sweden, Norway, and Finland — regions particularly far from the European core — have relatively strong international trade. For trade in goods and services, certain capitals and other large cities have an evident dominant position. They are more dependent on international flows than other units in their own countries. This is the case of Madrid, Warsaw, Prague, and Vilnius. The same pattern is not so visible with goods transport, where internal traffic (especially in Poland and Spain) tends to dominate. There are countries in the ESPON space with particularly high shares of internal migration. These are Great Britain and the Scandinavian countries, but also Greece and partly Hungary, Czechia, and the Netherlands. On the other hand, international migrations dominate in Poland, Romania, Bulgaria, Croatia, Slovakia, Portugal, and the Baltic states, and also in Switzerland, Ireland, and Iceland. In several countries, internal migration patterns are visible, disrupting the dominance of foreign migration. This is particularly the case in Poland and Romania. Local metropolises there serve as alternatives to foreign destinations. In Western European countries the situation is reversed. Metropolises are characterised by a higher share of international migration, which results from the mobility of highly skilled workers.

Two-dimensonial typology. Our two-dimension typology **weighted intensity vs balance** for the synthetic matrix of 11 flows indicates a strong group of highly intensive receivers in Switzerland and western Austria. It is the only compact group of regions belonging to highly intensive receivers. Apart from Switzerland and Austria, highly intensive receivers include individual metropolitan areas, e.g. Stockholm, Vilnius, Prague, Luxembourg, Copenhagen, and Hamburg. On the other hand, highly intensive senders are often regions located around metropolises, among them Vienna, Dublin, Brussels, Oslo, and Randstad. Our two-dimensional **weighted intensity vs concentration** analysis for a synthetic matrix composed of 11 flows shows highly intensive, strongly concentrated flows in regions of Norway and northern Sweden, Luxembourg, and eastern Switzerland. On the other hand, regions with highly intensive dispersed flows are mainly located in the European core, although the group includes such capitals outside the core as Copenhagen, Prague, and Bratislava. However, the core of the EU is characterized by a large diversity of region types. Our two-dimensional **weighted intesity vs average distance** typology for 11 flows shows long-range, highly intensive regions in northern Norway, in Helsinki, and in the Balearic Islands. In turn, regions with highly intensive short-range flows are located in Switzerland and northern Germany, with single ones in Belgium and the Netherlands. The French border is clearly marked, which shows that flows in France are longer than in those in its northern and eastern neighbours.

Structural approach.

Histograms. **Weighted intensity** index. Many regions do not have an airport. For this reason, **air passengers** is the only flow where the dominant value for the index equals zero. For the other two flows, **FDI capital** and **patents**, the dominant is very sharp with low values of the indicator. **Balance** index. Air passengers is certainly one of the most balanced flows. Capital FDI (dominance of senders) and H2020 (dominance of receivers) are characterized by the greatest deviations from equilibrium. **Distance**. Short distance occurs primarily in labour mobility, but also in goods freight, services, and — quite surprisingly — migratory flows. In turn, the longest distances are characteristic of flows under the Erasmus program and for air passengers.

Econometric analysis. For interlinkages between flows we applied an econometric analysis, including the other flows as explanatory factors. The results are meaningful and provide a new layer for discussion of the relationships between flows.

- Trade of goods exerts a positive influence on migration, FDI, and knowledge.
- Services exert a positive influence on trade of goods, migration, and knowledge estimations.
- Migration relates positively with knowledge flows and negatively with FDI. The effects on trade of goods and services are unclear.
- FDI shows a positive influence on migration and knowledge.

- Erasmus shows a positive relation with trade of goods. The effects on services, migration, and FDI are unclear.
- H2020 and patents show a positive relation with services and FDI. The effects on trade of goods and migration are unclear.

Dominant flow. The picture resembles a mosaic. **Goods freight** flows definitely dominate in most regions of Poland. **Goods trade** is dominant in northern Italy and northeastern France, but also in Belgian Flanders and the western parts of Czechia, Slovakia, and Hungary. **Services** is a fairly puzzling flow that dominates regions as diverse as Scotland and Northern Ireland, as well as southern Italy, with Sicily and Sardinia included. **Capital FDI** competes with airports for dominance in metropolises. In some metropolitan areas, thanks to the presence of airports, **air passengers** is usually the dominant flow. **Labour mobility** is the domain of densely urbanized regions. **Migrations** dominate the southeastern part of the ESPON space. **Tourism** is quite surprisingly dominant in the compact area of western France, in Mecklenburg (Germany), and on the Norwegian-Swedish border, but also, less surprisingly, in the Alpine regions of the Italian-Austrian border, on the Dalmatian coast in Croatia, and in Cantabria (Spain). **Erasmus** is dominant in Finland, Estonia, and Latvia, as well as in Portugal, Spain, and individual regions of Italy and France. Quite surprisingly, it is also the dominant flow in most Central and Eastern European capitals. Participation in **H2020** projects is the domain of many capitals. The "kingdom of **patents**" consists of West Germany and Switzerland.

Concentration of dependencies on individual flows. In keeping with the literature, we consider that a region's exposure to interregional dynamics or resilience depends on the diversity of its external relations. By this approach, regions that have a balanced composition of flows, rather than a concentration of one, are less exposed to external shocks or policy decisions that affect one flow in particular. In general, metropolises, including state capitals, have much greater dispersion in their involvement in particular flows, while peripheral areas with low populations are more likely to have a high concentration on one flow. We can also conclude generally that the farther a region lies from the European core, the greater its risk of concentration on individual flows. Regions in the core usually have diversified flow portfolios (except for the high concentration on FDI flows in Luxembourg and central Switzerland).

Clustering. We performed our clustering analysis for 11 flows as a supplement to indicate whether the regions are clustered for two indices: weighted intensity and balance. The results turned out to be positive and very interesting, especially in the context of weighted intensity. Six groups of regions emerged:

- Cluster 1 includes mainly capital city regions in the core of Europe and countries that joined the European Union in 2004. The other regions all serve simultaneously as "islands" of larger flows and as the time gateways of areas peripheral to the core.
- Cluster 2 includes most of the peripheral regions of southern and Central-Eastern Europe. Interestingly, this group also includes French and Italian as well as several UK and Finnish regions. These are less involved in the space of flows and can be described as peripheral.
- Cluster 3 represents the core of the European space of flows. It includes Austria, Switzerland, most of Germany, the Benelux countries, southern Scandinavia, and most of the UK and Ireland. They actively participate in the space of flows, with highly intense socioeconomic flows (trade, freight, migration, tourism) usually accompanied by high values in commuting and knowledge (especially patent) flows.
- Cluster 4 includes port-city regions in northwestern Europe and northern Scandinavia that specialise primarily in trade flows. The position of these regions in terms of service flows is also relatively high. Although not a port, Liechtenstein is also part of this group.
- Cluster 5 is Luxembourg, an outlier with high values for FDI capital flows and very high values also for participation in H2020, commuting, and services.
- Cluster 6 is dominated by regions with strong air-passenger and tourism flows, island regions included.

Dynamic approach. Interregional flows are growing across Europe, in line with the cohesion policies in effect. The intensity of interregional flows increased in 2010-2018 at a stable annual pace, while the average cumulative increase in nine flows for 2010-2018 is 22.5%. However, there are a few outliers:

- The increase in air-traffic dynamics (passenger traffic) above the level recorded for tourism indicates the growing importance of air transport in intra-European travel (at least until 2018, i.e. before the COVID-19 pandemic). This demonstrates that the challenge for transport policy remains the strengthening of long-distance rail links. Past trends suggest that there is a concentration of tourist traffic in air transport, which means an increasing role for it in greenhouse gas emissions.

- Migration dynamics are stabilising. This may imply a levelling off of differences in living standards and well-being between different parts of Europe as well as an indirect effect of ageing. As living standards in the European Union become more equal, internal flows may decrease (according to classical migration theory) or stabilize. For residents of Central and Eastern Europe, wages in the European core in 2018 were no longer as attractive as they were a dozen years earlier. Moreover, in some peripheral areas resources for migration are running out (mainly the elderly population remains there). Because of these processes, internal migration is gradually being replaced by migration inflows from outside the ESPON space. This leads us to conclude that migration policy (including immigration from outside the EU) should be more territorialised. It should also respond to rapidly changing directions of migration.
- The most dynamic capital FDI flows with a simultaneous decline in the intensity of knowledge flows (patents) may indicate that integration into the R&D sector is not keeping pace with economic integration. This suggests that EU support to date (cohesion policy) has insufficiently promoted the spread of R&D to Europe's periphery.

General conclusions

- We have diagnosed several overlapping systems of flow imbalances between European regions. In addition to imbalances in the overall core-periphery system, there are imbalances in the network of major metropolises and strong national imbalances, especially in the largest countries.

- The role of internal flows (especially in large countries) is still very important. It affects international relations, as in some cases competition between foreign and domestic flows is evident (e.g. in tourism and also in migration in peripheral countries).

- Some of the results obtained (including cluster analysis) can be treated as measuring the success of European integration. This is especially true for economic flows (primarily trade). In their case, the core area of Europe is the most extensive, and regions in Germany, France, and Spain as well as western Poland and Czechia are similar in the structure of their flows. Even non-metropolitan regions there participate in Castells' "space of flows".

- The distribution of both people and knowledge flows differentiates the European space much more than that of economic flows (especially trade). This may mean that social integration is slower than economic integration.

- The intensity of flows is less spatially differentiated than their balance. It is balance that determines the European core-periphery system. The number of units with a positive balance of flows is smaller (than the number with high intensity), and differences exist within the EU core as well.

- In the European space there are "islands" of clearly higher intensity of flows of various types. They include regions with national capitals, financial centers (especially Luxembourg), and sea ports, as well as areas with high attractiveness for settlement and tourism.

- Metropolises in peripheral countries (southern and Central-Eastern Europe) play a special role. The structure of their connections is special compared with that of other regions, as confirmed by our cluster analysis. They serve as "gateway cities" connecting their countries with the European space of flows. Their clear role in this respect is evidence of the gradual polycentric development of Europe outlined in 1991 by Kunzmann and Wegener and subsequently incorporated into the ESDP.

- In some places, zones that are European inner peripheries have been preserved. We observe them between the core of ESPON space and the zones of influence of satellite metropolises (e.g. on the border between France and Spain and between Germany and Poland).

- There are still regions in the European space where historical factors and/or cultural specificities may be the main factors shaping their position in the space of flows. This can be interpreted through path dependency theory. Examples include countries with a colonial past (Cyprus, Malta) but also regions in Central and Eastern Europe that have been subject to frequent changes of state affiliation (Poland, Romania).

- The highest dynamics of FDI flows with simultaneous declines in the intensity of knowledge flows may indicate that integration in the R&D sector is not keeping pace with the intensity of flows, and thus with economic integration. Combined with the different spatial distributions of the two types of flows, this may imply a territorial polarization in knowledge under most regions' full integration into the economic system.

- Excessive simultaneous dynamism and concentration of FDI flows may threaten to cause an imbalance between financial flows and trade and social relations.

- The pattern of migration flows combined with their dynamics is evidence of a gradual rebalancing of the system of people flows. The increase in migration intensity that took place after the EU's enlargement has slowed down. The metropolises of Central and Eastern Europe have become alternatives for mass foreign migration.

- The system of short-term people flows does not undergo favourable changes from the point of view of reducing CO_2 emissions. The dynamics of growth are higher in air-traffic flows than in total tourism flows. In both cases they are greater than for all other flows (except FDI).

The new territorial evidence provided here might help to improve the formulation of regional development strategies, thereby protecting the key flows, helping to create a balanced pattern of interregional relations, and minimizing strong dependencies. Public intervention should favour the diversification of regions' external relations. This includes both promoting different types of external flows and increasing the number of geographically defined partners. In this context, a mosaic pattern of high-intensity flows with many regional partners should be regarded as positive.

As a final remark, exposure and resilience — in relation to interregional flows — are region- and flow-specific. In other words, there is no one-size-fits-all policy for interregional relations, and regional development strategies should take this into account and make use of the specificities identified in this research.

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Annex

Figure 4.1: Scatter plot between total goods exported by region I and the regional average age.

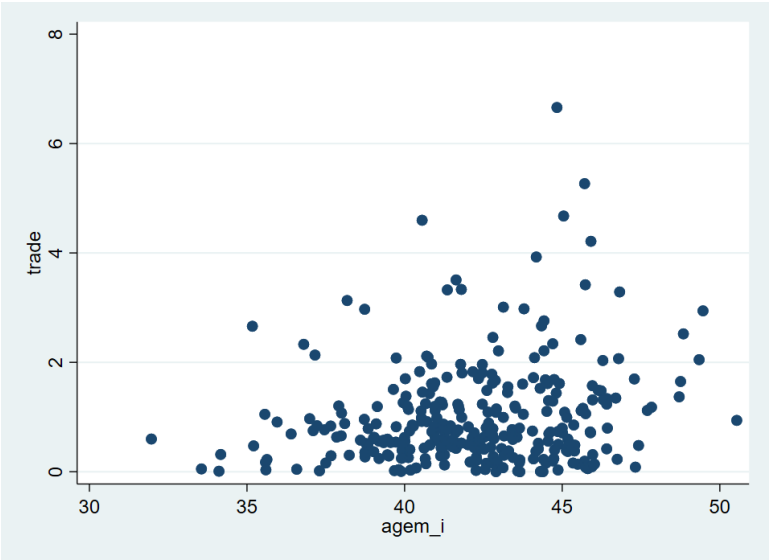


Figure 4.2: Scatterplot between total services exported by region I and the regional average age.

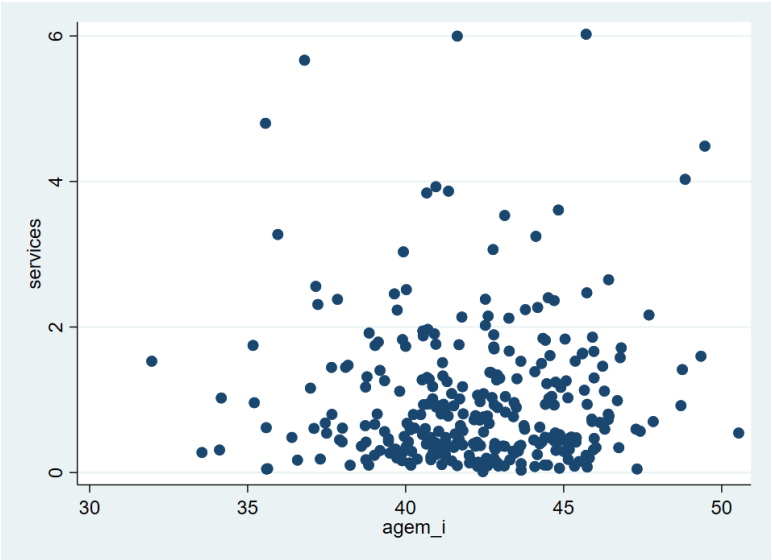


Figure 4.3: Scatterplot between total migrants with origin in *i* and the regional average age.

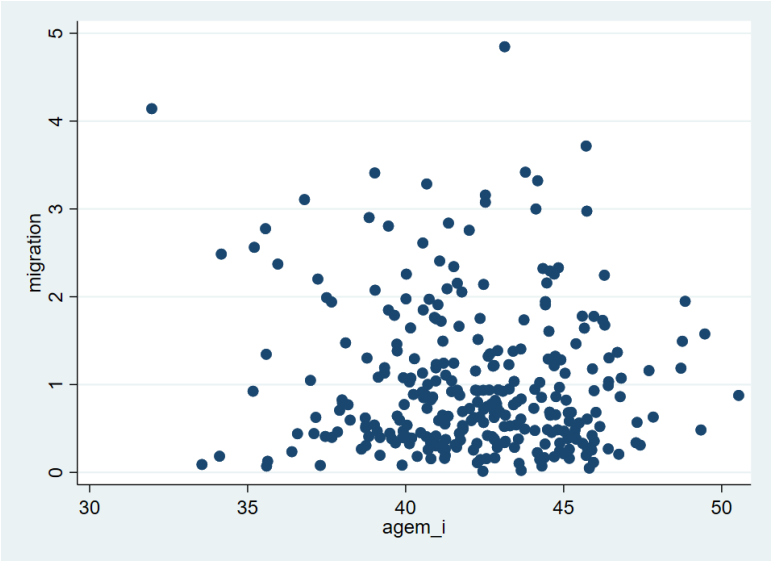


Figure 4.4: Scatterplot between total FDI with origin in *i* and the regional average age.

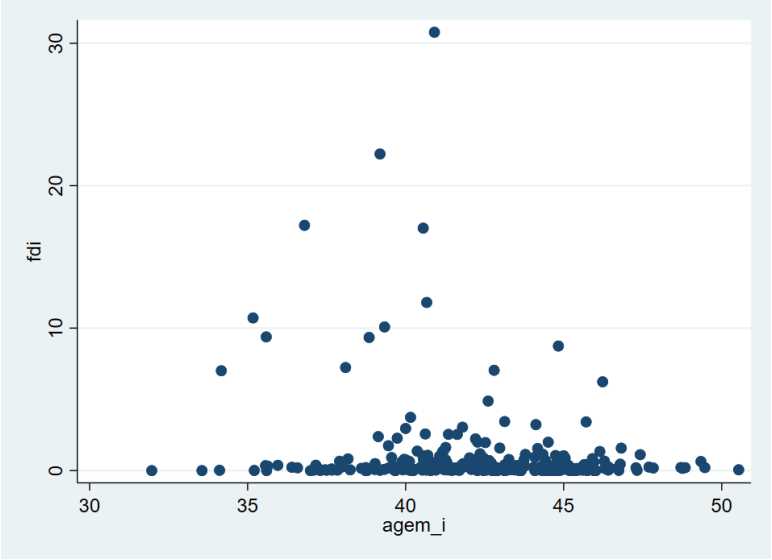


Figure 4.5: Scatterplot between total Knowledge flows with origin in *i* and the regional average age.

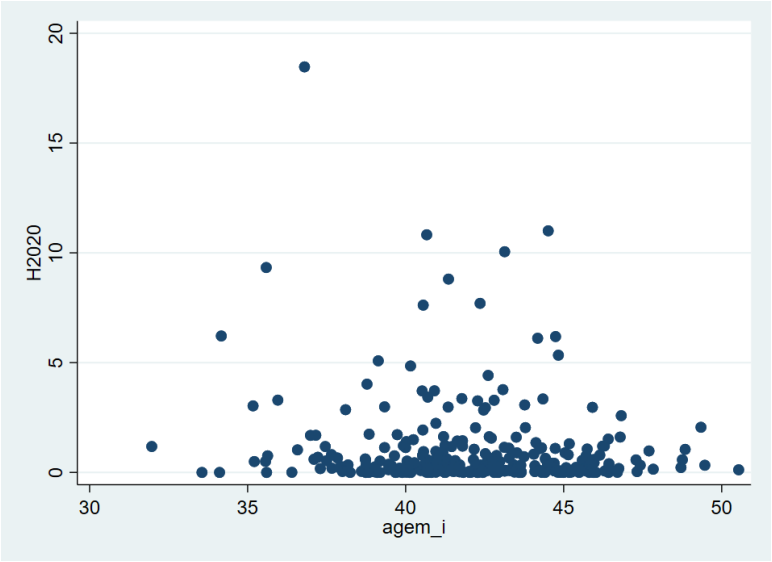


Figure 4.6: Scatterplot: interregional flows of goods vs difference in the average age of i&j.

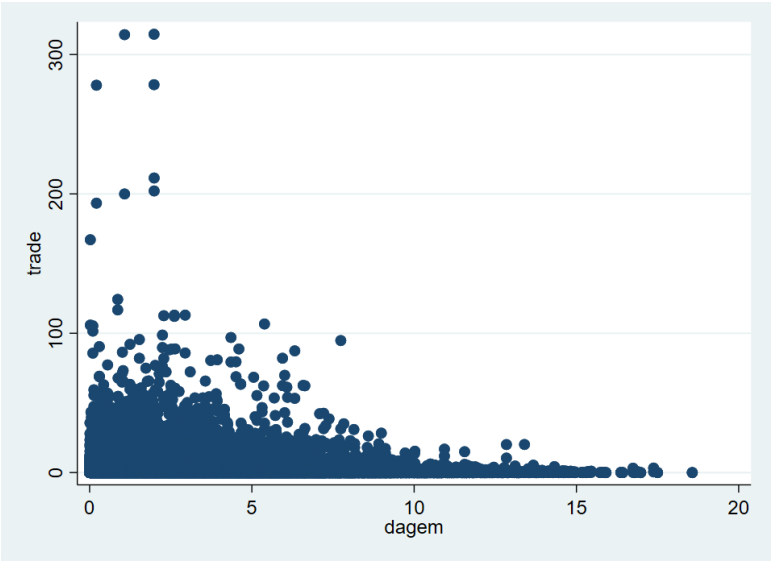


Figure 4.7: Scatterplot: interregional flows of services vs difference in the average age of i&j.

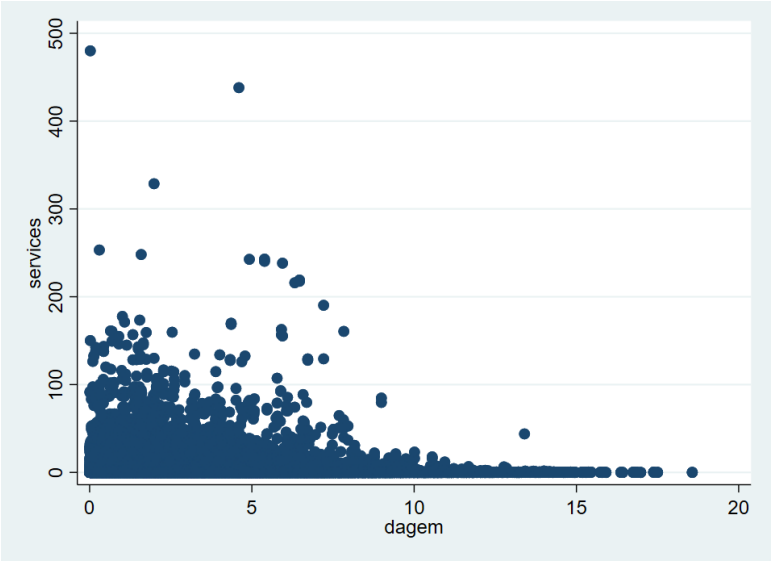


Figure 4.8: Scatterplot: interregional flows of migration vs difference in the average age of i&j.

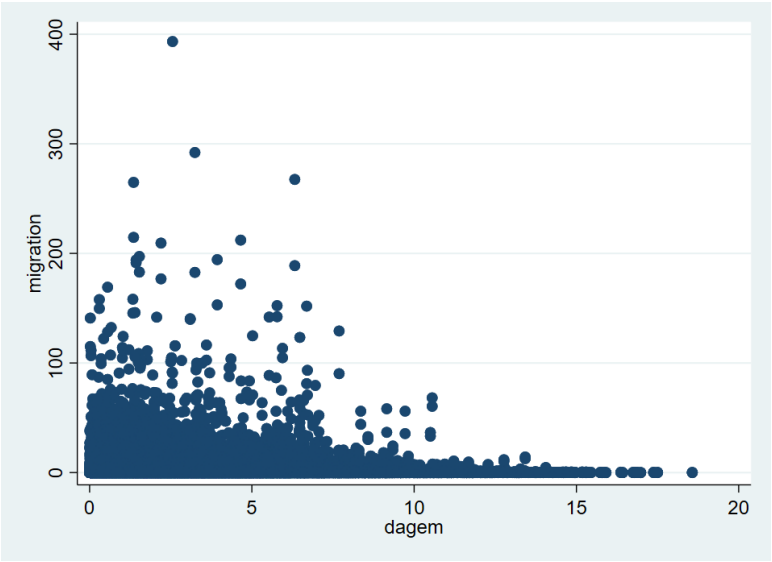


Figure 4.9: Scatterplot: interregional flows of FDI vs difference in the average age of i&j.

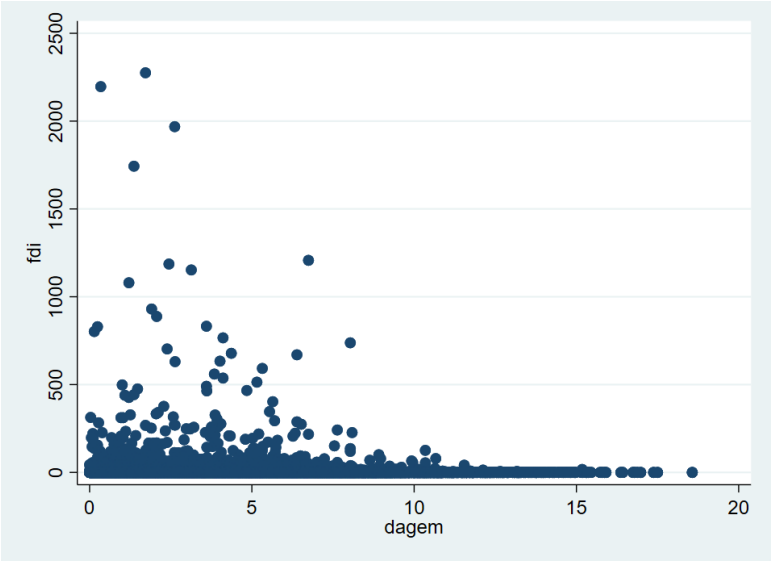
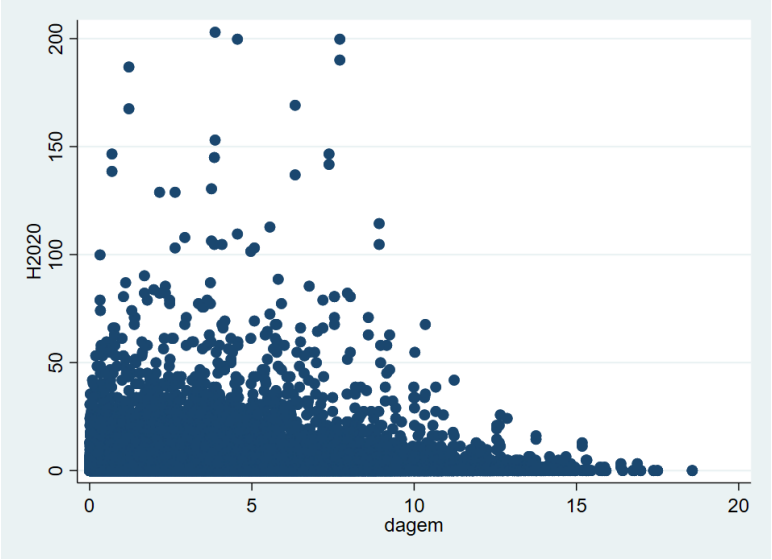


Figure 4.10: Scatterplot: interregional knowledge flows vs difference in the average age of i&j.



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