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A Drive Time-Based Definition of Cross-Border Regions and Analysis of Population Trends

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Executive Summary

The EU internal border regions are an important source of growth and jobs. Their socio-economic potential can be further exploited. The European Commission identified more than 200 administrative and legal obstacles to cross-border cooperation, mostly associated with accessing jobs, doing business and using public services across frontiers. New obstacles keep on also appearing while cross-border interactions increase. If only 20% of those obstacles were removed, border regions could additionally generate 2% in GDP and more than one million jobs (European Commission, 2017).

This study aims to add technical insights to the debate about overcoming the cross-border obstacles to growth and jobs in the EU internal border regions. It proposes new border geography by defining distinct drive time zones (30, 30-60, 60-90, 90+ minutes) to terrestrial paved border crossing points. The drive time zones are delineated by applying network analysis algorithms to the TomTom Multinet (2017) road network data, based on governing speed limits for passenger cars and assuming free-flow i.e. without congestions and/or border crossing delays. Paved bridges and river ferries are also included. At the next stage, the study looks at the population changes during the period 2001-2011 in the adjacent to the borders "30 minutes" drive time zones and compares these changes with the respective country population trends¹. The analysis encompasses thirty one couples of EU border areas and three complex border regions, where more than two EU border areas are included. The analysis is executed in the context of the Knowledge Centre for Territorial Policies (KCTP) of the European Commission (European Commission, 2019b).

The analysis of population changes in border areas vice-versa the ones at country level allows characterising the cross-border regions according to common patterns defined as follows:

- Cluster 1 "**Faster growing borders**", where border population growth is **higher** than country population growth on both sides of the border.
- Cluster 2 "**Slower growing borders**", where border population growth is **lower** than or equal to the country population growth on both sides of the border.
- Cluster 3 "**Diverging borders**", where the border population trend (positive or negative) is **better** than the country population trend (positive or negative) on one side of the border and **worse** on the other side of the border (complex regions included).
- Cluster 4 "**Underperforming borders**", where the border population trend (positive or negative) is **worse** or equal to the country population trend (positive or negative) on both sides of the border (complex regions included).
- Cluster 5 "**Faster declining borders**", where border population decline is **deeper** than country population decline on both sides of the border.
- Cluster 6 "**Shrinking borders in growing countries**", where border population **declines**, while country population **grows** on both sides of the border.

The breakdown of the thirty four EU cross-border regions per clusters is displayed in Figure 1 and Table 1.

Clusters 1 "Faster growing borders" and 2 "Slower growing borders" comprise eleven EU Member States (European Commission, 2019a), broken down into ten pairs, where upward border population trends are observed on both sides of the frontier. These countries are chiefly elder EU Member States (accession before 2004) from Western and

¹ The year 2011 was the latest one, which detailed population statistics at LAU2 level was available for by the time of performing the study (the first quarter of 2019).

Central Europe. There might be still some unexploited potential, including via cross-border interactions, to further stimulate economic attractiveness and population growth in those border areas.



Figure 1: Map of EU cross-border regions per clusters (1 to 6) based on population dynamics at country level and in the "30 minutes" drive-time border areas within 2001-2011

Clusters 3 "Diverging borders" and 4 "Underperforming borders" contain EU Member States couples and complex regions with diverse border population trends on the two sides of the frontier and/or vice-versa country population trends. Given the greater variability in border population trends, these two clusters encompass the highest number of countries (20) and pairs (16). Due to the large membership, there are no distinct geographical patterns. The only EU Member States, which are not present in Clusters 3 and 4, are located in Northern Europe – Sweden, Finland, Estonia and Latvia². The diversity in population behaviour of border zones implies that there might be room for

² Malta and Cyprus do not have terrestrial borders with other EU Member States. Ireland and the United Kingdom are excluded from the analysis, too.

further improvement via, amongst others, intensified cross-border interactions. It might be therefore useful to analyse in greater detail at EU, national, regional and local levels the potential opportunities and unexploited reserves.

Table 1: Breakdown of EU cross-border regions per clusters (1 to 6) based on population dynamics at country level and in the "30 minutes" drive-time border areas within 2001-2011

EU cross-border regions assessed			
1.	Austria-Germany	2.	Austria-Slovakia
3.	Poland-Slovakia	4.	Denmark-Sweden
5.	France-Italy	6.	Austria-Italy
7.	Italy-Slovenia	8.	Austria-Slovenia
9.	Belgium-Netherlands	10.	France-Belgium
11.	Germany-Denmark	12.	Bulgaria-Greece
13.	Austria-Hungary	14.	Hungary-Romania
15.	Spain-France	16.	Croatia-Slovenia
17.	Euregio Maas Rhein (Netherlands-Belgium-Germany)	18.	Upper Rhine (France-Germany-Switzerland)
19.	Netherlands-Germany	20.	Lithuania-Poland
21.	Austria-Czech Republic	22.	Germany-Poland
23.	Hungary-Slovakia	24.	Portugal-Spain
25.	Grande Region (France-Belgium-Germany-Luxembourg)	26.	Czech Republic-Germany
27.	Estonia-Latvia	28.	Lithuania-Latvia
29.	Croatia-Hungary	30.	Bulgaria-Romania
31.	Hungary-Slovenia	32.	Finland-Sweden
33.	Czech Republic-Poland	34.	Czech Republic-Slovakia

Background colour legend:

- Cluster 1 "Faster growing borders" (red);
- Cluster 2 "Slower growing borders" (orange);
- Cluster 3 "Diverging borders" (yellow);
- Cluster 4 "Underperforming borders" (green);
- Cluster 5 "Faster declining borders" (blue);
- Cluster 6 "Shrinking borders in growing countries" (dark blue);

Clusters 5 "Faster declining borders" and 6 "Shrinking borders in growing countries" include twelve EU countries, broken down into eight pairs, where downward border population trends are observed on both sides of the frontier. All newer (accession in 2004, 2007 and 2013) continental EU Member States from Eastern Europe³ are found here. More intensified cross-border interactions might contribute to improving economic performance and settlement attractiveness. It might thereby reverse or at least – relieve

³ As already explained, the island countries Cyprus and Malta are excluded from the analysis.

to some extent the downward border population trends. For a stronger positive impact, synergies with other incentives and instruments might be considered.

Mountainous landscape, unfavourable climate, remoteness regarding bigger urban agglomerations or other socio-economic and natural obstacles could significantly discourage human settlements and consequently – hold back cross-border interactions. Additional infrastructure developments, such as more and better roads and/or higher number of paved border crossings could sometimes improve cross-border commuting. Such developments are, nevertheless, not always sufficient to remove the fundamental setbacks of border settlements, especially if those setbacks are associated with non-road network related challenges like the ones mentioned above.

The clusters from Figure 1 and Table 1, and the related findings are drawn based on a particular set-up of the assessment framework. If other criteria are added or replace the currently used ones for analysing border areas and their susceptibility to cross-border commuting, the picture from Figure 1 and Table 1 might get quite a different shape. Updated population data might also result in modifications to the clusters' composition.

1 Explanatory Brief

The EU internal border regions cover approximately 40% of EU territory, host 30% of EU's population and generate 30% of EU's GDP, being thereby an important source of growth and jobs. They accommodate almost 2 million cross-border commuters, including 1.3 million cross-border workers. The socio-economic potential of border regions can be further exploited. A review, launched in 2015 by the European Commission, revealed more than 200 specific administrative and legal obstacles to cross-border cooperation, mostly associated with accessing jobs, doing business and using public services across frontiers. New obstacles keep on also appearing while cross-border interactions increase. It has been estimated that if only 20% of the existing obstacles were removed, border regions would additionally earn 2% in GDP and more than one million jobs (European Commission, 2017).

Several recent studies looked at these cross-border challenges. The ESPON study (ESPON, 2018) explores territorial patterns of cross-border public services (CPS) and highlights how CPS provision helps European border regions to improve integration. According to this study, CPS contribute to reducing negative border effects, improving connections, raising awareness of cross-border potential and supporting cross-border flows of people. Another study of European Commission's Joint Research Centre (Christodoulou *et al.*, 2019) proposes a set of indicators and tools that allow policy makers to measure accessibility and connectivity of border regions in Europe. The methodology, developed in this study, aims to facilitate identifying areas where transport infrastructure may be insufficient and prioritising potential investments based on specific criteria. The border regions are identified based on a straight-line buffer of 25 km from each border between EU countries. A follow up study (Christodoulou *et al.*, 2019) further discusses road accessibility and network efficiency issues in border regions of Europe with some policy insights. Finally, a study by Poelman and Ackermans (2017) explores passenger rail accessibility in Europe's border areas. The study uses passenger rail timetables in combination with spatial data on stations and population density, and then highlights the diversity of border areas regarding the availability, speed and frequency of cross-border rail services. The results indicate that the cross-border rail services often score lower than domestic services. It defines border areas as buffer areas covering 25 km on either side of the border.

In the above context, the current study aims to add technical insights to the ongoing debate about overcoming the cross-border obstacles to growth and jobs in EU border regions. It proposes new border geography by defining distinct drive time zones (30, 30-60, 60-90, 90+ minutes) to terrestrial paved border crossing points. At the next stage, the study looks at the population changes during the period 2001-2011 in the adjacent to the borders "30 minutes" drive time zones and compares these changes with the respective country population trends during the same period. The straightforward assumption is that where the border population trend was superior to the country one, the border zone was more attractive to live and vice-versa. Concentration of population in border areas could also open the door to further enhancing economic and settlement attractiveness by improved cross-border exchange.

The time frame 2001-2011 was selected because, by the time of performing the study, it was the most recent period, which detailed demographic data at local level (LAU 2) were available for. More recent population data were only available at regional level (i.e. NUTS 3), which was not sufficiently detailed to the scale of the assessment.

The following analysis is performed in the context of the Knowledge Centre for Territorial Policies of the European Commission (European Commission, 2019b). It is based on state-of-the-art and trusted sources of road network and demographic data.

The ultimate goal of this report is to provide an easy-to-understand summary of a few key facts and trends in the EU internal terrestrial border zones, coming along a dedicated approach that is explained in following Chapter 2 and Annex 6.1.

2 Data and methods

2.1 Country border data

The 2016 dataset of NUTS (Nomenclature of Territorial Units for Statistics) has been applied for the definition of country borders. The total EU borders amounts to nearly 103 thousand km and contains thirty seven internal (1,463 km, 11 %) and thirty eight external (1,373 km, 11 %) terrestrial frontiers, as well as twenty four (100,123 km, 78 %) coastal lines. This study assessed terrestrial borders only – thirty six of the thirty seven internal⁴ frontiers and two external⁵ ones (Figure 2).



Figure 2: The thirty six internal and the two external EU terrestrial borders assessed in this study

⁴ The internal British / Irish border has not been addressed.

⁵ France-Switzerland and Germany-Switzerland, because they are parts of the Upper Rhine complex region – see later in the main text.

Three complex and partially overlapping cross-border regions, composed of eight internal and two external frontiers, were also analysed due to way these territories are organised in INTERREG Cooperation Programmes⁶ – Figure 3. As a result, five internal terrestrial EU borders⁷ were not assigned to specific datasets because they were allocated to complex datasets / regions from Figure 3. Three frontiers⁸ have been partially included in more than one datasets, because complex regions have not always covered the full border between two countries.

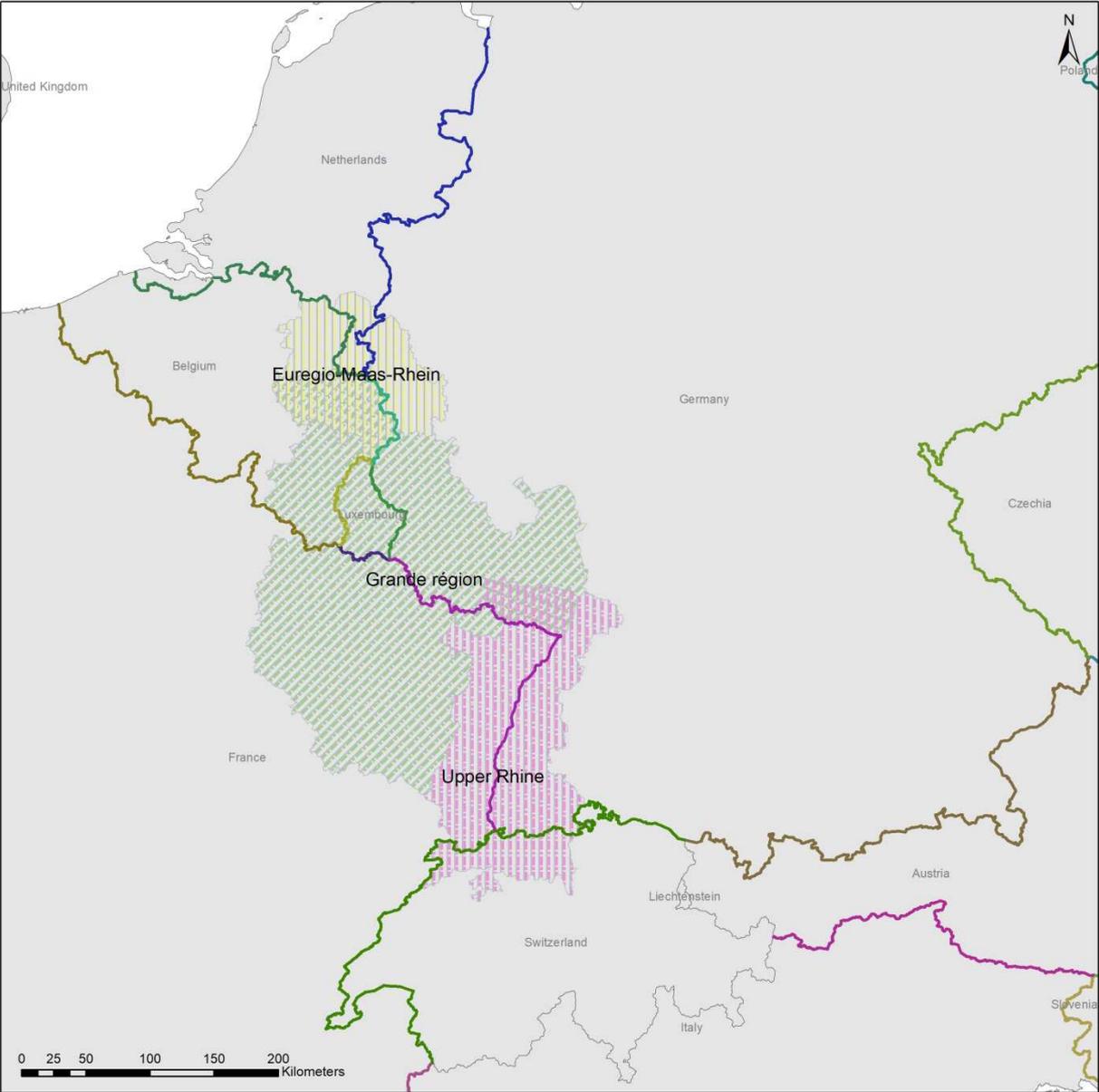


Figure 3: The three complex regions covered: Euregio-Maas-Rhein (Netherlands-Germany, Germany-Belgium, Belgium-Netherlands), Grande Region (Luxembourg-Belgium, Luxembourg-France, Luxembourg-Germany, France-Belgium, France-Germany, Germany-Belgium) and Upper Rhine (France-Germany, France-Switzerland, Germany-Switzerland)

⁶ <https://www.interregeurope.eu/>

⁷ Germany-Belgium, Germany-Luxembourg, Belgium-Luxembourg, Luxembourg-France, France-Germany.

⁸ Germany-Netherlands, Netherlands-Belgium and Belgium-France.

Altogether, thirty four datasets of linear frontier data, corresponding to the cross-border regions from Table 2, have been assessed, broken down as follows:

- Thirty one datasets for internal bilateral EU borders;
- Three datasets for complex regions;

Table 2: List of the thirty four EU cross-border regions that have been analysed in this study

EU cross-border regions assessed			
1.	Austria-Germany	2.	Austria-Slovakia
3.	Poland-Slovakia	4.	Denmark-Sweden
5.	France-Italy	6.	Austria-Italy
7.	Italy-Slovenia	8.	Austria-Slovenia
9.	Belgium-Netherlands	10.	France-Belgium
11.	Germany-Denmark	12.	Bulgaria-Greece
13.	Austria-Hungary	14.	Hungary-Romania
15.	Spain-France	16.	Croatia-Slovenia
17.	Euregio Maas Rhein (Netherlands-Belgium-Germany)	18.	Upper Rhine (France-Germany-Switzerland)
19.	Netherlands-Germany	20.	Lithuania-Poland
21.	Austria-Czech Republic	22.	Germany-Poland
23.	Hungary-Slovakia	24.	Portugal-Spain
25.	Grande Region (France-Belgium-Germany-Luxembourg)	26.	Czech Republic-Germany
27.	Estonia-Latvia	28.	Lithuania-Latvia
29.	Croatia-Hungary	30.	Bulgaria-Romania
31.	Hungary-Slovenia	32.	Finland-Sweden
33.	Czech Republic-Poland	34.	Czech Republic-Slovakia

2.2 Data on road networks and border crossing points

The Pan-European TomTom Multinet (2017) road network data has been used for the estimation of travel times to border crossings.

The border crossing points have been defined where paved roads from different countries intersected with country borders. Non-paved border crossing points have been excluded from the assessment in order not to overestimate the locations used by population to cross the national borders. Paved bridges (such as the Øresund one between Malmö and Copenhagen) and river ferries have been considered as terrestrial frontiers and hence, both have been included in the analysis. Altogether, two thousand three hundred thirty three (2,333) paved border inter-sections have been identified – Figure 4.

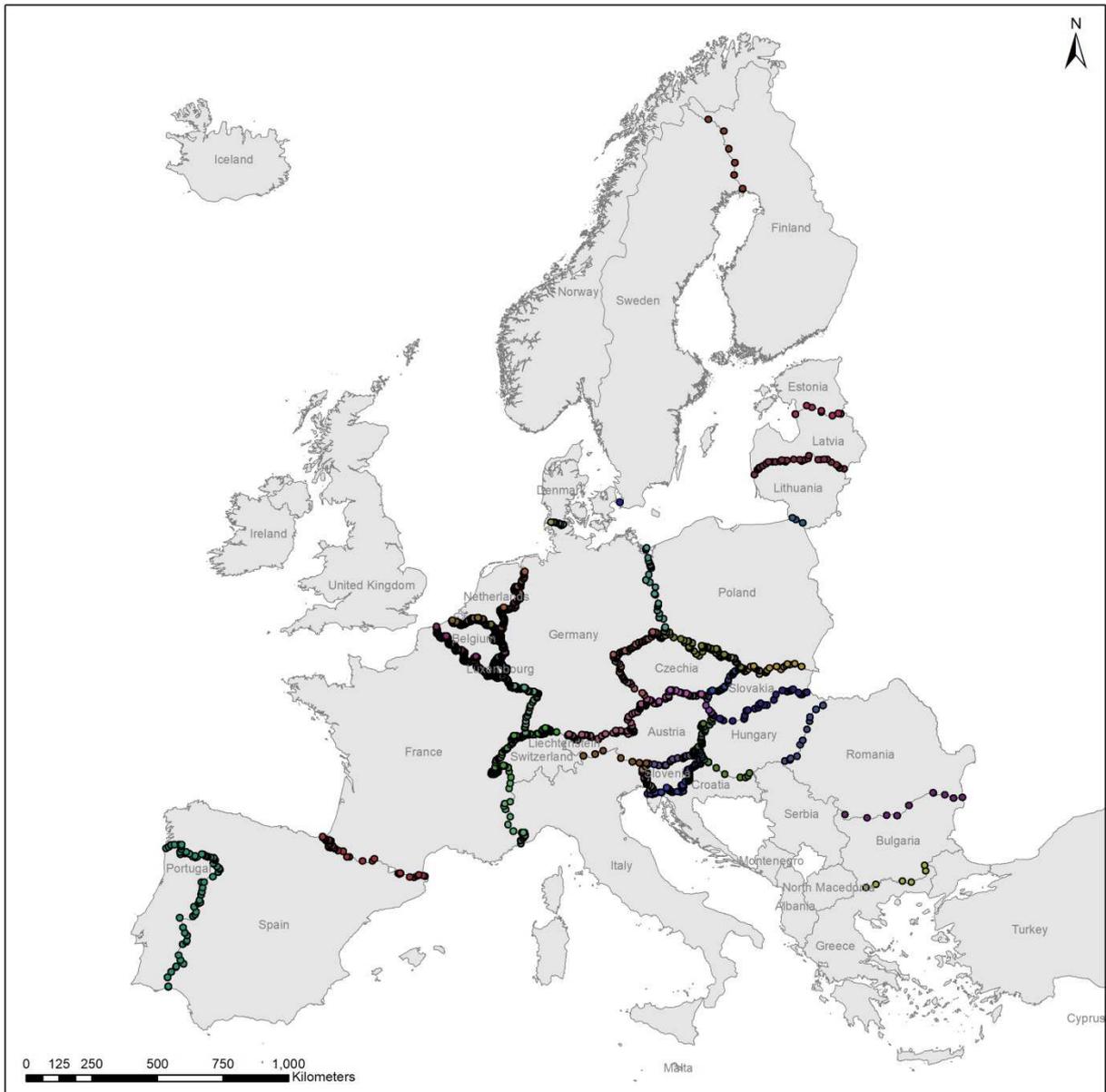


Figure 4: Paved road intersections, including paved bridges and river ferries, showing the places where different road networks from different countries intersect

2.3 Population data

The demographic characterisation of cross-border regions consisted in assessing the population stocks and trends between 1961 and 2011. This long time series of population for cross-border regions is documented in the graphs in Annexes 6.2 to 6.7. The population growth in the period 2001-2011 is shown and described in more detail in Chapter 3, and was the key parameter behind the clustering proposed therein.

The source for the population data was a dataset, commissioned by DG REGIO and containing population records between 1961 to 2011 in 10-year intervals (census years) at LAU2 (i.e. municipal) level (Gløersen and Lürer, 2013). To the best of authors' knowledge, this was the most updated and spatially detailed long time series of population counts available by the time of performing this study.

To estimate population within the cross-border areas between 1961 and 2011, population records, linked to centroids of municipalities, were overlaid with the "30 minutes" drive time border zones by using a Geographical Information System (GIS).

2.4 Additional data for preparation of Origin-Destination Matrix

In order to model drive times to border crossings, "origin" points have been created as regularly spaced points at 10 km intervals, plus centroids of urban clusters that comprise continuously populated areas with at least five thousand (5,000) inhabitants and density of at least three hundred (300) inhabitants per square kilometre – Figure 5. In total, fifty four thousand seven hundred seventy three (54,773) points for preparation of origin-destination datasets (matrixes) have been used. The datasets have been created by respecting a buffer of 200 km from the border and included points from neighbouring countries only. When the 200 km zone included not only the neighbouring countries, the buffer has been clipped, so to include points from the neighbouring countries only.

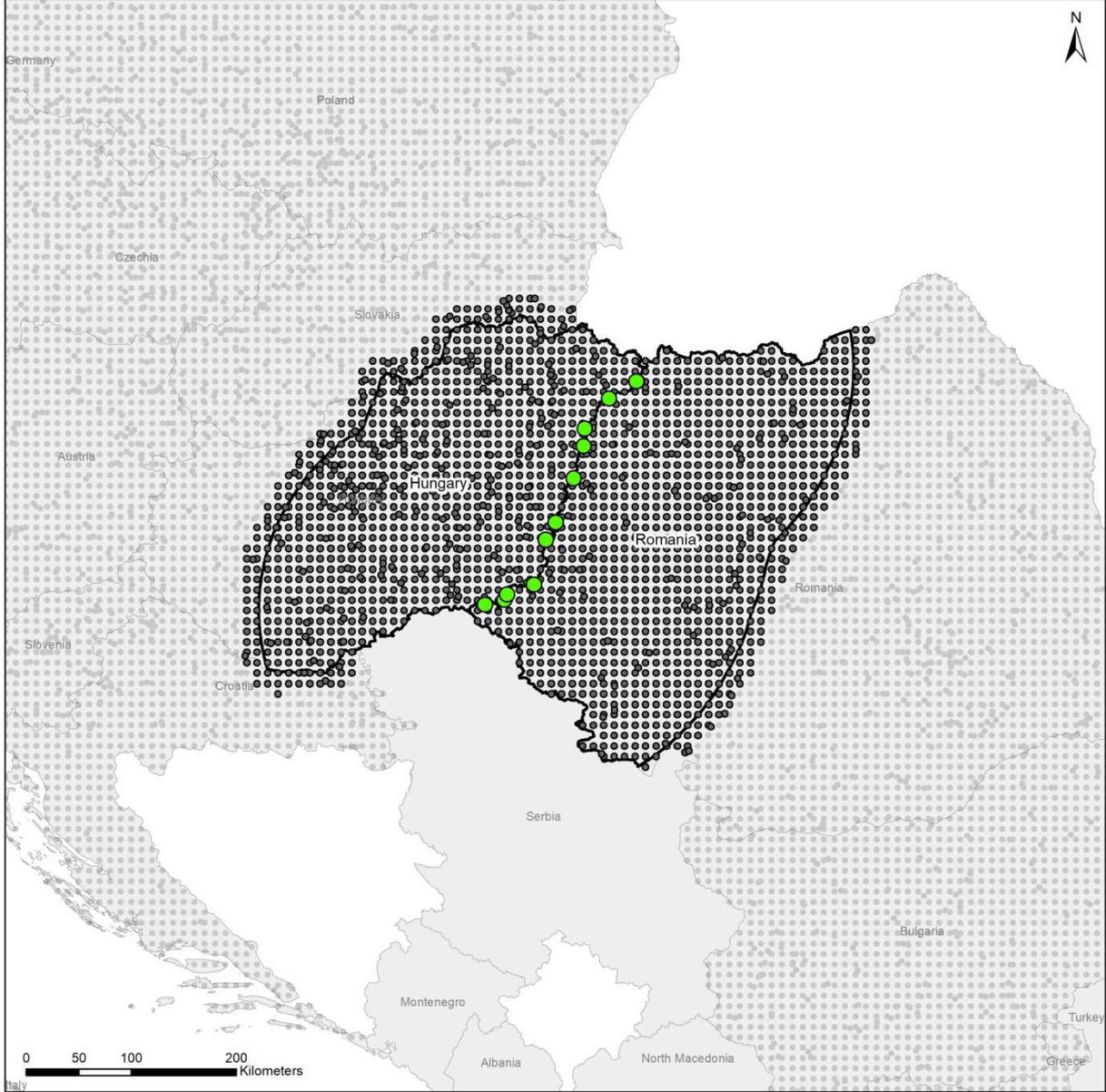


Figure 5: Example (from the Hungarian-Romanian border) of origin points dataset

2.5 Conceptual model for definition of drive time-based cross-border regions

Origin and destination point datasets have been used to estimate travel times to land border crossings using the road network. The travel times have been calculated between a pre-defined set of origin and destination points, based on the principle of the "first rank closest destination only". The "first rank closest destination only" approach implies that the paths [Origin-Destination (OD) Lines] to the destinations are generated from the origin points. One origin point may have paths to more than one destination point. The shortest OD Line (and the closest destination point) gets assigned Rank 1, the second shortest OD line (and the second closest destination point) obtain Rank 2, and so on. Only Rank 1 is considered in this study.

Ideal drive times, based on governing speed limits for passenger cars and assuming free-flow i.e. without congestions and/or border crossing delays, have been applied in the OD calculations. The use of ideal drive times is an important, but objective limitation in the analysis, because congestion varies significantly with the time of the day, days of the week and seasons.

Extra drive time (based on 50km/h assumed speed) has been added when the "origin" points were adjacent to (but not directly on) the road network of land border crossings.

The resulting drive-time areas on each side of the border have been drawn in four time intervals, as illustrated in Figure 6:

- Up to 30 minutes (the red zone from Figure 6);
- Between 30 and 60 minutes (the orange zone from Figure 6);
- Between 60 and 90 minutes (the grey zone from Figure 6);
- Above 90 minutes (the blue zone from Figure 6);

For the purpose of delineating cross-border zones, only the first time interval (up to 30 minutes of drive time) has been selected for thorough analysis in the current report because it has been perceived as the most relevant one for cross-border interactions. The assessment can obviously be extended to the other drive-time zones, but in such a case the analysis would become far more sophisticated, as a much greater number of factors may influence the population dynamics.

Additional technical information about the definition of cross-border workflow / scenarios is provided in Annex 6.1.

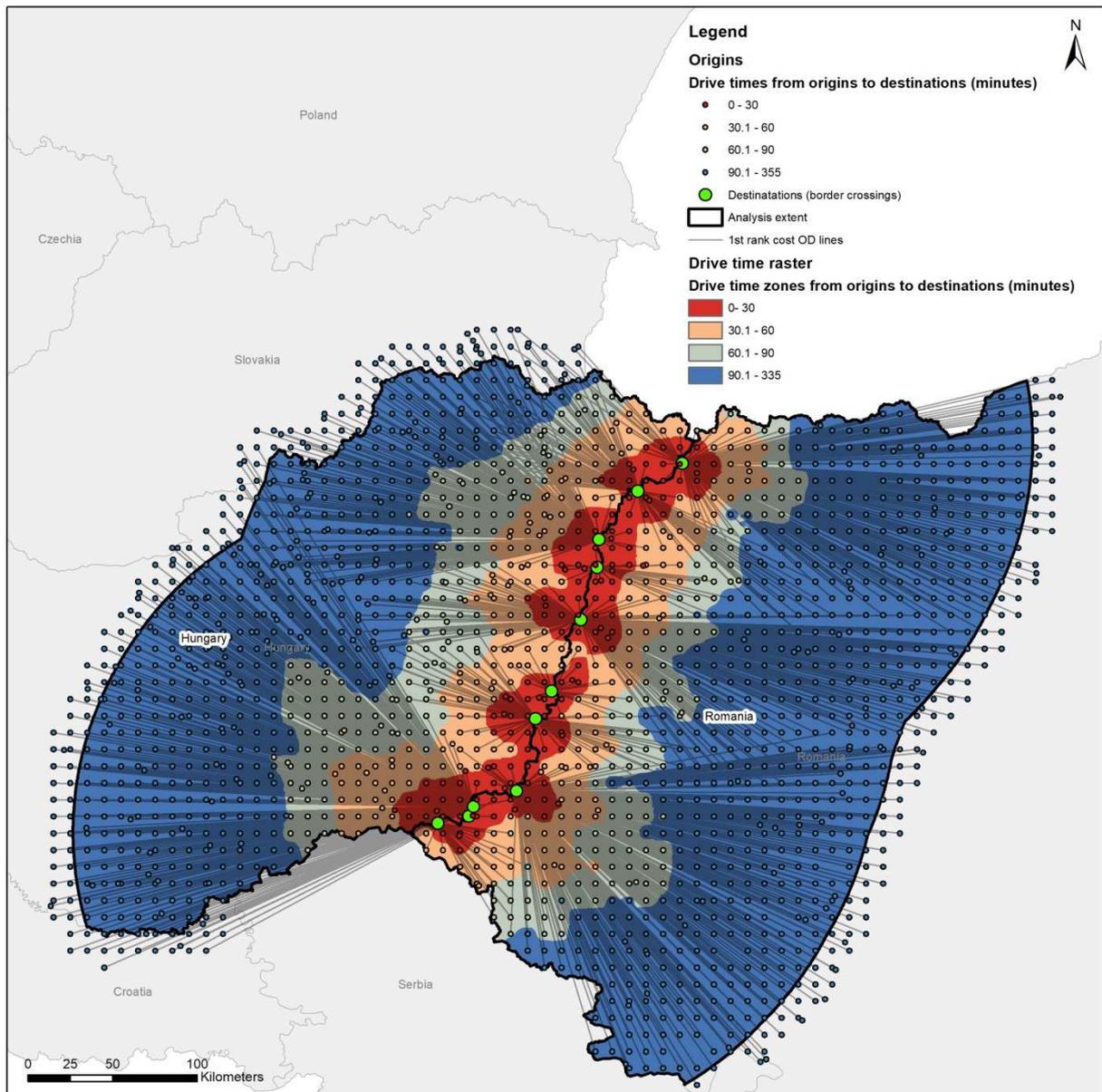


Figure 6: Network analysis concept (Romanian-Hungarian border case). The lines illustrate the 1st rank shortest OD lines. For simplicity reasons, the OD paths are visualised as straight lines, but in fact they represent ideal drive times on real roads.

3 Clustering of EU cross-border regions

3.1 Approach

In order to better distinguish amongst different cross-border regions and reveal certain common patterns, the analytical part of the study aimed to classify (cluster) the thirty four EU cross-border regions that were assessed in this report (Table 2). The differences between the 2001-2011 population evolution in the "30 minutes" drive-time border zones versus the 2001-2011 population evolution at country level has been selected as criteria for clustering. As already hinted in Chapter 2, the "30 minutes" drive time zone has been shortlisted because it has been deemed as the most relevant to the cross-border commuting. The population evolution in longer (above 30 minutes) drive-time zones might have been influenced to a much higher extent by other, non-cross border related factors e.g. urban agglomerations. The co-relations amongst various drive-time areas e.g. the "30-minutes" ones versus the "30-60 minutes" one, might be quite diverse and hence – result in a substantial, but unnecessary complication of the analysis.

Along the above classification analysis, six clusters have been defined as follows:

- Cluster 1 "**Faster growing borders**", where border population growth is **higher** than country population growth on both sides of the border.
- Cluster 2 "**Slower growing borders**", where border population growth is **lower** than or equal to the country population growth on both sides of the border.
- Cluster 3 "**Diverging borders**", where the border population trend (positive or negative) is **better** than the country population trend (positive or negative) on one side of the border and **worse** on the other side of the border (complex regions included).
- Cluster 4 "**Underperforming borders**", where the border population trend (positive or negative) is **worse** or equal to the country population trend (positive or negative) on both sides of the border (complex regions included).
- Cluster 5 "**Faster declining borders**", where border population decline is **deeper** than country population decline on both sides of the border.
- Cluster 6 "**Shrinking borders in growing countries**", where border population **declines**, while country population **grows** on both sides of the border.

The six clusters are sketched in Table 3 and described in greater detail in the following sections from 3.2 to 3.7. In each section, the relative (in percentages) change in the "30 minutes" drive-time border population and in the county population is displayed. The respective absolute dynamics (in thousand inhabitants) and maps of drive time areas (below 30, 30-60, 60-90, above 90 minutes) are presented in Annexes 6.2 to 6.7.

There have been few cases where border population evolution has been found approximately equal to country population evolution. In all those cases it has been assumed that there would be still some unexploited potential for cross-border interactions so that the border areas become relatively more attractive to live than the rest of the country. Hence, they have been allocated to the respective clusters, where the population dynamics within the "30-minutes" drive-time zone was inferior to the population dynamics at country level.

The six clusters from Table 3 and the related findings, explained in the following sections from 3.2 to 3.7, are drawn based on a particular set-up of the assessment framework. If other criteria are added or substitute the currently used ones for analysing border zones and their susceptibility to cross-border commuting, the breakdown of cross-border zones per clusters might look quite differently. An update of the population data could also reveal new trends and thus, lead to a different composition and interpretation of the clusters.

Table 3: Cluster definition based on population dynamics at country level and in cross-border areas within "30 minutes" drive-time from the border in two neighbouring EU Member States or complex regions within 2001-2011

	C ₁	B ₁	B ₂	C ₂
Cluster 1	Growth	Higher growth	Higher growth	Growth
Cluster 2	Higher growth	Growth	Growth	Higher growth
Cluster 3	Worse trend	Better trend	Worse trend	Better trend
Cluster 4	Better trend	Worse trend	Worse trend	Better trend
Cluster 5	Decline	Deeper decline	Deeper decline	Decline
Cluster 6	Growth	Decline	Decline	Growth

Legend:

Cluster 1 "Faster growing borders" (red);

Cluster 2 "Slower growing borders" (orange);

Cluster 3 "Diverging borders" (yellow);

Cluster 4 "Underperforming borders" (green);

Cluster 5 "Faster declining borders" (blue);

Cluster 6 "Shrinking borders in growing countries" (dark blue);

C₁ – Country population in neighbouring country / region No. 1;

B₁ – Border population in neighbouring country / region No. 1;

B₂ – Border population in neighbouring country / region No. 2;

C₂ – Country population in neighbouring country / region No. 2;

3.2 Cluster 1: Faster growing borders

The first cluster comprises couples of EU border areas where the population growth in the "30 minutes" drive-time border zone perimeter is higher than the country population growth on both sides of the border. Such a situation implies that living in border areas is highly attractive and in particular – more attractive compared to the country average. This attractiveness might be due to natural factors like favourable landscape or climate, and/or socio-economic factors e.g. presence of urban agglomerations or economic / industrial hubs, well developed infrastructure, cross-border interactions, etc. It might also be the case of border zones that are recovering from / overcoming setback that hampered interactions in the past. There might be still some room, including via intensified cross-border interactions, to further stimulate the overall economic attractiveness and hence, population growth in those areas.

As shown in Figure 7 and Annex 6.2, there are four pairs in this cluster, composed of totally six EU Member States, heavily concentrated in Central Europe. Both Austria and Slovakia have two cross-border areas in the cluster, including their mutual one. The superior border population growth in the Austria-Slovakia couple appears to be driven by the inclusion of the Slovak capital Bratislava and the immediate proximity of the Austrian capital Vienna to the boundary of the "30 minutes" drive-time Austrian zone – Figure 19 from Annex 6.2. The well-developed road infrastructure also contributes to the attractiveness of the two border areas and facilitates cross-border interactions.

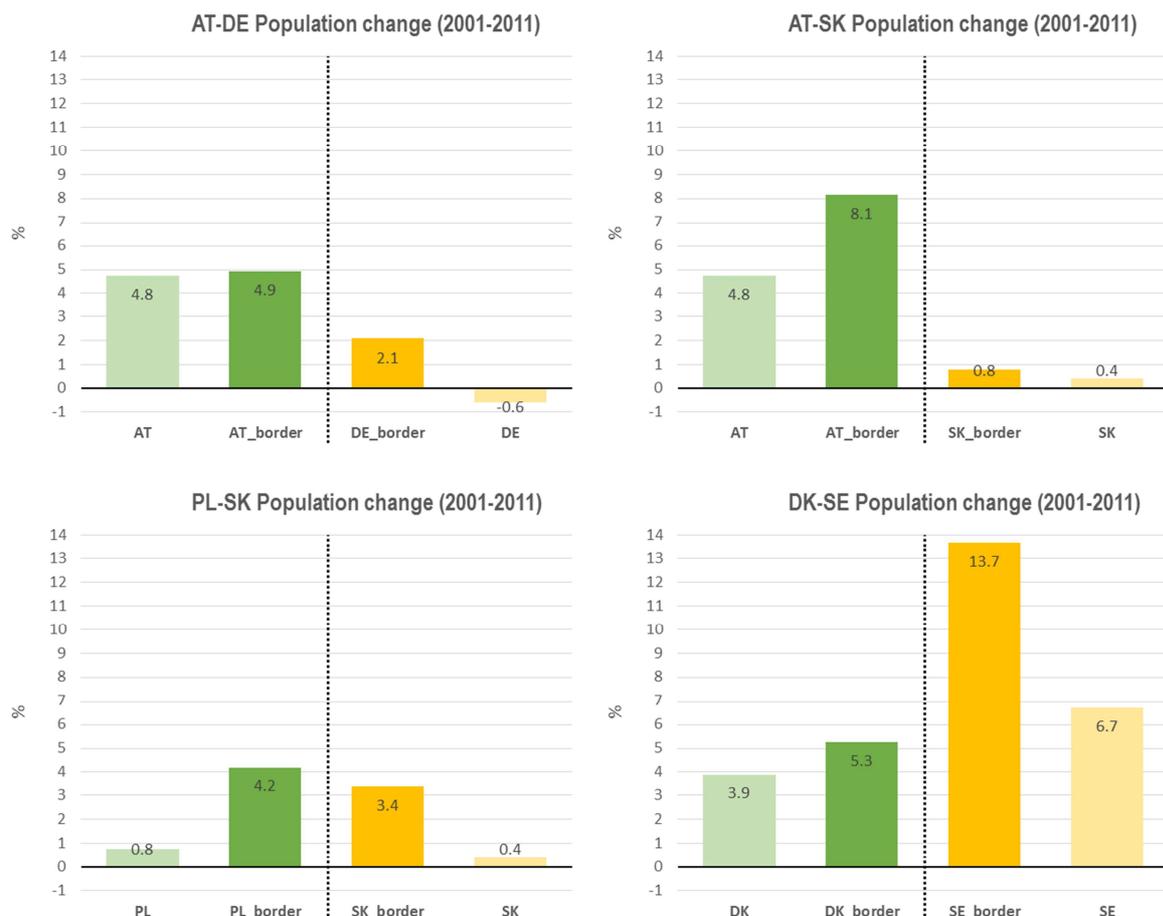


Figure 7: Population dynamics at country level and in the "30 minutes" drive-time border areas in Austria-Germany (top left), Austria-Slovakia (top right), Poland-Slovakia (bottom left) and Denmark-Sweden (bottom right) within 2001-2011, in %

The widest gap between border and country growth – 7 percentage points – is registered in Sweden (from the Denmark-Sweden couple), eventually driven, amongst others, by the proximity to the Danish capital Copenhagen via the Øresund bridge (Figure 20 from Annex 6.2). The inclusion of Copenhagen into the "30 minutes" drive-time zone appears to be a driver for the superior border population growth compared to the country one in Denmark. The cross-border cooperation (the Øresund Strategy) is very well developed and functioning in a number of socio-economic areas (European Commission, 2018).

The Austria-Germany pair is the only one where a negative country population trend is observed in one of the countries (Germany). The nearby (in the "30-60 minutes" drive-time area) location of the third largest German city – the Bavarian capital Munich (Figure 19 from Annex 6.2), and the mountainous landscape in the Western wing of the Austrian-German frontier, do not negatively impact the population trend in the "30 minutes" drive-time zone. The cross-border cooperation between Austria and Germany/Bavaria has a long and successful track record (Amt der Oberösterreichischen Landesregierung, 2019), triggered also by historical factors, language and socio-cultural similarities.

The superior population growth in border areas of the Poland-Slovakia pair is based on a rather modest number of inhabitants – approximately one million altogether (Figure 18 from Annex 6.2). The low total population might be due to the mountainous landscape (the Tatras). The Tatras are largely protected areas, but also a popular touristic zone (Zwijacz-Kozica *et al.*, 2013; Getzner and Švajda, 2015).

3.3 Cluster 2: Slower growing borders

The second cluster comprises pairs of EU border areas where the border population growth in the "30 minutes" drive-time zone is lower or (in just in one case) equal to the country population growth on both sides of the border. This configuration suggests that living in the countries is attractive, but the border element seems of preventing the cross-border regions from reaching the respective country growths. These differences might be due to natural factors like less favourable landscape or climate, and/or socio-economic factors – remoteness from urban agglomerations or economic / industrial hubs, particular infrastructure developments, etc. It might also be the case of border regions not being able to overcome some border setbacks. There might be additional reserves, including via strengthened cross-border interactions, for the border population growth to catch up with the country one and thus, further boost the overall economic attractiveness of border areas.

As shown in Figure 8, Figure 9 and Annex 6.3, there are six couples in this cluster, composed of totally six EU Member States. This numbers imply that geographically-wise Cluster 2 "Slower growing borders " is more concentrated than Cluster 1 "Faster growing borders " (again six counties, but in just four pairs). The members of the cluster are located in two main parts of Europe – Southern / Central Europe (Figure 8) and Benelux (Figure 9). In terms of total number of inhabitants, however, the two Benelux couples (Figure 22 from Annex 6.3) outpace by far the other four pairs in Southern / Central Europe (Figure 21 from Annex 6.3). This might be due, amongst others, to higher

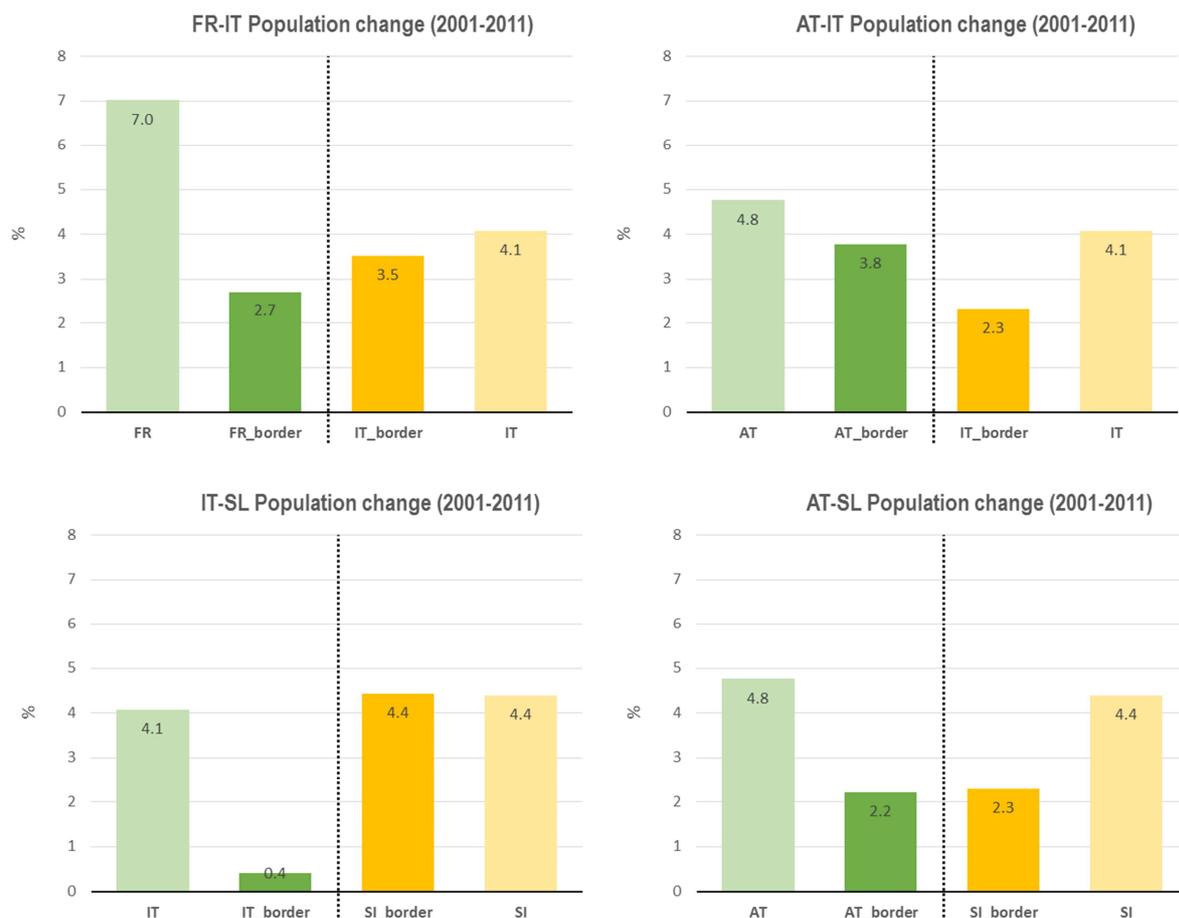


Figure 8: Population dynamics at country level and in the "30 minutes" drive-time border areas in France-Italy (top left), Austria-Italy (top right), Italy-Slovenia (bottom left) and Austria-Slovenia (bottom right) within 2001-2011, in %

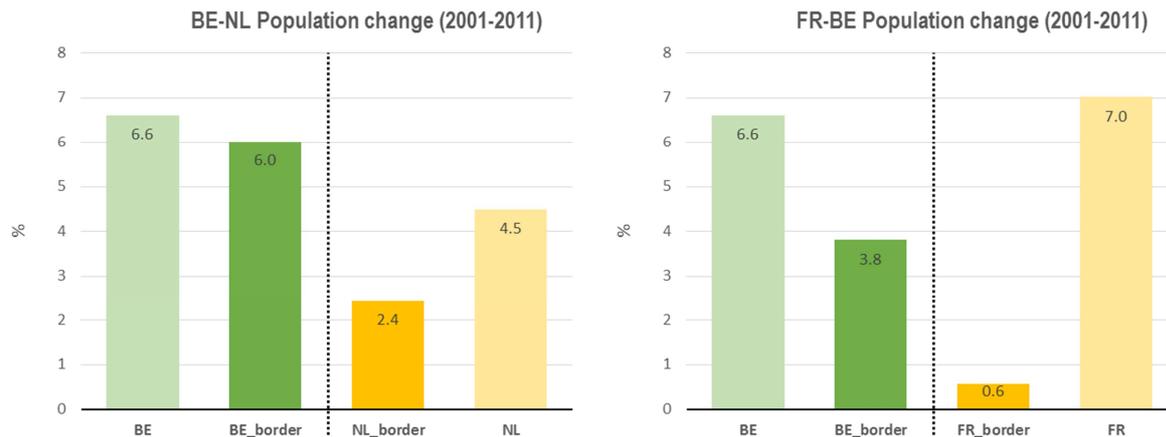


Figure 9: Population dynamics at country level and in the "30 minutes" drive-time border areas in Belgium-Netherlands (left) and France-Belgium (right) within 2001-2011, in %

population densities⁹ and flatter landscape that facilitates road construction and commuting from a wider area in Benelux (Figure 25 from Annex 6.3). Conversely, the Alps impose substantial limitations to cross-border connectivity in Southern / Central Europe, especially for the couples France-Italy and Italy-Austria (Figure 23 from Annex 6.3).

The most represented country in Cluster 2 "Slower growing borders" is Italy, whose all three terrestrial border zones with other EU Member States, all of them situated in the Northern part of the country, fall into it. Italy is followed by Austria, Slovenia, France and Belgium, each of them with two border areas. Austria is to be highlighted in particular, considering that the country has also two border zones in Cluster 1 "Faster growing borders". Altogether, these observations mean that the majority¹⁰ of Austrian border regions, especially the Western and Southern ones, are not coping with the country population trend. This fact implies negative border effects and hence, a need for policy intervention to overcome those border effects.

Large urban agglomerations seem to have certain impact on the population dynamics in the border areas and at country levels. In both pairs, the Belgium capital Brussels falls outside the "30-minutes" drive-time zone (Figure 25 from Annex 6.3), which fact might predispose the inferior border population growth. On the other hand, the Belgium border zone in the Belgium-Netherlands couple contains the second (Ghent), third (Antwerp) and fifth (Liege) largest cities in the country, while in the Dutch zone only the fifth (Eindhoven), sixth (Tilburg) and ninth (Breda) biggest cities are found. As a result, the negative border effects might be disguised by the attractiveness of these urban centres within the Belgian border area – the relative growth on the Belgian side is 2.5 times higher than on the Dutch side. As for the France-Belgium couple, the absolute population in France is larger, but the population growth on the Belgian border side is higher – Figure 22 from Annex 6.3. The cross-border interactions are well developed in those two pair thanks to the long history of evolution, traditional relationships, language and cultural similarities. It is also widely quoted as "best practice" examples in a number of areas¹¹. Regardless all these positive facts and factors, the border population growth is still not capable to match the country population growth.

⁹ By 2017, in inhabitants per km2: Belgium – 374, Netherlands – 501, versus France - 106, Italy – 203, Austria – 107 and Slovenia – 103 (EUROSTAT, 2018)..

¹⁰ Four out of totally six. The border region with Hungary is also peculiar with population growth within 2001-2011, which growth is nonetheless lower than the national population growth (see next Cluster 3).

¹¹ The majority of "good practice" examples in (European Commission, 2017) are from the Benelux area.

3.4 Cluster 3: Diverging borders

The third cluster comprises couples of EU border areas and complex regions where the population trend (growth or decline) in the "30 minutes" drive-time zone is better than the country trend on one side of the border and worse – on the other side of the border (complex regions included). The diverging trends on the two sides of the border imply that there might be room for improvement, including via cross-border interactions. The difference might also be due to natural constraints, such as mountainous landscape or large rivers, or other setbacks that are challenging to overcome. It might be useful to further analyse at EU, national, regional and local levels the potential cross-border opportunities.

Owing to the above specifics, Cluster 3 "Diverging borders" presents a more diverse cross-border snapshot than previous Cluster 1 "Faster growing borders" and Cluster 2 "Slower growing borders" – from population growth in border zone and country-wide on both sides of the border (Spain-France, Figure 11) to population decline in border zone and country-wide on both sides of the border (Hungary-Romania, Figure 10). Cluster 3 "Diverging borders" contains the highest number of EU Member States amongst all clusters – thirteen, split up in seven couple and two complex regions (Figure 10 and Figure 11). Due to the high number of countries, it is more challenging to define distinct regional patterns. The most represented country is Germany (in particular her Northern and Western borders) with four appearance – in two couples and two complex regions, followed by France, Netherlands and Hungary with two appearances. As a result, some



Figure 10: Population dynamics at country level and in the "30 minutes" drive-time border areas in Germany-Denmark (top left), Bulgaria-Greece (top right), Austria-Hungary (bottom left) and Hungary-Romania (bottom right) within 2001-2011, in %

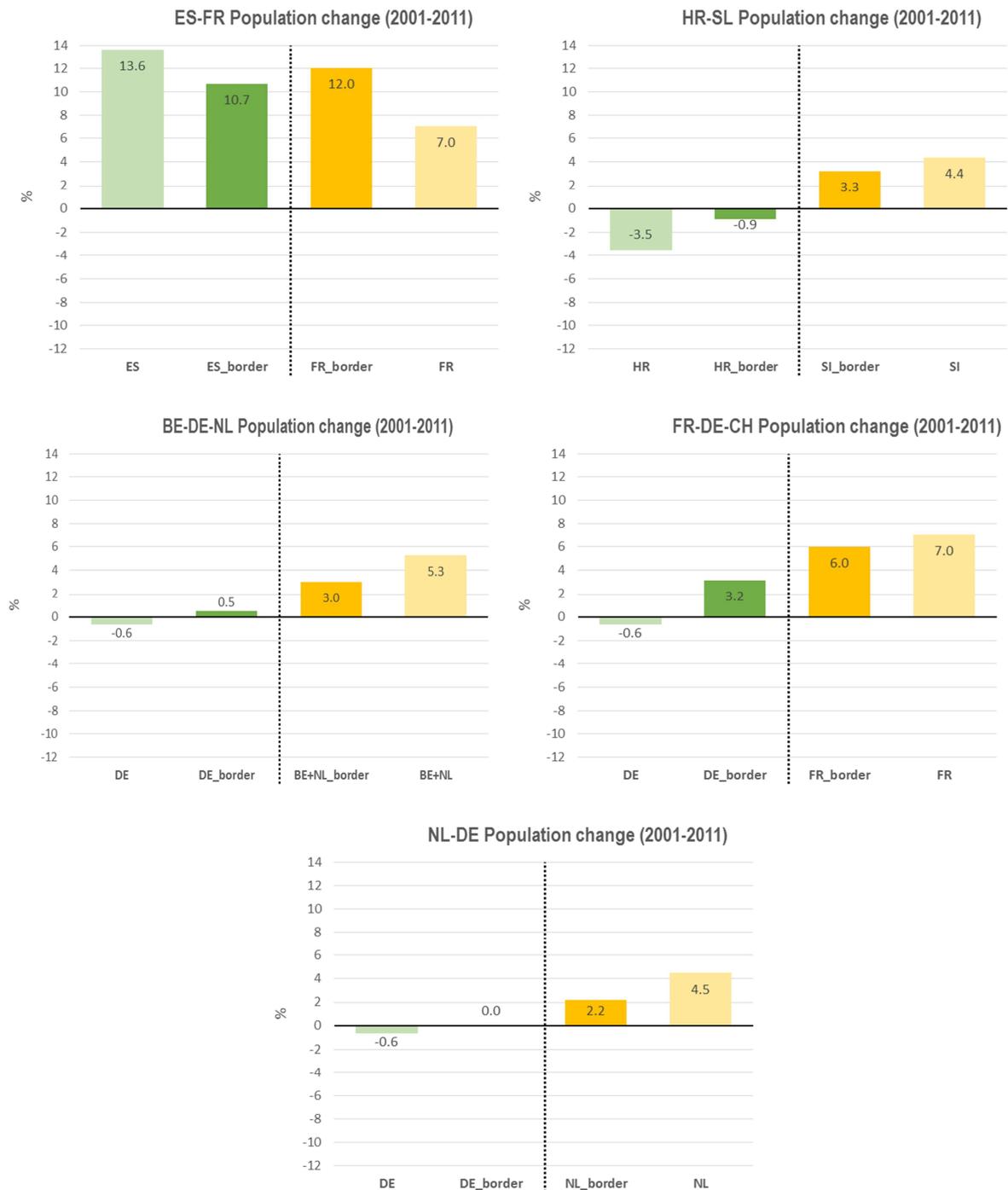


Figure 11: Population dynamics at country level and in the "30 minutes" drive-time border areas in Spain-France (top left), Croatia-Slovenia (top right), Euregio Maas Rhein (Netherlands-Belgium-Germany, middle left), Upper Rhine (France-Germany-Switzerland, middle right) and Netherlands-Germany (bottom centre) within 2001-2011, in %

sort of geographical concentration could be identified in Central Europe (Western Romania, Hungary, Austria, Croatia and Slovenia – Figure 30 and Figure 31 from Annex 6.4) and Western Europe (Western Germany, Eastern parts of Netherlands, Belgium and France – Figure 32 and Figure 33 from Annex 6.4). Two couples are also located in Southern Europe (Spain-France – Figure 31 from Annex 6.4 and Bulgaria-Greece – Figure 29 from Annex 6.4), and one – in Northern Europe (Germany-Denmark, Figure 29 from Annex 6.4).

The extent of total population is rather diverse in the nine cross-border regions in Cluster 3 "Diverging borders". It ranges from about three hundred thousand (300,000) inhabitants in the Bulgaria-Greece couple (Figure 26 from Annex 6.4) to nearly ten million (10,000,000) inhabitants in the Netherlands-Germany pair (Figure 28 from Annex 6.4).

The difference between population dynamics in the border zone and country-wide is quite diverse, too. The widest one – almost 11 percentage points – is in the South-European couple of Bulgaria-Greece (Figure 10). The narrowest gap – slightly above 1 percentage point, is found in the other South-European pair of Spain-France (Figure 11). In both cases, the "30-minutes" drive-time area is heavily constrained by challenging mountainous landscapes. These are the Pyrenees on the Spanish-French border (Figure 31 from Annex 6.4) and the Pirin-Rhodopes mountain chain on the Bulgarian-Greek border (Figure 29 from Annex 6.4), which is situated mostly in Bulgaria.

The Central European sub-cluster encompasses three couples – Hungary-Romania, Austria-Hungary and Croatia-Slovenia. The case of Hungary is particularly interesting, because at the frontier with Romania the Hungarian border population shrinks noticeably (border trend inferior to the country, still downward one), while at the frontier with Austria the Hungarian border population slightly grows (border trend superior to the country one). The more extensive development of road network, the higher number of cross-border connections and consequently – the generally wider "30 minutes" drive-time perimeter (Figure 30 from Annex 6.4) might contribute, amongst others, to these diverse population trends. Another potentially positive circumstance is that the Austrian capital Vienna falls very close to the boundaries of the "30 minutes" drive-time zone. This fact might partially explain the poorer "30 minutes" drive-time population trend compared to the country one in Austria. As for the Croatia-Slovenia pair, the cross-border connections are well developed, owing also to historical factors. The population decline on the Croatian side is smaller compared to the one at country level, eventually because the capital Zagreb and the third largest city in the country – Rijeka, fall into the "30 minutes" drive-time zone (Figure 31 from Annex 6.4). For the same reasons, the total population on the Croatian border side is more than double the population on the Slovenian side (Figure 27 from Annex 6.4). As regards Slovenia, the population growth in the "30 minutes" drive-time zone in Slovenia is lower than the country one largely because the capital Ljubljana, which is by far the largest city in the country¹², falls outside the "30 minutes" drive-time border zone with Croatia (Figure 31 from Annex 6.4). On the other hand, the proximity of the Croatian capital Zagreb to the "30 minutes" drive-time Slovenian border zone might provide opportunities for cross-border interactions in terms of economic activities, employment, provision of services, etc. The Croatian border zone might benefit, for example, of the touristic opportunities (SPA, hiking, etc.) offered by the nearby Slovenian border zone.

The Western European cluster also embraces three elements – one couple (Netherlands-Germany) and two complex regions: Euregio Maas Rhein (Netherlands-Belgium-Germany) and Upper Rhine (France-Germany-Switzerland). The most distinct features of this sub-cluster are the highly populated (at least 1.5 million inhabitants) border zones of "30 minutes" drive-time (Figure 27 and Figure 28 from Annex 6.4), thanks to favourable landscape, dense road network, multiple border crossings and concentration of large urban centres (Figure 32 and Figure 33 from Annex 6.4). In all three cases the German border zones comprise some of the most advanced German regions and enjoy superior population trends than the country one. For the other three countries – Netherlands, Belgium and France – the population growth in the border zone is slightly inferior to the country one, possibly because the border zone does not comprise major urban centres. The border area, nevertheless, seems quite attractive to live. Cross-border commuting for various purposes, including work, appears to be a widely observed phenomenon. The fruitful cross-border interactions in all these three cases have long history since the initial

¹² The second largest city in the country – Maribor – is three times smaller in terms of population.

years of the EU¹³ and they are often quoted as "best practice" examples in a number of fields (European Commission, 2017). Incremental gains and synergies might be sought especially with regard to further increasing the settlement attractiveness for the Dutch, Belgian and French border zones.

The Northern couple of Denmark-Germany is peculiar with the second lowest (after the Bulgaria-Greece one) total population in Cluster 3 "Diverging borders", amounting to around 400 thousand inhabitants, but spread along quite a short frontier of just 68 km. The majority of this population lives on the German side, where the largest city in the "30 minutes" drive-time zone is located – Flensburg having about 90 thousand inhabitants. The German border zone population is also on the rise, while the one on the Danish side is on decline.

¹³ Including the EU's predecessor – the Western European Union (1954)

3.5 Cluster 4: Underperforming borders

The fourth cluster comprises pairs of EU border areas and complex regions where the population trend (positive or negative) in the "30 minutes" drive-time zone is worse or equal to the country population trend (positive or negative) on both sides of the border, including complex regions. The relative underperformance of border zones implies that there might be room for improvement via, amongst others, intensified cross-border interactions. Similarly to other clusters, the underperformance might be influenced by natural constraints that are challenging and costly to overcome, such as large rivers or mountainous landscape. It might also be the case of border regions that are not capable to cope with increasing border challenges and setbacks. It might be useful to further analyse at EU, national, regional and local levels the available opportunities and unexploited reserves.

Cluster 4 "Underperforming borders" is the second largest one (after Cluster 3 "Diverging borders") and comprises twelve EU Member States, split up in six couples and one complex region – Figure 12 and Figure 13 and Annex 6.5. Germany has again (like in Cluster 3 "Diverging borders") the highest frequency of appearance – in three cases, followed by Poland and Czech Republic with two appearances each. The cluster is heavily concentrated in Eastern / Central Europe – Lithuania, Poland, Eastern Germany, Czech Republic, Slovakia, Austria and Hungary. The other two locations in the cluster are the Luxembourg borders with all her neighbours (the Grande Region of France-Belgium-

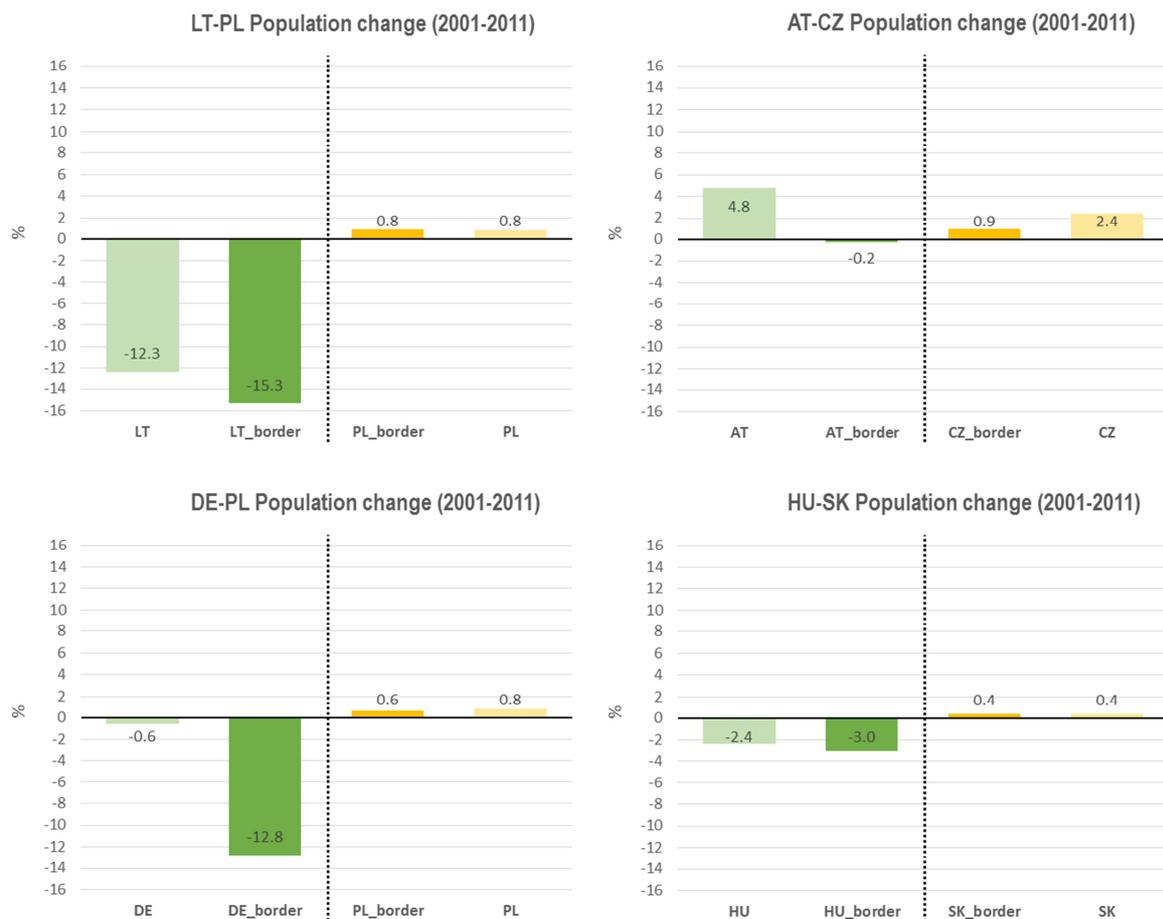


Figure 12: Population dynamics at country level and in the "30 minutes" drive-time border areas in Latvia-Poland (top left), Austria-Czech Republic (top right), Germany-Poland (bottom left) and Hungary-Slovakia (bottom right) within 2001-2011, in %



Figure 13: Population dynamics at country level and in the "30 minutes" drive-time border areas in Portugal-Spain (top left), Grande Region (Luxembourg-Belgium-Germany-France, top right) and Czech Republic-Germany (bottom centre) within 2001-2011, in %

Germany-Luxembourg) and Portugal-Spain in the South-western corner of the EU. The deepest (exceeding 15%) loss of population in border areas is encountered in Lithuania at the frontier with Poland – Figure 12. This fall in border population seems to be driven by the substantial overall drop in population nationwide (due to emigration, amongst others), coupled with the absence of major urban centres in the "30 minutes" drive-time zone (Figure 37 from Annex 6.5). The border trend at the Polish side (equal to the country one) might be partially impacted by immigration from nearby non-EU states – Belarus and Ukraine (Harper, 2018; Yeliseyeu, 2018).

The largest gap between border and country population trends is observed in Eastern Germany, at the border with Poland – more than 12 percentage points, especially when juxtaposed to the slight population growth on the Polish side (Figure 12). This notable divergence might be driven by factors of various socio-economic natures. The location of large urban centres, including the German capital of Berlin, in the next "30-60 minutes" drive-time zone (Figure 38 from Annex 6.5) might also somehow attract population from the "30 minutes" drive-time zone. The Polish cross-border commuters, in search of more and better jobs in Germany, while enjoying lower living costs in Poland, might also have a contribution. The well-developed road network, especially on the German side, further stimulates cross-border commuting. As a cumulative result, towards the end of the assessed period the population in the Polish border zone surpassed one million inhabitants and exceeded the population in the German border zone (Figure 35 from Annex 6.5).

The socio-economic specifics of Eastern Germany in the Northern part of the German-Czech border, along with the mountainous landscape in the Southern part of the border, might be amongst the factors for the continuous drop of population in the German border zone with Czech Republic (Figure 36 from Annex 6.5). The potential for cross-border interactions might be greater compared to the one at the German-Polish border due to the historical socio-cultural relations and the much larger total population (Figure 36 versus Figure 35 from Annex 6.5).

The border population in the other pair, where Czech Republic appears – the one with Austria, is fairly stable (Figure 12) and relatively proportional (Figure 34 from Annex 6.5) on both sides of the border. One reason for the poorer population trends in the "30 minutes" drive-time zone compared to the country ones might be that major urban agglomerations fall in the neighbouring "30-60 minutes" drive-time zone. In Czech Republic these are Brno (the second largest city after the capital Prague) and České Budějovice, while in Austria – the capital Vienna and Linz (the third largest city) – Figure 37 from Annex 6.5. The mountainous landscape in the Western wing of the Austrian-Czech border might also hinder to some extent cross-border commuting and interactions.

The situation in the Hungary-Slovakia pair appears similar to the Austria-Czech Republic case. The deeper drop in the "30 minutes" drive-time border zone in Hungary might be due to the capital Budapest – by far the largest city in the country¹⁴, hosting about 20% of total country population. Budapest is located in the neighbouring "30-60 minutes" drive-time frontier zone, but right next to the boundary of the "30 minutes" drive-time zone – Figure 38 from Annex 6.5.

The longest internal EU terrestrial frontier¹⁵ in the EU of more than 1,200 km belongs to the South-western couple of Portugal-Spain – Figure 39 from Annex 6.5. On both sides of the "30 minutes" drive-time border zone no major urban agglomerations are placed, especially in the Northern wing of the border. The slightly better trend in the Spanish border zone might eventually be due to the two cities contained in it – Vigo (≈300 thousand inhabitants) in the North and Badajoz (≈150 thousand inhabitants) in the South. The population trends and the drive-time border area in the coastal zones are positively impacted by the intensive development of touristic industry and road networks, triggered by favourable location, fresher climate and flatter landscape.

The trends in the Grande Region are a bit peculiar. Due to the small size of Luxembourg, the whole country enters into the "30 minutes" drive-time zone – Figure 40 from Annex 6.5. The border population trends are therefore equal to the country ones. Similarly to the other Benelux borders, the cross-border interactions around Luxembourg are very well developed in a number of socio-economic areas. The aggregated decline in the German-Belgian-French zone around Luxembourg is due to the population drop in Germany that is larger than the combined population increase in Belgium and France – Figure 35 from Annex 6.5.

¹⁴ The second largest city in Hungary – Debrecen, is 8-9 times smaller in terms of number of inhabitants.

¹⁵ Called "La Raya" in Spanish and "A Raia" in Portuguese (the strip)

3.6 Cluster 5: Faster declining borders

The fifth cluster could be perceived as opposite to Cluster 2 "Slower growing borders". Cluster 5 "Faster declining borders" comprises couples of EU border areas, where the population decline in the "30 minutes" drive-time border perimeter is deeper than the population decline at country level on both sides of the border. Such an outline implies that the countries are losing population due to e.g. ageing and/or emigration, but the situation is even more aggravated in border areas. Cross-border interactions might improve the downward trends, but they are not likely to overcome the prevailing national factors that hold back the living attractiveness country-wide and in particular - in border zones. The stronger unattractiveness of border zones might also be due to natural factors, e.g. challenging landscape or unfavourable climatic conditions. Any incremental cross-border measures might have greater impact, if combined with other initiatives and interventions.

As shown in Figure 14 and Annex 6.6, there are seven EU Member States in this cluster, split up in four pairs. The cluster has a clear geographical breakdown – the three Baltic States (Latvia being the only country in Cluster 5 "Faster declining borders" to be part of two couples) and South-eastern Europe (the Balkan Peninsula). All these four cross-border regions are sparsely populated – from just about one hundred thousand (100,000) inhabitants in the Estonia-Latvia couple, where also the deepest drop in population is recorded (more than 13 percentage points), to less than one million

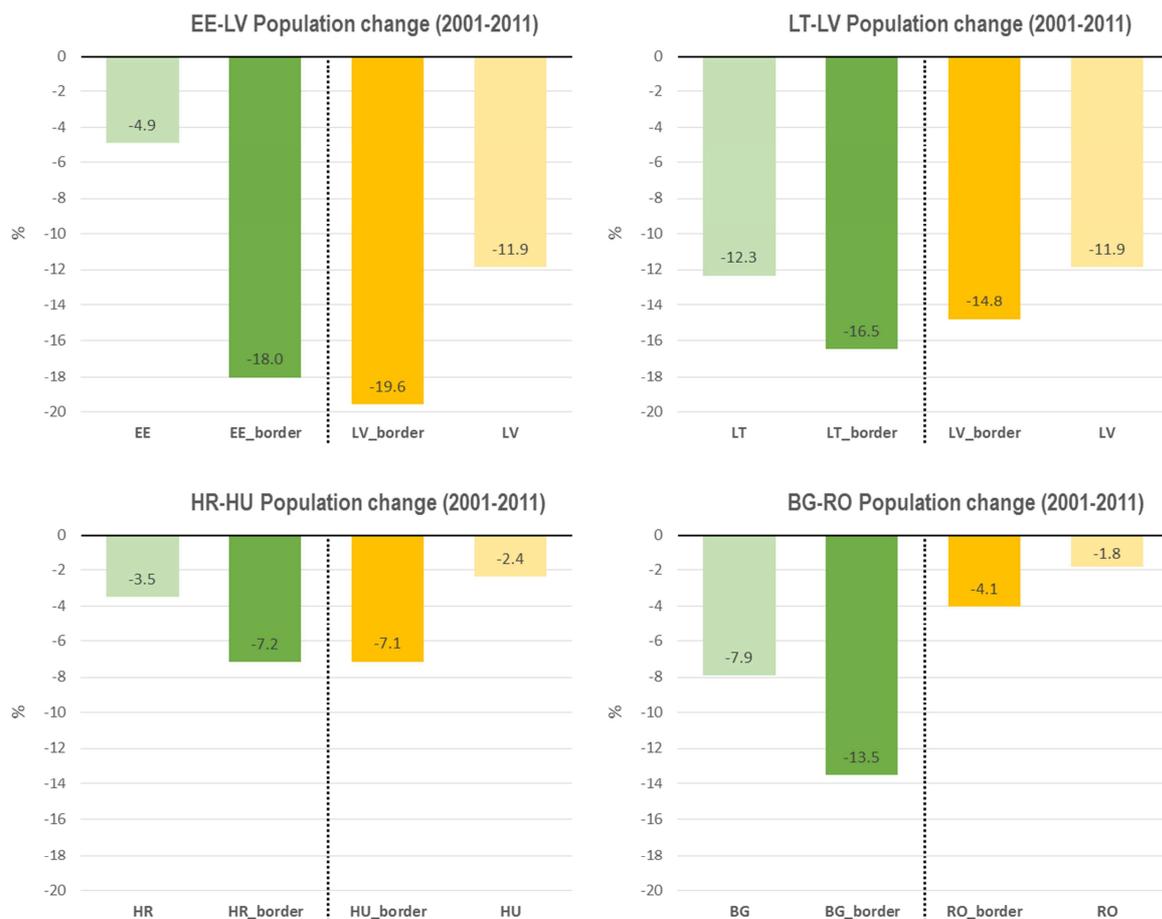


Figure 14: Population dynamics at country level and in the "30 minutes" drive-time border areas in Estonia-Latvia (top left), Latvia-Lithuania (top right), Croatia-Hungary (bottom left) and Bulgaria-Romania (bottom right) within 2001-2011, in %

(1,000,000) inhabitants in the Bulgaria-Romania pair (Figure 41 from Annex 6.6).

There could be various reasons for these negative border population trends. Some of them might be the absence of major urban centres in the "30 minutes" drive time zones (in the Baltics area – Figure 42 from Annex 6.6) combined with rather limited number of border crossings (Croatia-Hungary, Figure 43 from Annex 6.6) and with under-developed national road network (Bulgaria-Romania, Figure 43 from Annex 6.6). The case of the Bulgaria-Romania couple is further complicated by the presence of an important natural obstacle (the river of Danube) along most of the border with just two bridges over it.

3.7 Cluster 6: Shrinking borders in growing countries

The last, sixth cluster could be described as opposite to Cluster 1 "Faster growing borders". Cluster 6 "Shrinking borders in growing countries" comprises pairs of EU border areas, where population declines in the "30 minutes" drive-time border perimeter, while it grows country-wide on both sides of the border. In a single case (Hungary from the Hungary-Slovenia pair in Figure 15), country population declines in one of the countries, but the shrinkage at country level is much smaller compared to the drop in the border zone. Opposed to Cluster 1 "Faster growing borders", the situation in Cluster 6 "Shrinking borders in growing countries" implies that living in border areas is quite unattractive. There could be various reasons for that phenomenon – natural (e.g. unfavourable landscape or climatic conditions) or socio-economic (e.g. lagging economic development) ones. In any case, the trends in the border zones are so distinct from the evolution at country level, so that incremental stand-alone cross-border measures might be expected to have minor impact. Such measures would not be likely to reverse the negative border population trends alone, especially where important natural restrictions prevail, if not combined with other initiatives and interventions.

As shown in Figure 15 and Annex 6.7, there are seven EU Member States in this cluster, split up in four pairs. Czech Republic has two border areas in the cluster – with Poland and Slovakia, i.e. the Eastern part of the country. The cluster is identified in Central / Eastern Europe, as well as in Northern Scandinavia. The widest gap between negative border values and positive country values – almost 14 percentage points – is registered

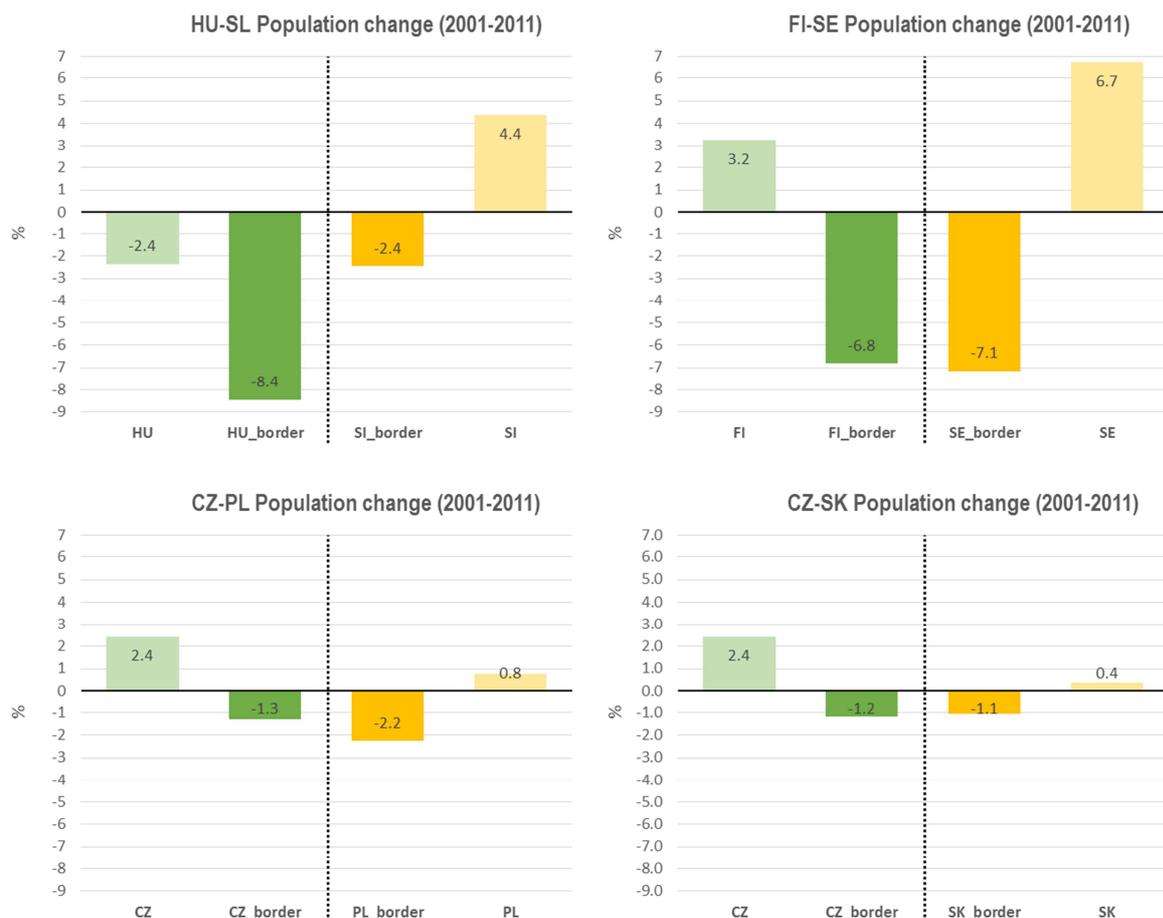


Figure 15: Population dynamics at country level and in the "30 minutes" drive-time border areas in Hungary-Slovenia (top left), Finland-Sweden (top right), Czech Republic-Poland (bottom left) and Czech Republic-Slovakia (bottom right) within 2001-2011, in %

in Sweden (from the Finland-Sweden couple).

The reasons for the negative trends in the border population seem to be different in the various country couples. In Northern Scandinavia the adverse climatic conditions do not favour population settlements. The resulting very low absolute population (Figure 45 from Annex 6.7) and population densities predispose rather limited development of road network – Figure 46. The absence of larger urban areas within the "30 minutes" drive-time frontier zone, especially on the Hungarian side, might be a reason for the negative trend in border population in the Hungary-Slovenia couple. The two cases, where Czech Republic is involved, are indeed quite different, because the total population figures are much higher compared to the two previous cases (Figure 45 and Figure 44 from Annex 6.7), as well as the gaps between border population decline and country population growth are much narrower (Figure 15).

areas is relatively attractive, but not as much as the country average. There might be additional reserves, including via intensified cross-border interactions, for the border population growth to catch up with the country one and thus, further boost the overall economic attractiveness of border areas.

Table 4: Breakdown of EU cross-border regions per clusters (1 to 6) based on population dynamics at country level and in the "30 minutes" drive-time border areas within 2001-2011

EU cross-border regions assessed			
1.	Austria-Germany	2.	Austria-Slovakia
3.	Poland-Slovakia	4.	Denmark-Sweden
5.	France-Italy	6.	Austria-Italy
7.	Italy-Slovenia	8.	Austria-Slovenia
9.	Belgium-Netherlands	10.	France-Belgium
11.	Germany-Denmark	12.	Bulgaria-Greece
13.	Austria-Hungary	14.	Hungary-Romania
15.	Spain-France	16.	Croatia-Slovenia
17.	Euregio Maas Rhein (Netherlands-Belgium-Germany)	18.	Upper Rhine (France-Germany-Switzerland)
19.	Netherlands-Germany	20.	Lithuania-Poland
21.	Austria-Czech Republic	22.	Germany-Poland
23.	Hungary-Slovakia	24.	Portugal-Spain
25.	Grande Region (France-Belgium-Germany-Luxembourg)	26.	Czech Republic-Germany
27.	Estonia-Latvia	28.	Lithuania-Latvia
29.	Croatia-Hungary	30.	Bulgaria-Romania
31.	Hungary-Slovenia	32.	Finland-Sweden
33.	Czech Republic-Poland	34.	Czech Republic-Slovakia

Background colour legend:

- Cluster 1 "Faster growing borders" (red);
- Cluster 2 "Slower growing borders" (orange);
- Cluster 3 "Diverging borders" (yellow);
- Cluster 4 "Underperforming borders" (green);
- Cluster 5 "Faster declining borders" (blue);
- Cluster 6 "Shrinking borders in growing countries" (dark blue);

The most populated Cluster 3 "Diverging borders" contains thirteen EU Member States, where the population trend (growth or decline) in the border zone is better than the country trend in one of the countries and worse in the other country or countries (in the case of complex regions). Cluster 3 "Diverging borders" is present mostly in Central and Western Europe, but it is also found in Southern and Northern Europe. The diverging trends on the two sides of the border imply that there might be room for improvement, including via cross-border interactions. It might be therefore useful to further analyse at EU, national, regional and local levels the potential cross-border opportunities.

The second largest Cluster 4 "Underperforming borders" includes twelve EU Member States, where the population trend (growth or decline) in the border zone is worse or in the best case – equal to the country trend on both sides of the frontier. The cluster is concentrated in Eastern / Central Europe, but it is also encountered in Benelux and South-western Europe. The relative underperformance of border zones points towards potential for improvement via, amongst others, intensified cross-border interactions. It might be thus useful to further analyse at EU, national, regional and local levels the available cross-border opportunities and unexploited reserves.

Cluster 5 "Faster declining borders" incorporates seven EU Member States from the Baltic Rim and South-eastern Europe, where the population decline in the border perimeter is deeper than the population decline at country level on both sides of the frontier. Such an outline implies that the countries are losing population, but the situation is even more aggravated in border areas. Any incremental cross-border incentives might have stronger positive impact, if combined with other initiatives and interventions.

Cluster 6 "Shrinking borders in growing countries" covers seven EU Member States from Central / Eastern Europe and Northern Scandinavia, where population declines within the border perimeters, but it generally grows nationwide on both sides of the frontier. Such a situation indicates that living in border areas is highly unattractive. Any incremental cross-border measures might be expected to have minor positive impact, if not combined with other initiatives and interventions.

Mountainous landscape, unfavourable climate, remoteness regarding bigger urban agglomerations or other natural obstacles (e.g. large rivers) could significantly discourage human settlements and consequently – hinder cross-border interactions. Additional infrastructure developments could improve cross-border commuting. They might not be, however, capable to remove all fundamental setbacks of border settlements and cross-border commuting.

The clusters from Figure 16 and Table 4, and the related findings are drawn based on a particular set-up of the assessment framework. If other criteria are added or substitute the currently used ones for analysing border zones and their susceptibility to cross-border commuting, the picture from Figure 16 and Table 4 might look quite differently. An update of the population data could reveal new trends and thus, lead to a different composition and interpretation of the clusters.

Besides applying a more recent population database at LAU2 level, the following additional aspects can be considered in terms of potential future work:

- ✓ Enlarging the scope of the analysis to EEA countries (Liechtenstein and Norway¹⁶) and Switzerland, in particular, considering that Switzerland is in the centre of Europe and surrounded by four EU Member States;
- ✓ Expanding the assessment to the neighbourhood countries, especially Western Balkans and Turkey, in view of their terrestrial borders with the South-eastern wing of the EU;
- ✓ Including the "30-60 minutes" drive-time zones to the analysis and revealing their correlations with the "30 minutes" drive-time zones;
- ✓ Extending the assessment to other variables, besides population dynamics, in the border zones, such as e.g. daytime / night time population, impact of tourism, etc.
- ✓ Deepening the analysis of the underpinning reasons for particular population dynamics and drive-time border zones;

¹⁶ Being an island, Iceland would not be part of the analysis.

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6 Annexes

6.1 Cross-border definition workflow

The Unified Modelling Language (UML) (ISO/IEC JTC 1/SC 7 Software and systems engineering, 2005) is used to describe cross-border definition workflow / scenario. The UML diagram (Figure 17) displays the actions, as well as their sequence, to build the conceptual model. The framework consists of three main horizontal swim lanes: preparation of input data, spatial analysis and mapping. The arrows (↓, →, ←) indicate the sequence of actions. The short horizontal thick black lines (▬) indicate where parallel processing starts and ends.

The modelling framework has been implemented within a calculation environment, while for this study it was developed using ESRI inc. ArcGIS® software.

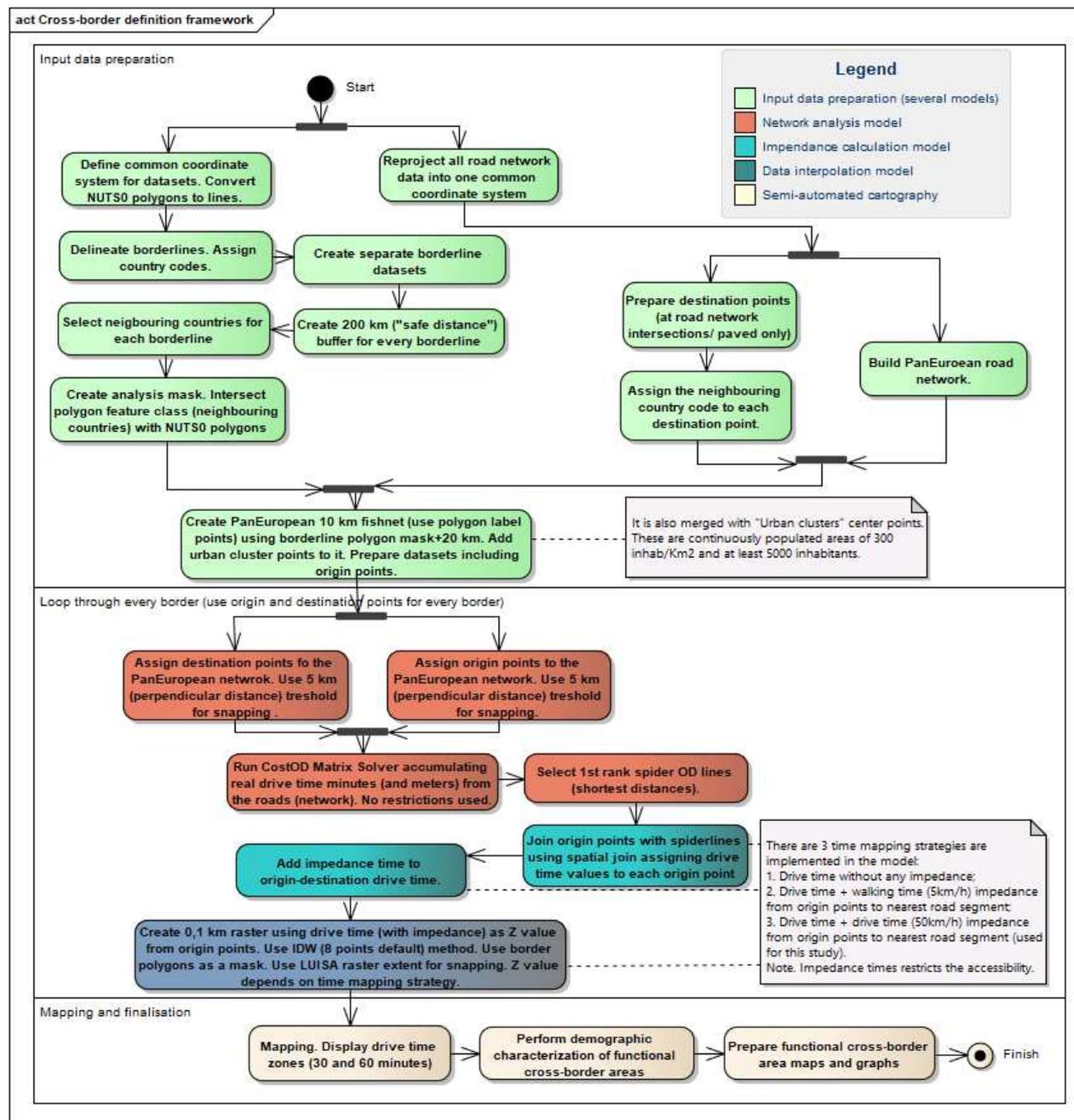


Figure 17: The UML activity diagram of the cross-border definition workflow (scenario)

6.2 Cluster 1: Faster growing borders – absolute population evolution 1961-2011 and drive-time (30-60-90 minutes) maps

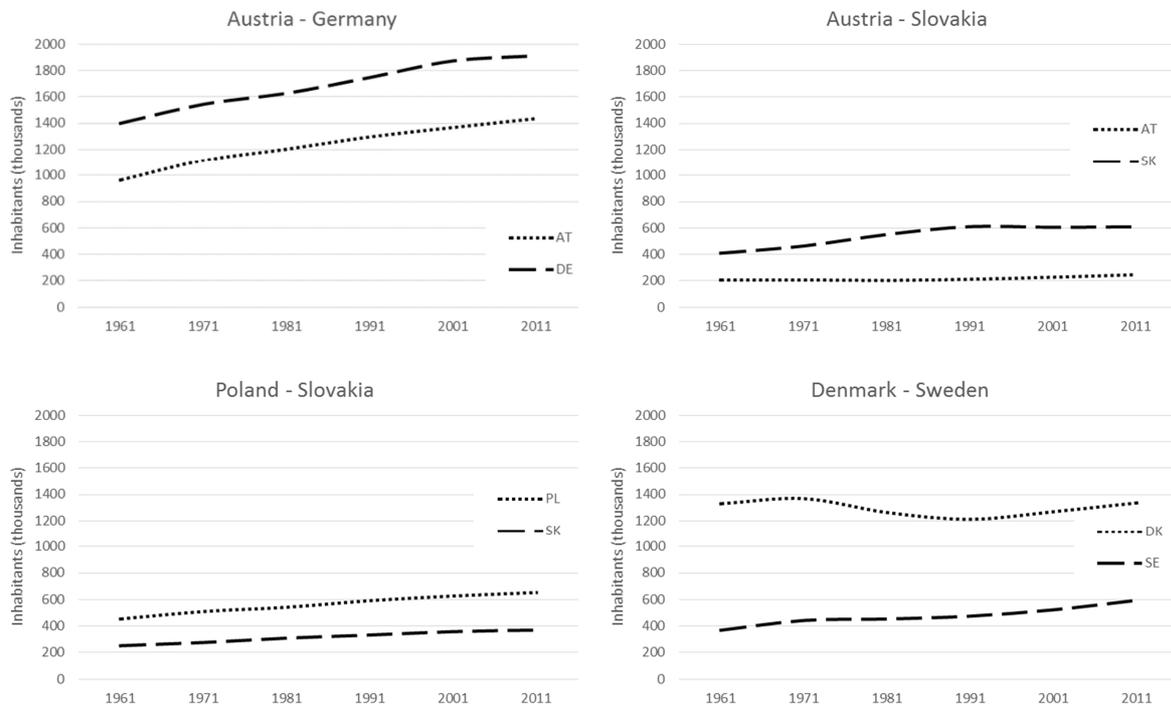


Figure 18: Population dynamics at country level and in the "30 minutes" drive-time border areas in Austria-Germany (top left), Austria-Slovakia (top right), Poland-Slovakia (bottom left) and Denmark-Sweden (bottom right) within 1961-2011, in thousand inhabitants

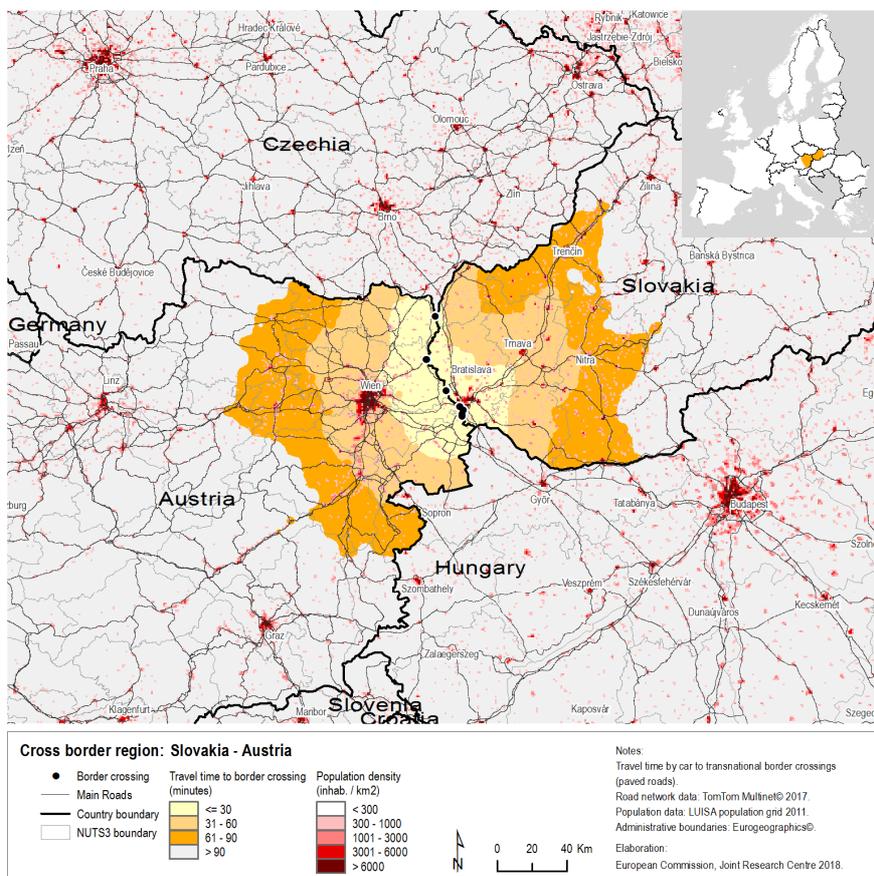
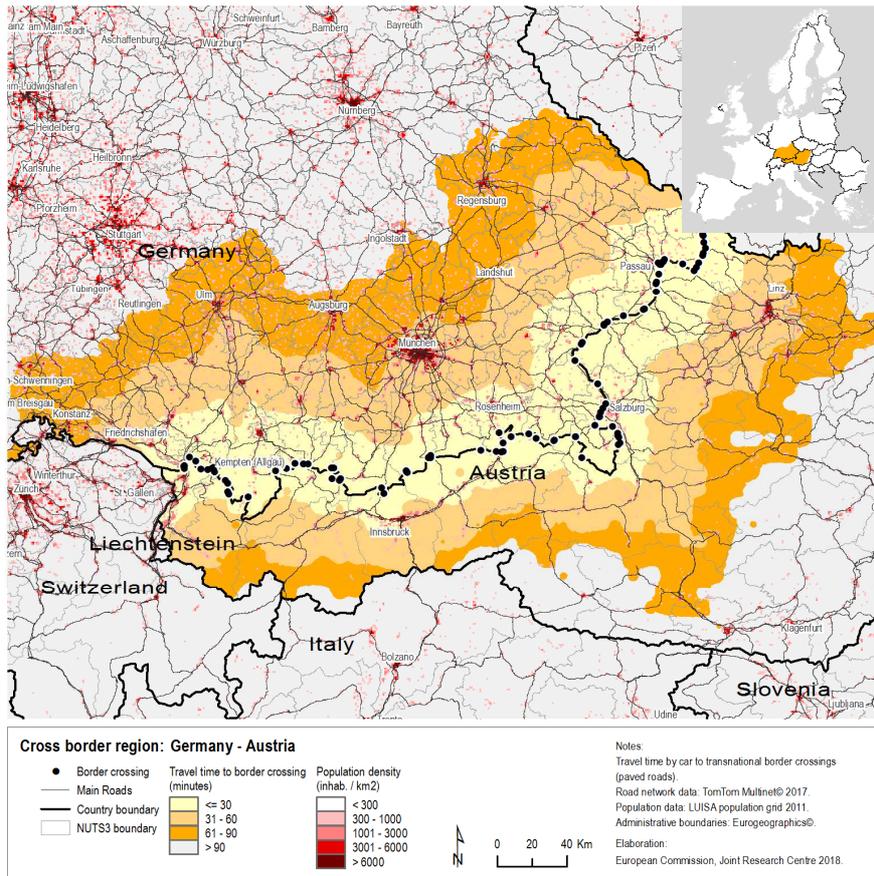


Figure 19: Area zones of 30-60-90-90+ minutes-drive from the border in Germany-Austria (top) and Slovakia-Austria (bottom) by 2017

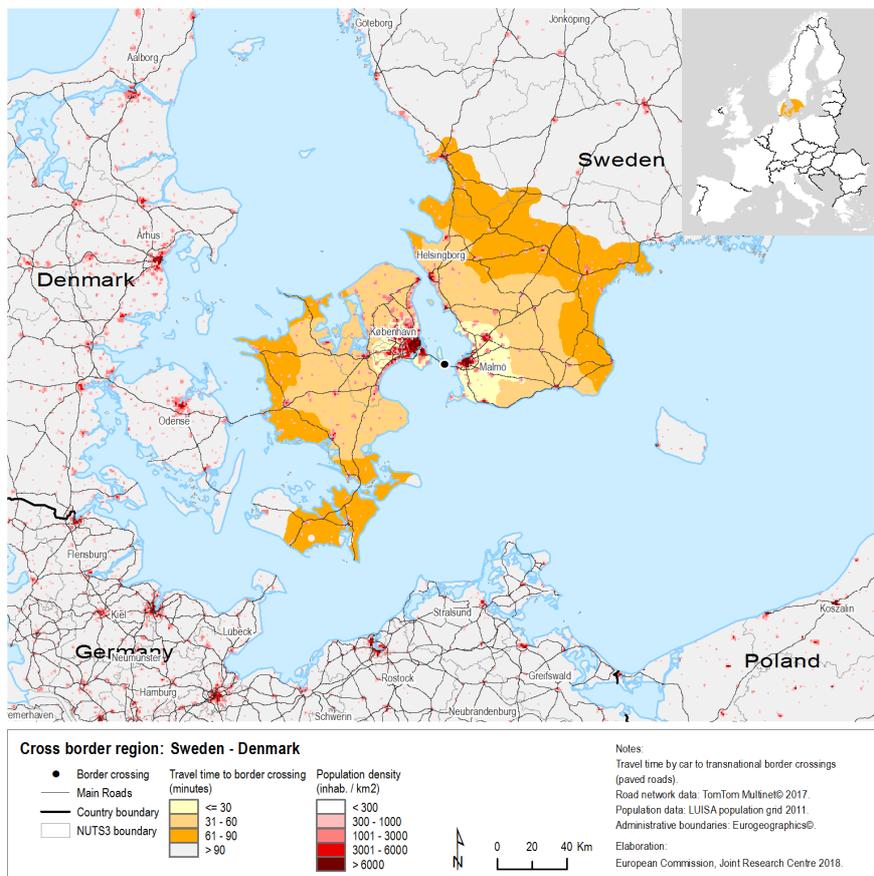
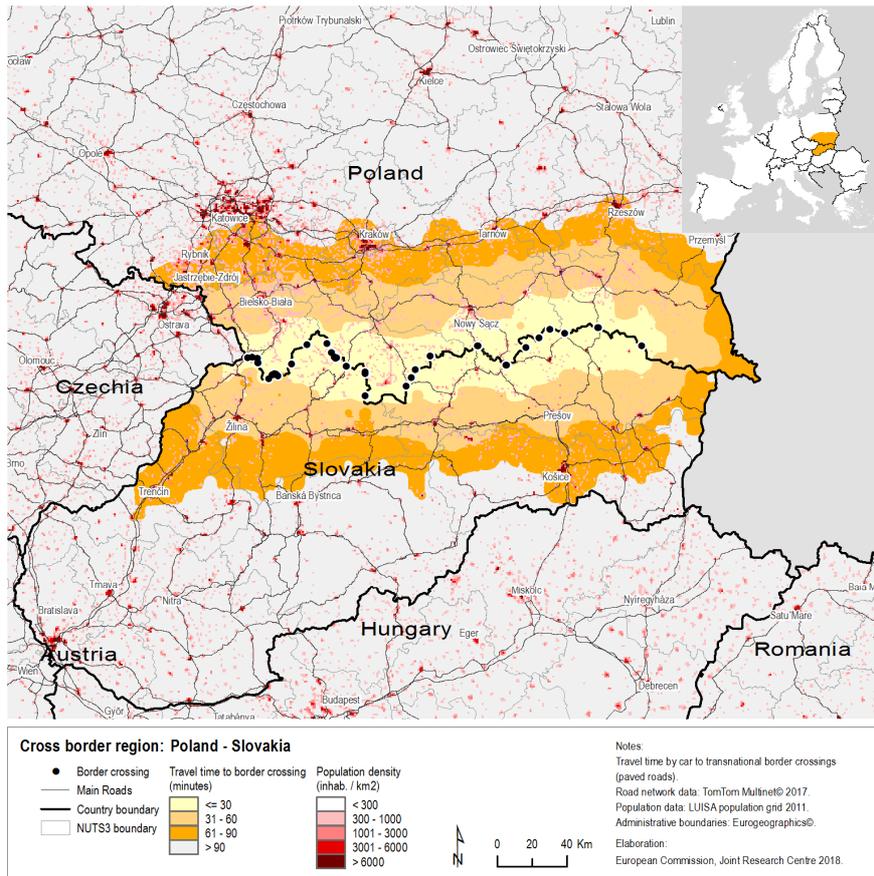


Figure 20: Area zones of 30-60-90-90+ minutes-drive from the border in Poland-Slovakia (top) and Sweden-Denmark (bottom) by 2017

6.3 Cluster 2: Slower growing borders – absolute population evolution 1961-2011 and drive-time (30-60-90 minutes) maps

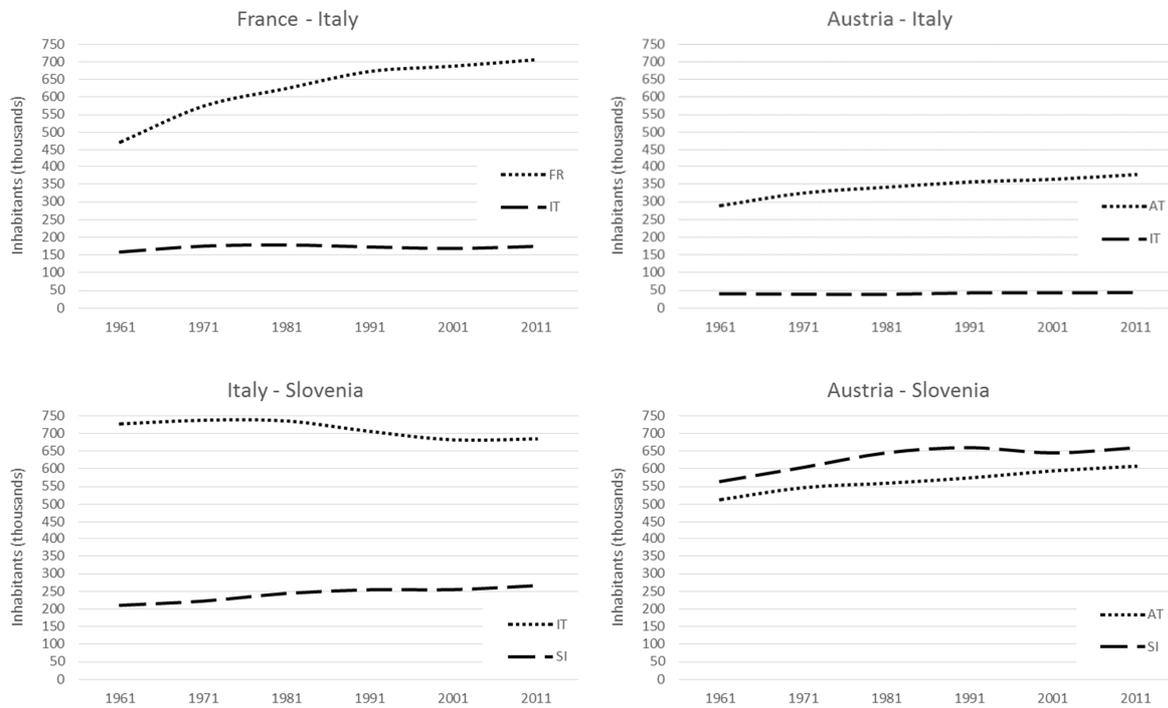


Figure 21: Population dynamics at country level and in the "30 minutes" drive-time border areas in France-Italy (top left), Austria-Italy (top right), Italy-Slovenia (bottom left) and Austria-Slovenia (bottom right) within 1961-2011, in thousand inhabitants (range 0-750)

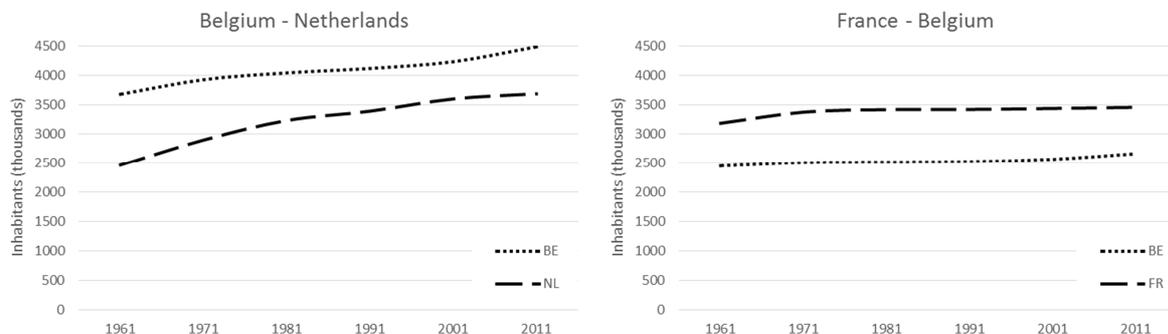


Figure 22: Population dynamics at country level and in the "30 minutes" drive-time border areas in Belgium-Netherlands (left) and France-Belgium (right) within 1961-2011, in thousand inhabitants (range 0-4500)

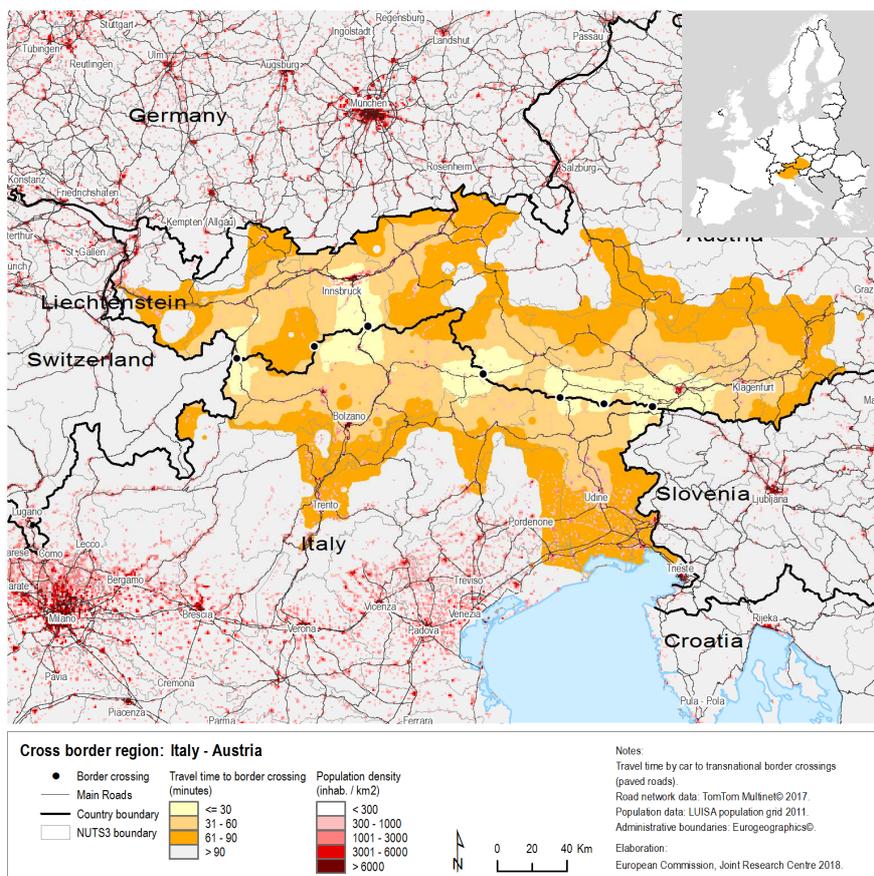
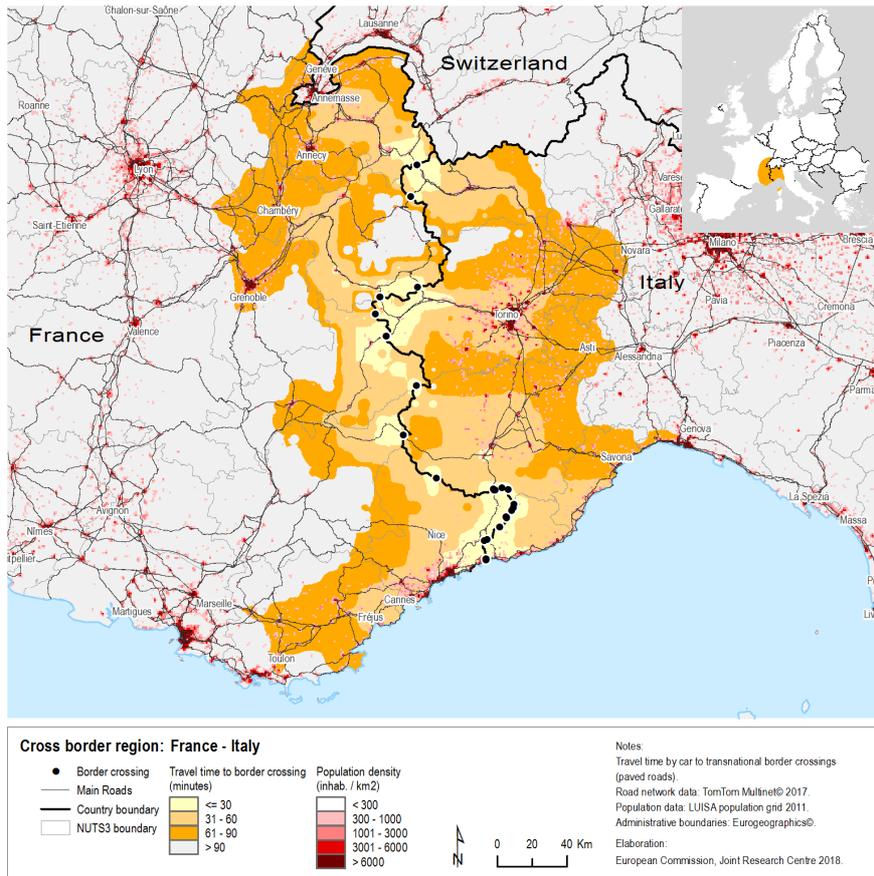


Figure 23: Area zones of 30-60-90-90+ minutes-drive from the border in France-Italy (top) and Italy-Austria (bottom) by 2017

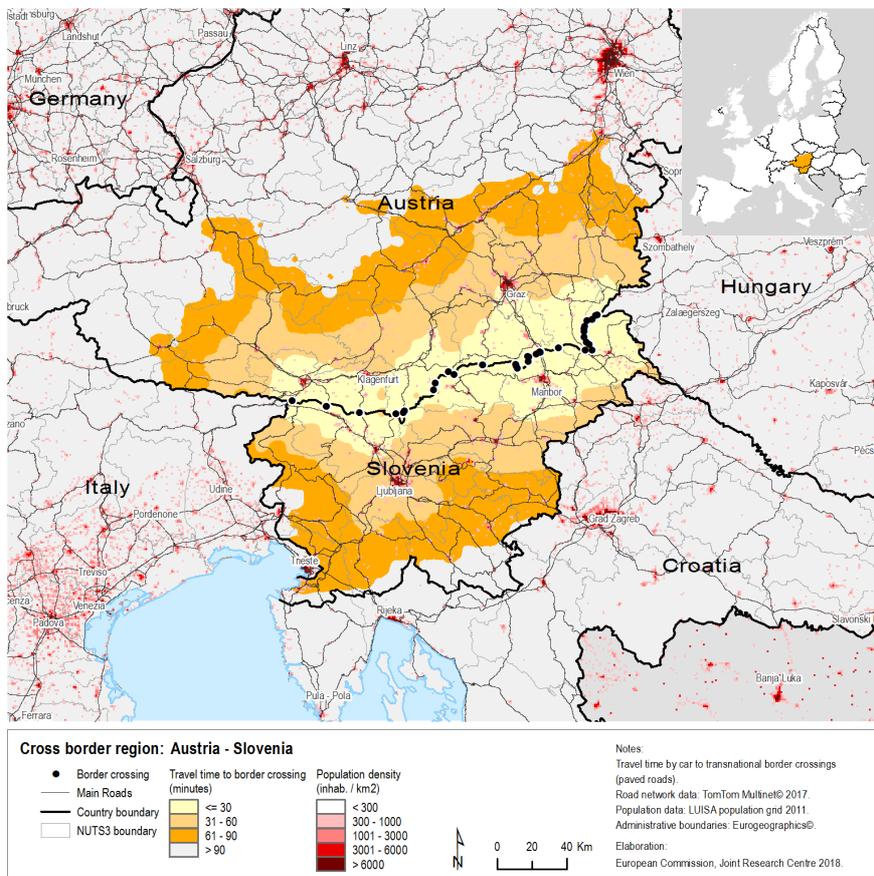
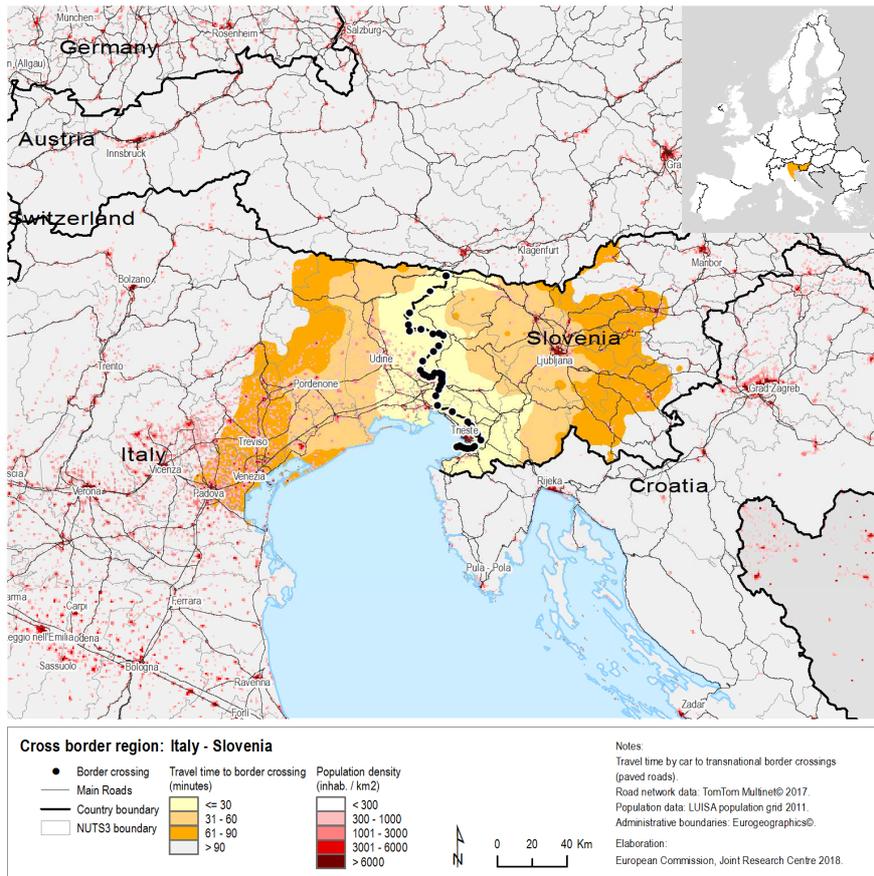


Figure 24: Area zones of 30-60-90-90+ minutes-drive from the border in Italy-Slovenia (top) and Austria-Slovenia (bottom) by 2017

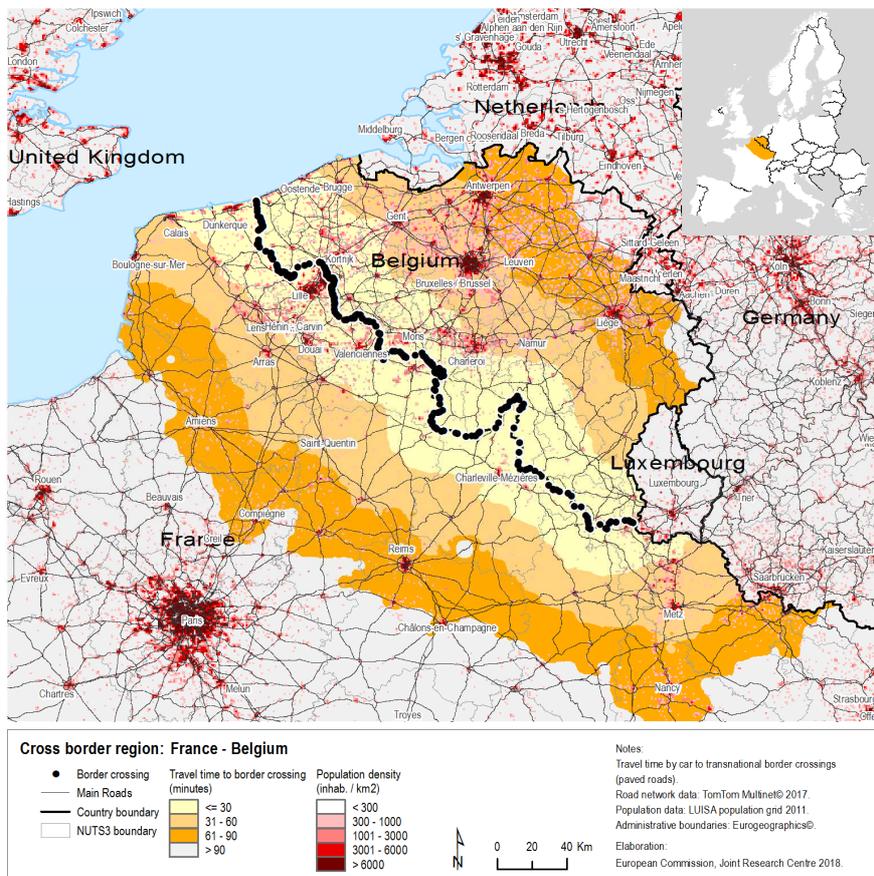
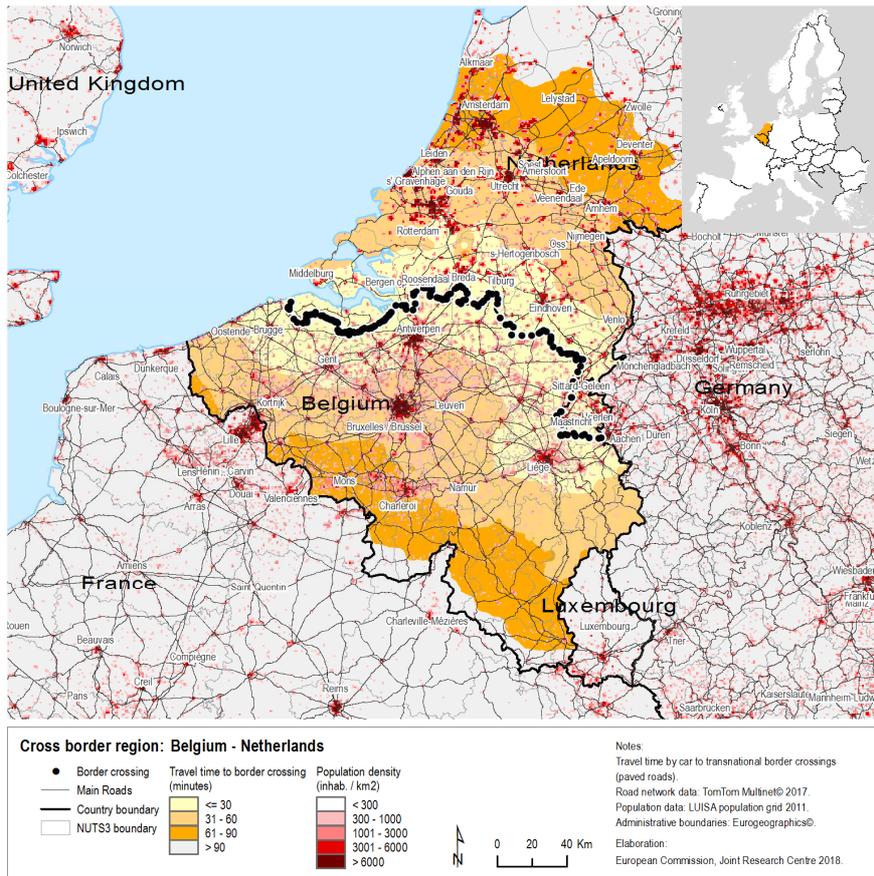


Figure 25: Area zones of 30-60-90-90+ minutes-drive from the border in Belgium-Netherlands (top) and France-Belgium (bottom) by 2017

6.4 Cluster 3: Diverging borders – absolute population evolution 1961-2011 and drive-time (30-60-90 minutes) maps

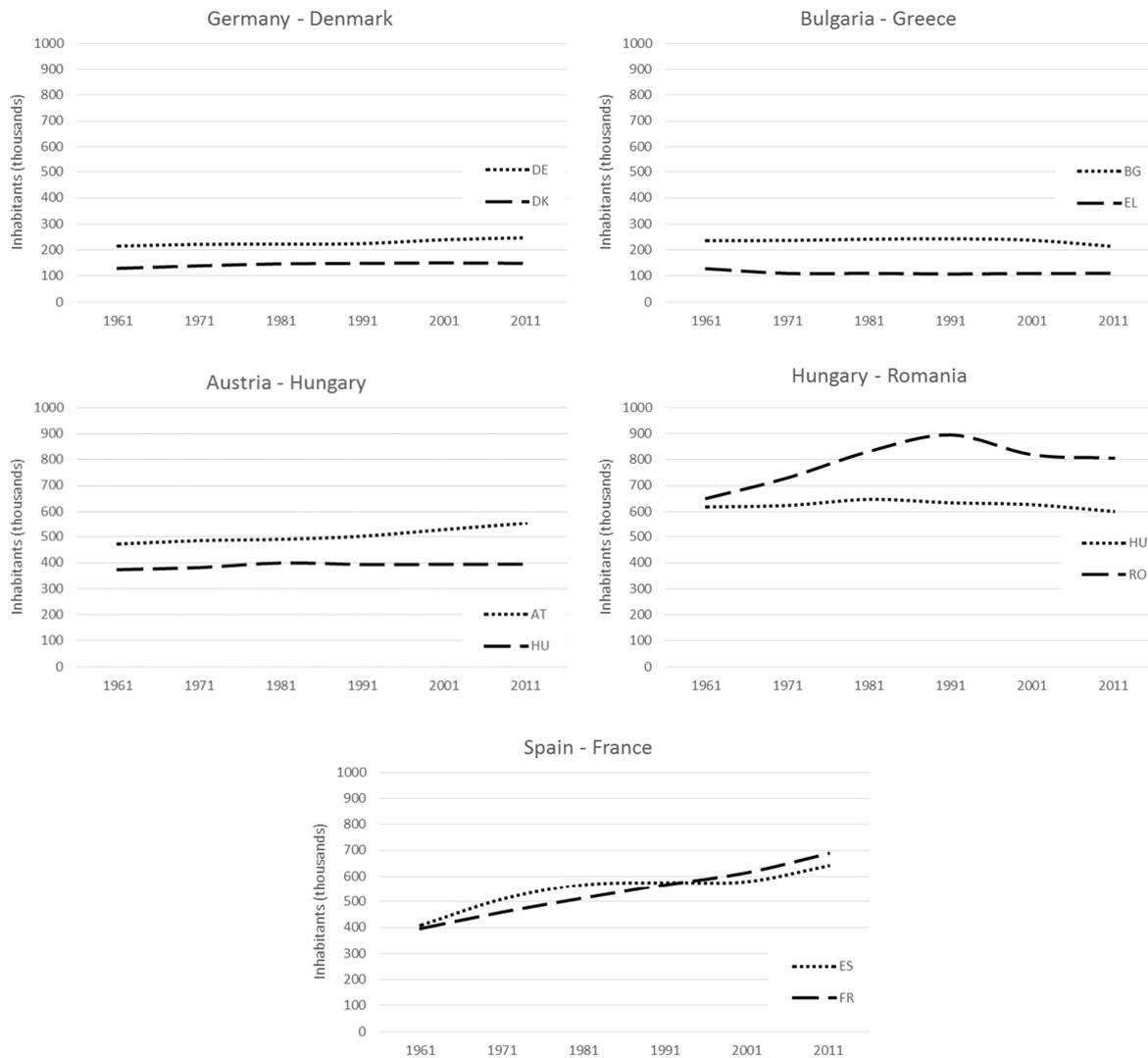


Figure 26: Population dynamics at country level and in the "30 minutes" drive-time border areas in Germany-Denmark (top left), Bulgaria-Greece (top right), Austria-Hungary (middle left), Hungary-Romania (middle right) and Spain-France (bottom middle) within 1961-2011, in thousand inhabitants (range 0-1000)

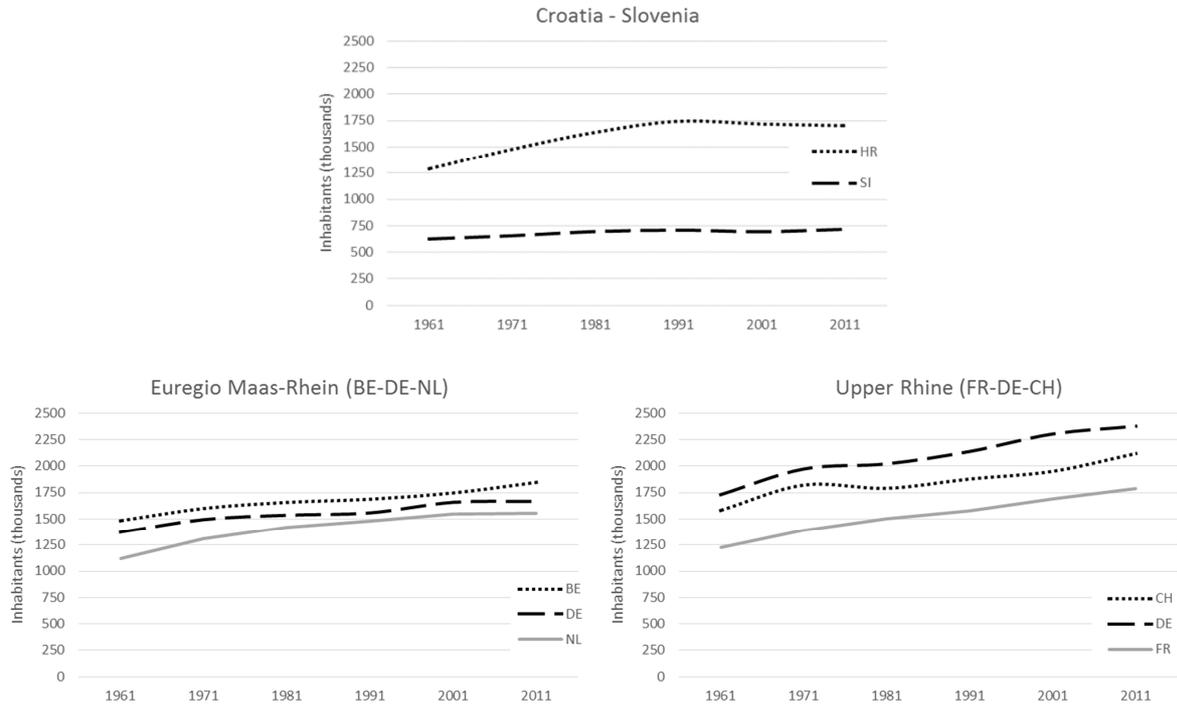


Figure 27: Population dynamics at country level and in the "30 minutes" drive-time border areas in Croatia-Slovenia (top middle), Euregio Maas-Rhein i.e. Belgium, Germany and Netherlands (bottom right) and Upper Rhine i.e. France, Germany and Switzerland (bottom left) within 1961-2011, in thousand inhabitants (range 0-2500)

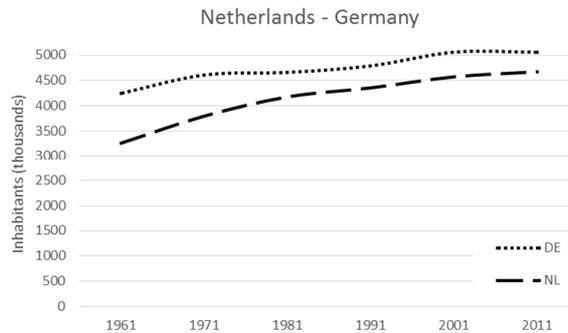


Figure 28: Population dynamics at country level and in the "30 minutes" drive-time border areas in Netherlands-Germany within 1961-2011, in thousand inhabitants (range 0-5000)

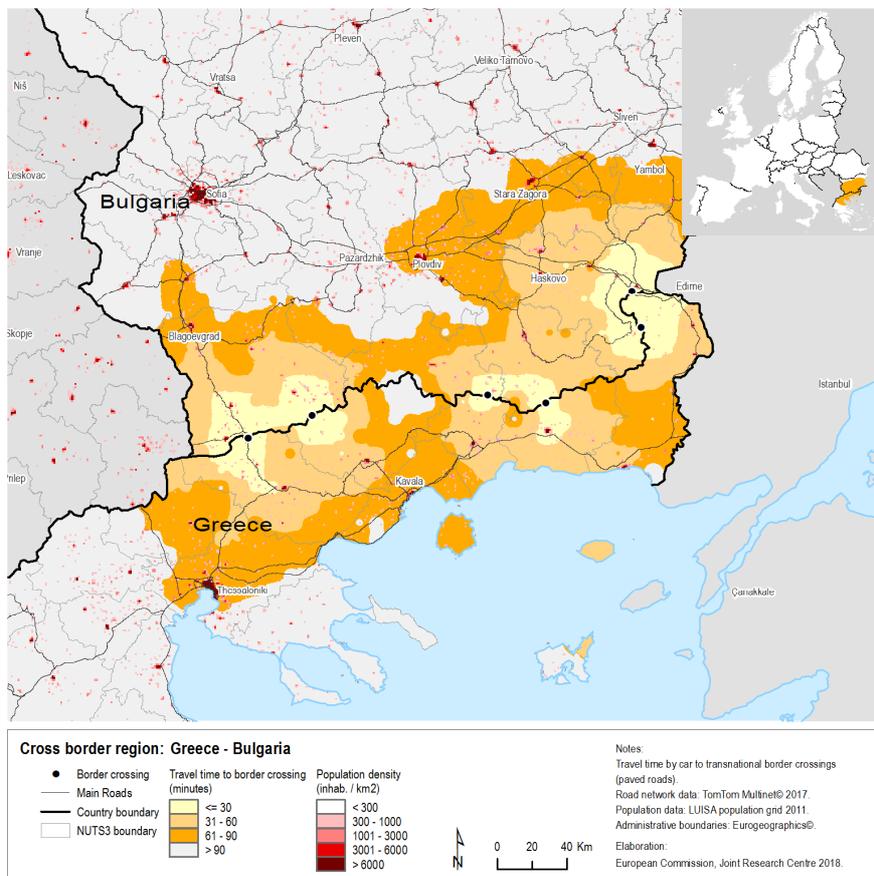
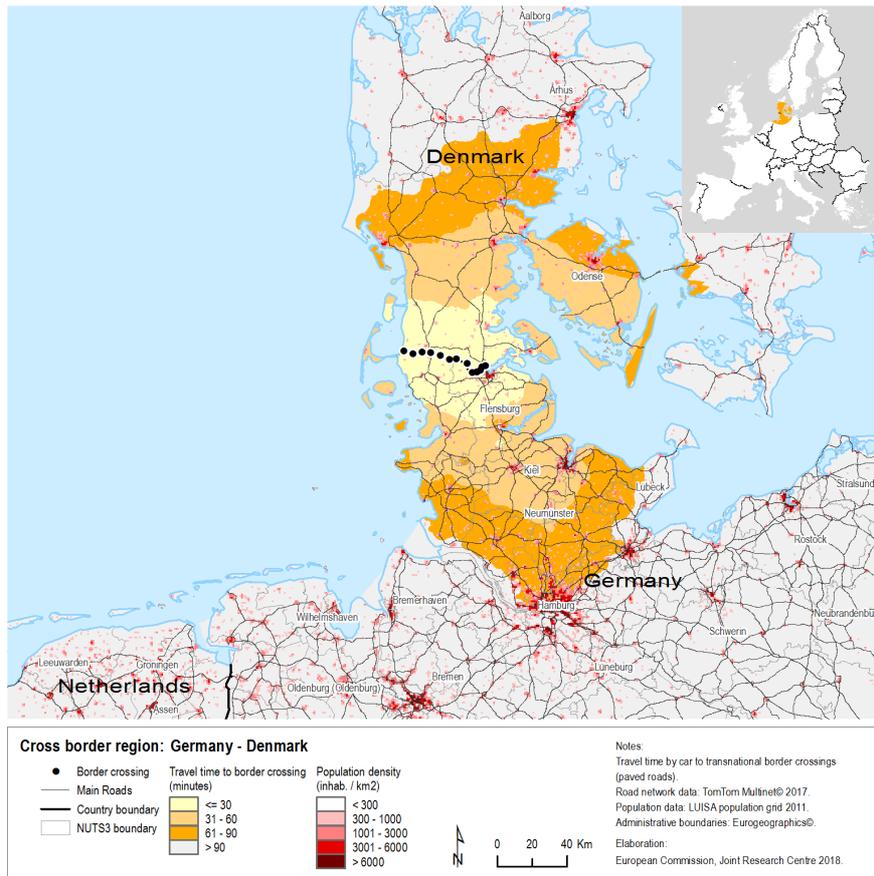


Figure 29: Area zones of 30-60-90-90+ minutes-drive from the border in Germany-Denmark (top) and Greece-Bulgaria (bottom) by 2017

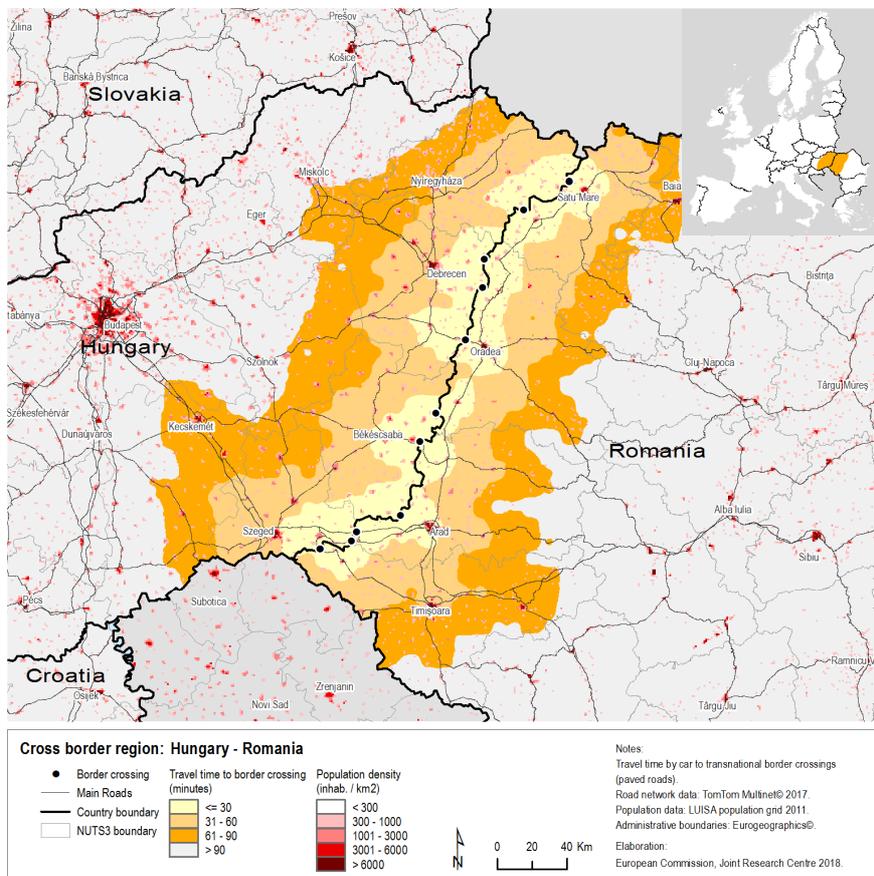
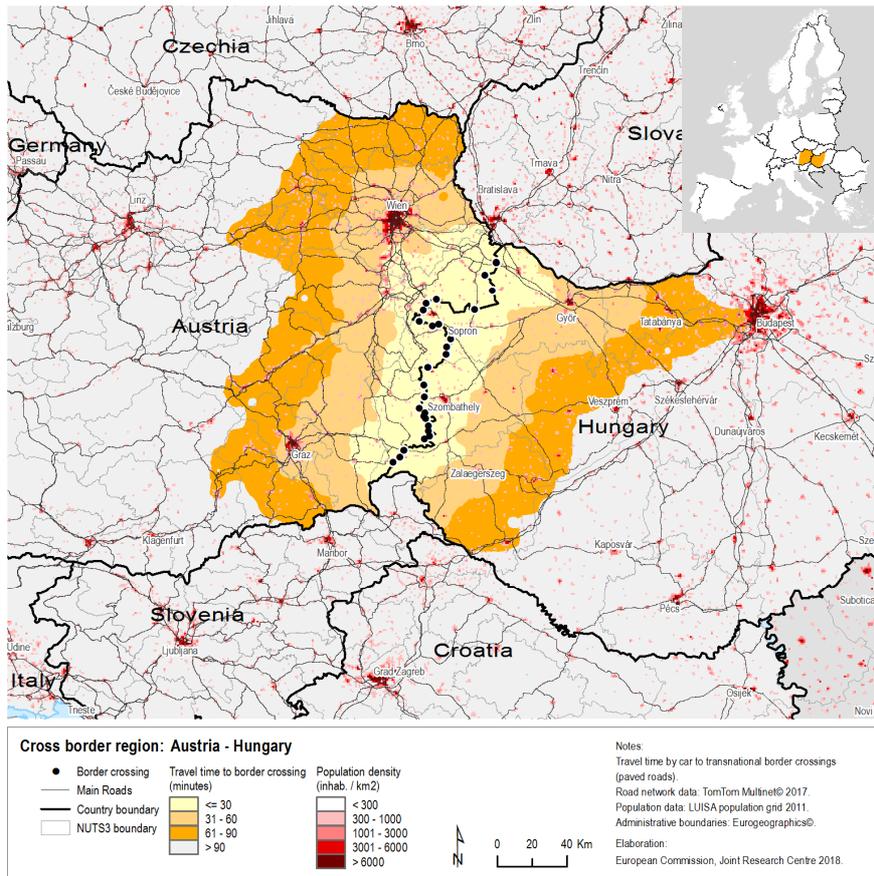


Figure 30: Area zones of 30-60-90-90+ minutes-drive from the border in Austria-Hungary (top) and Hungary-Romania (bottom) by 2017

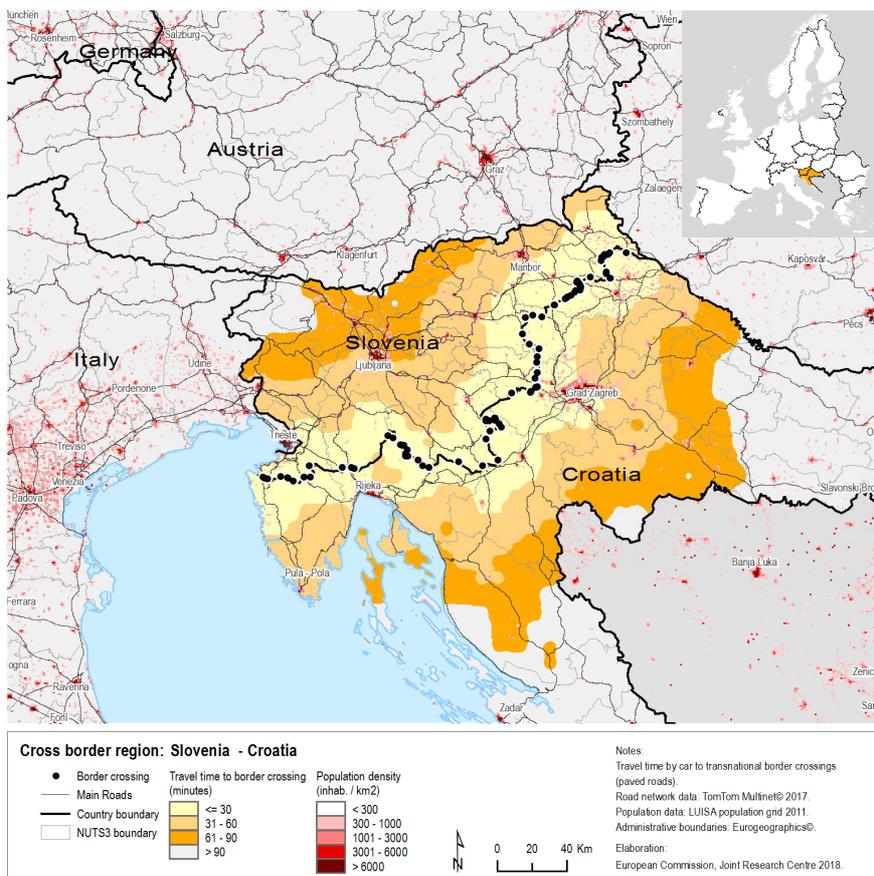
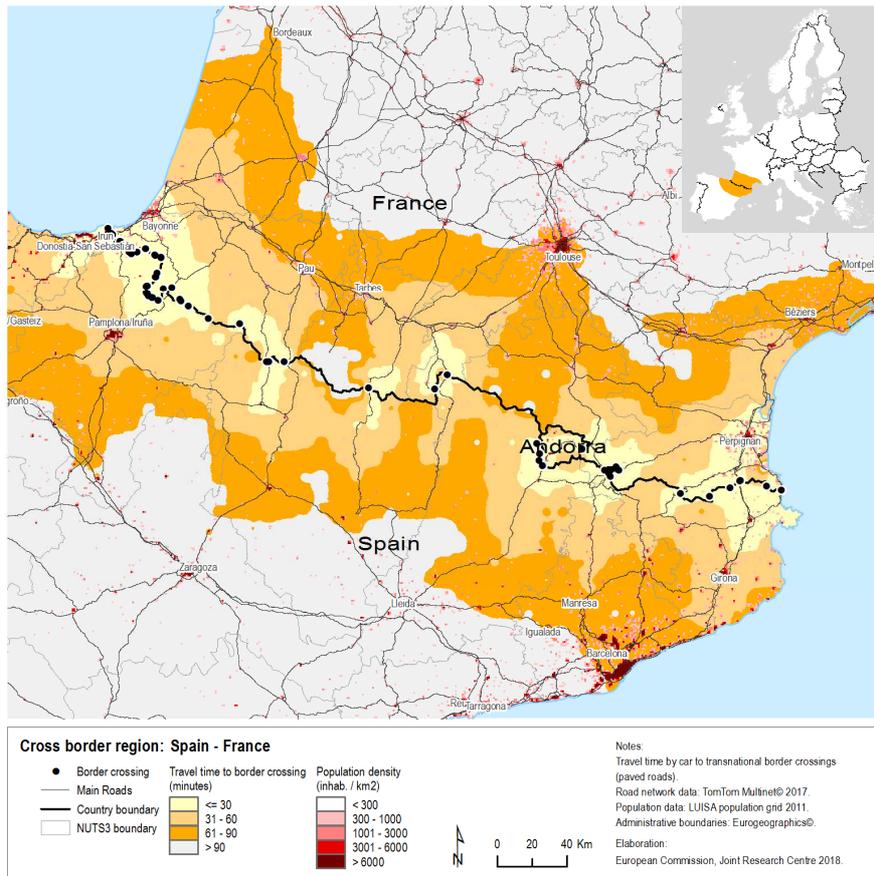


Figure 31: Area zones of 30-60-90-90+ minutes-drive from the border in Spain-France (top) and Slovenia-Croatia (bottom) by 2017

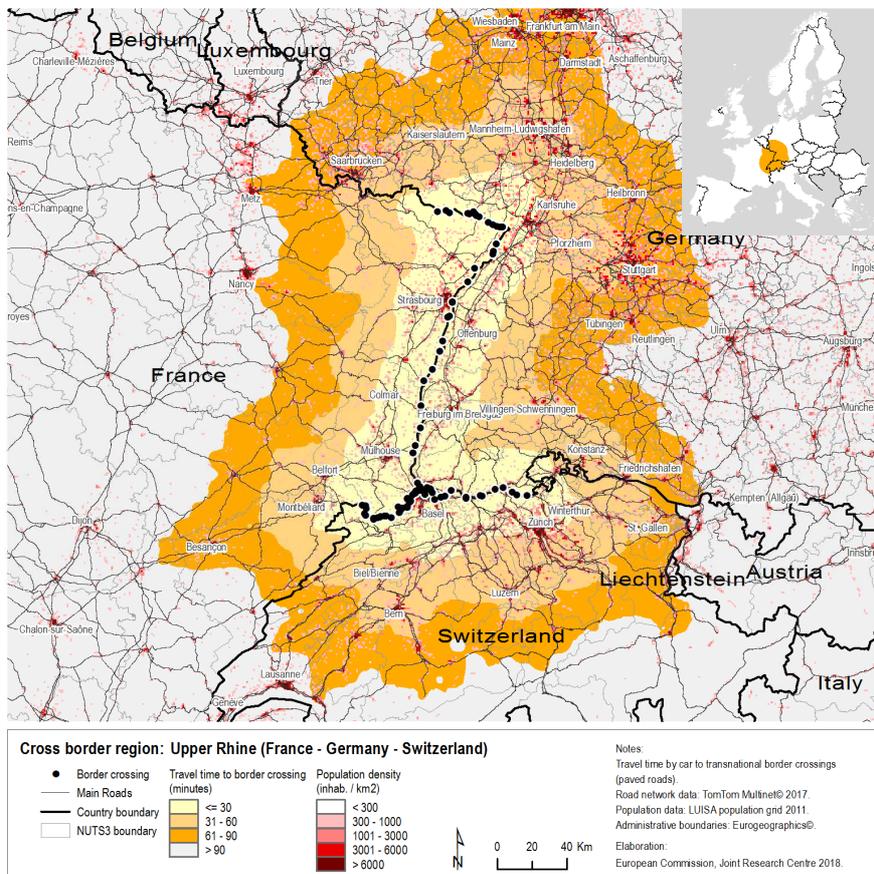
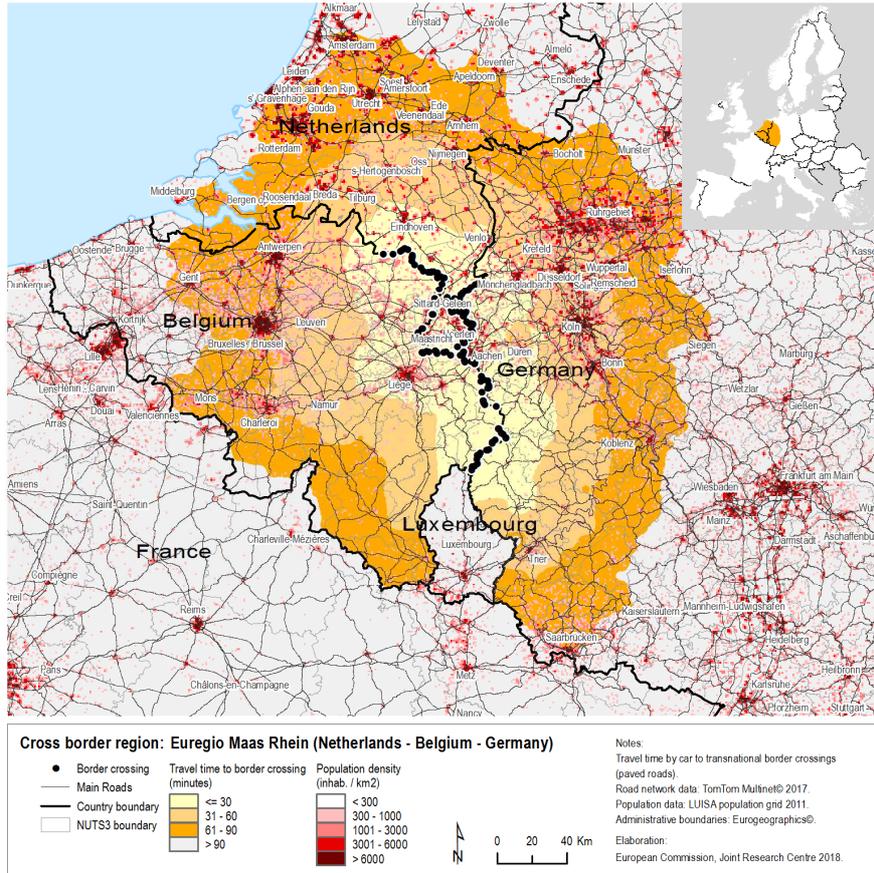


Figure 32: Area zones of 30-60-90-90+ minutes-drive from the border in Euregio Maas-Rhein, NL-BE-DE (top) and Upper Rhine, FR-DE-CH (bottom) by 2017

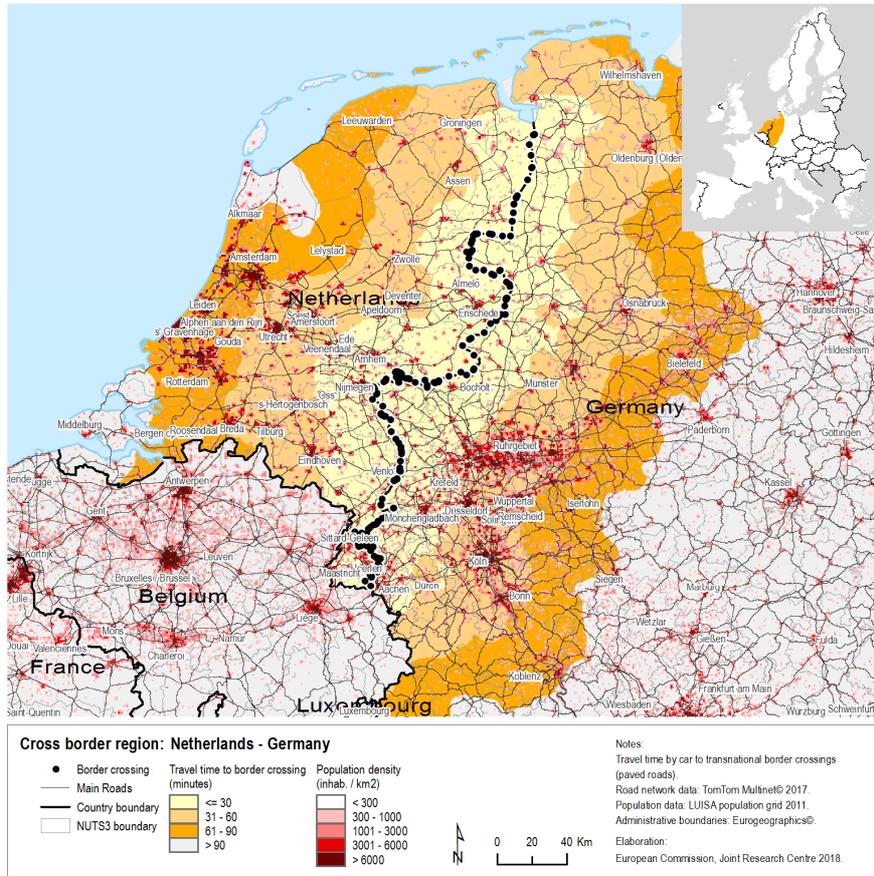


Figure 33: Area zones of 30-60-90-90+ minutes-drive from the border in Netherlands-Germany by 2017

6.5 Cluster 4: Underperforming borders – absolute population evolution 1961-2011 and drive-time (30-60-90 minutes) maps

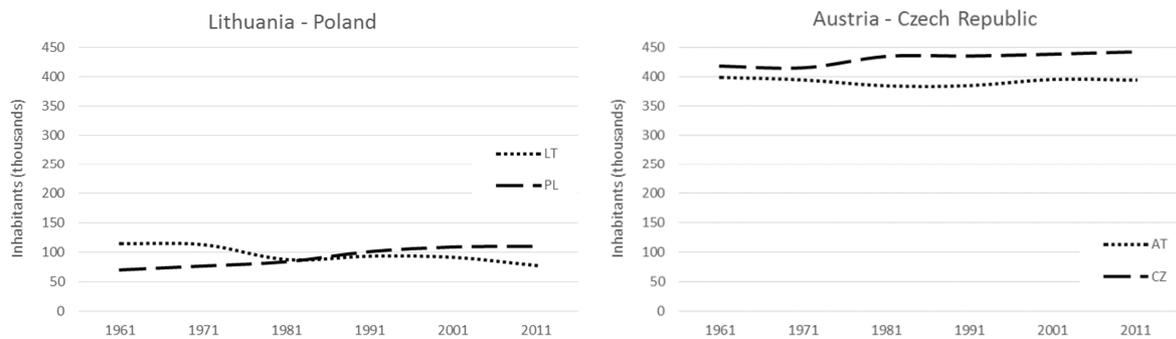


Figure 34: Population dynamics at country level and in the "30 minutes" drive-time border areas in Lithuania-Poland (left) and Austria-Czech republic (right) within 1961-2011, in thousand inhabitants (range 0-450)

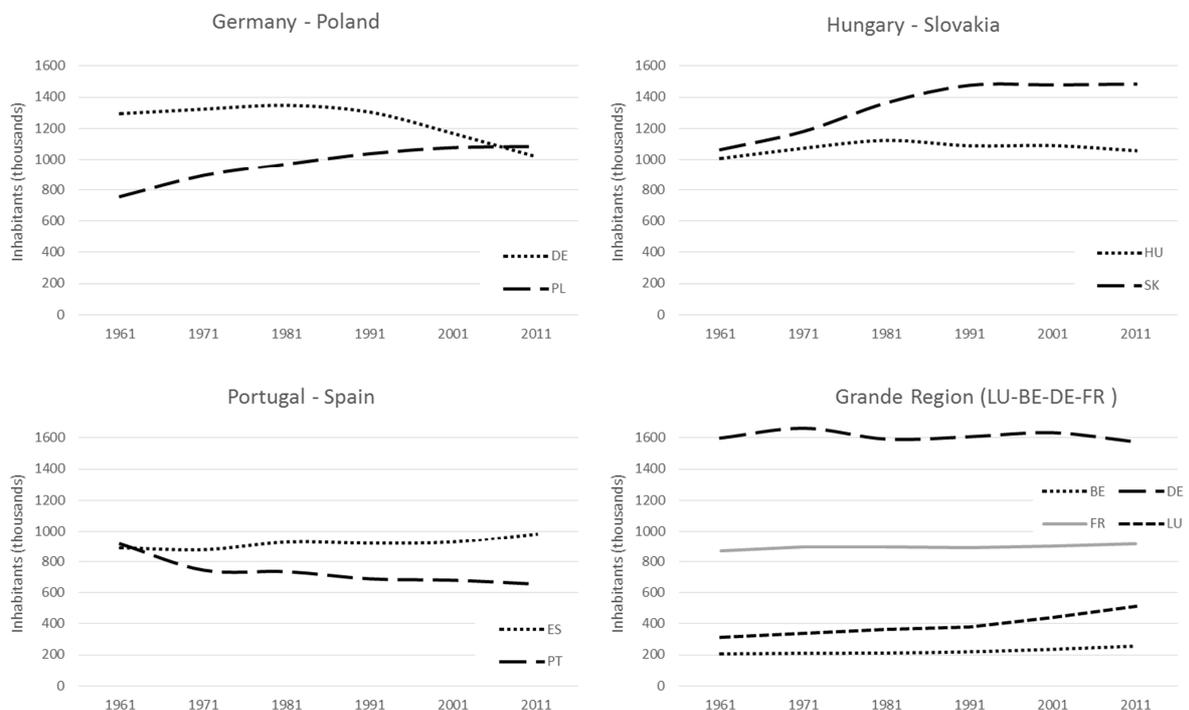


Figure 35: Population dynamics at country level and in the "30 minutes" drive-time border areas in Germany-Poland (top left), Hungary-Slovakia (top right), Portugal-Spain (bottom left) and Luxembourg-Belgium-Germany-France i.e. Grande Region (bottom right) within 1961-2011, in thousand inhabitants (range 0-1700)

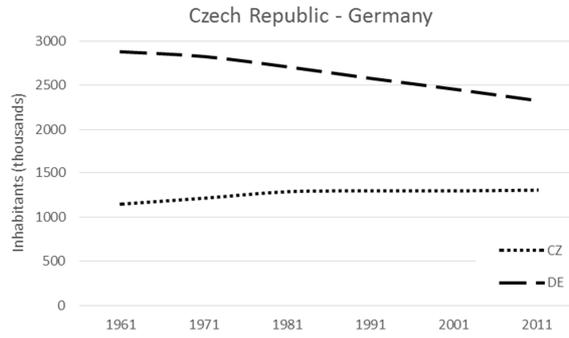


Figure 36: Population dynamics at country level and in the "30 minutes" drive-time border areas in Czech Republic-Germany within 1961-2011, in thousand inhabitants (range 0-3000)

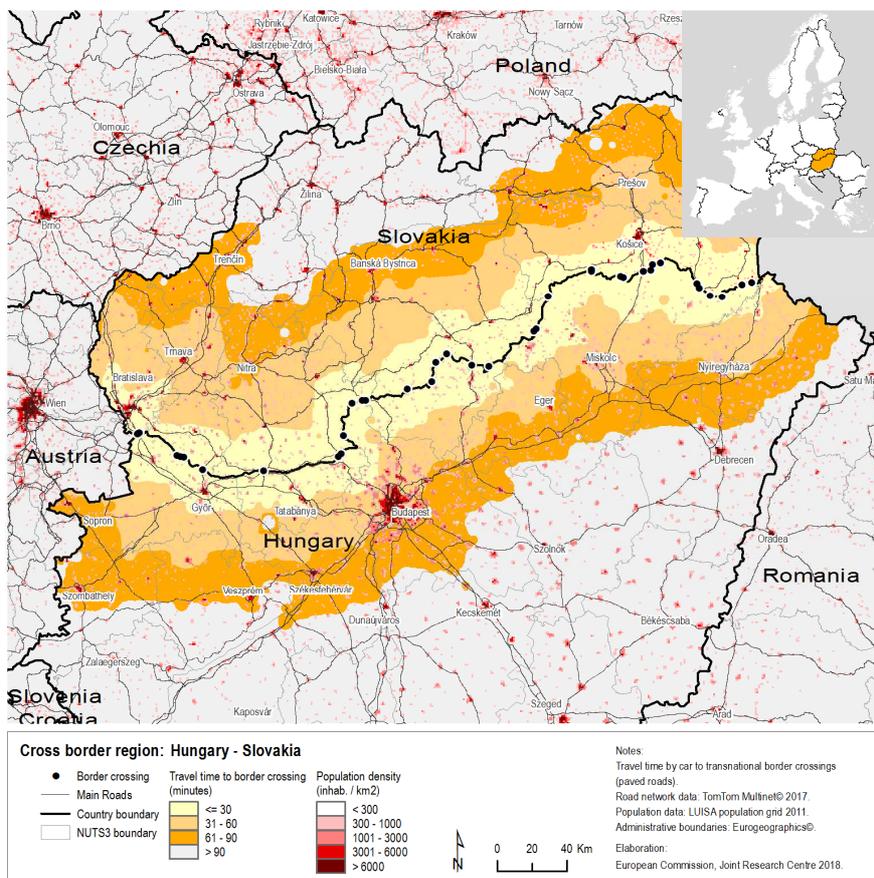
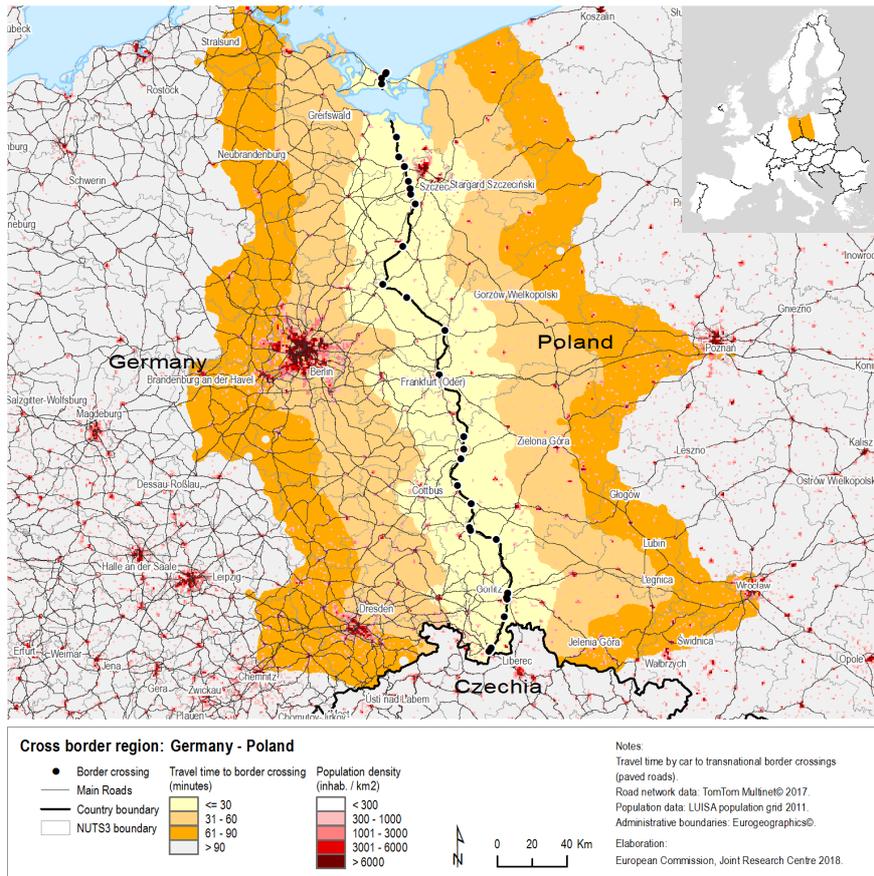


Figure 38: Area zones of 30-60-90-90+ minutes-drive from the border in Germany-Poland (top) and Hungary-Slovakia (bottom) by 2017

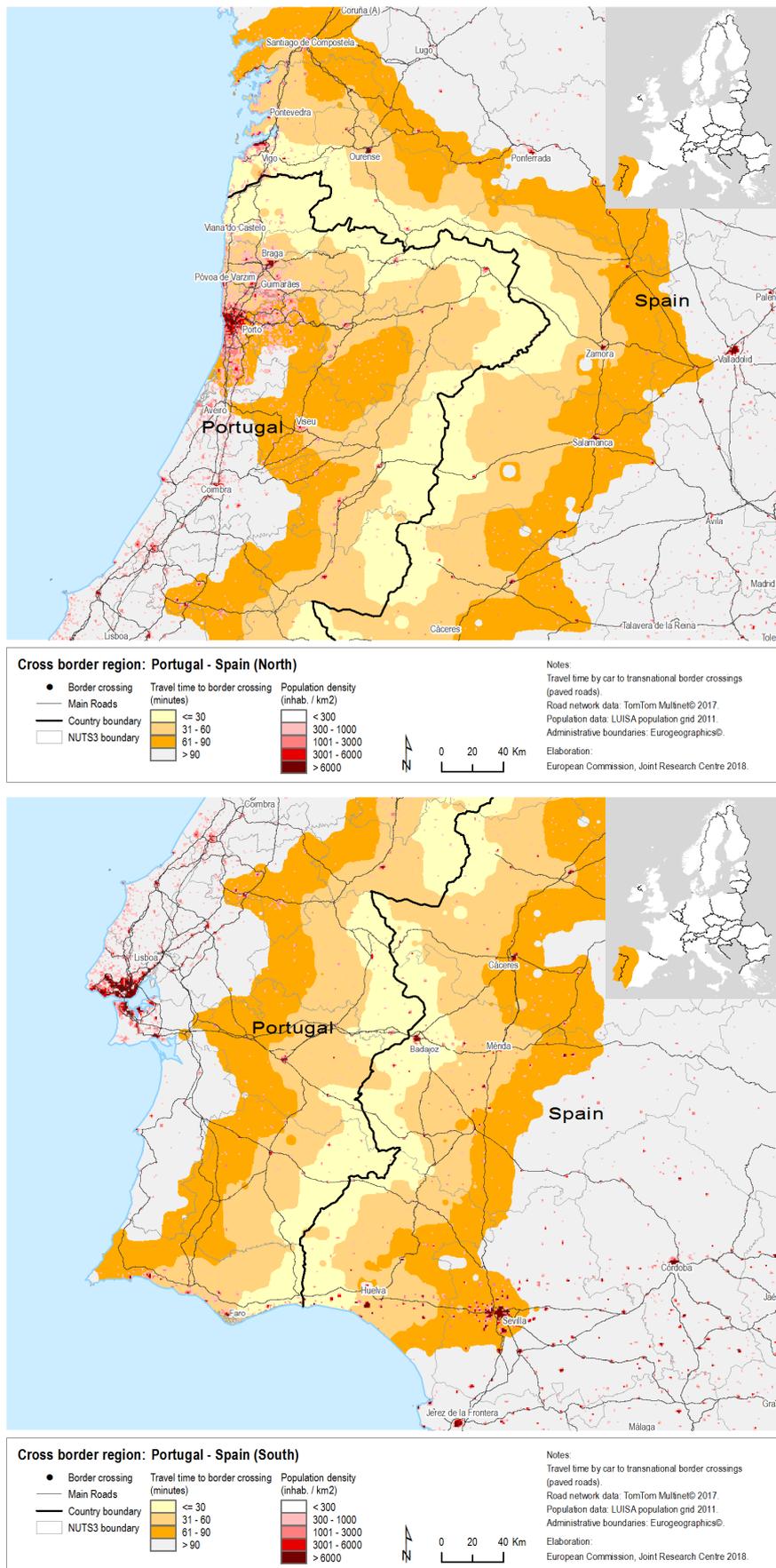


Figure 39: Area zones of 30-60-90-90+ minutes-drive from the border in Portugal-Spain: Northern border zone (top) and Southern border zone (bottom) by 2017

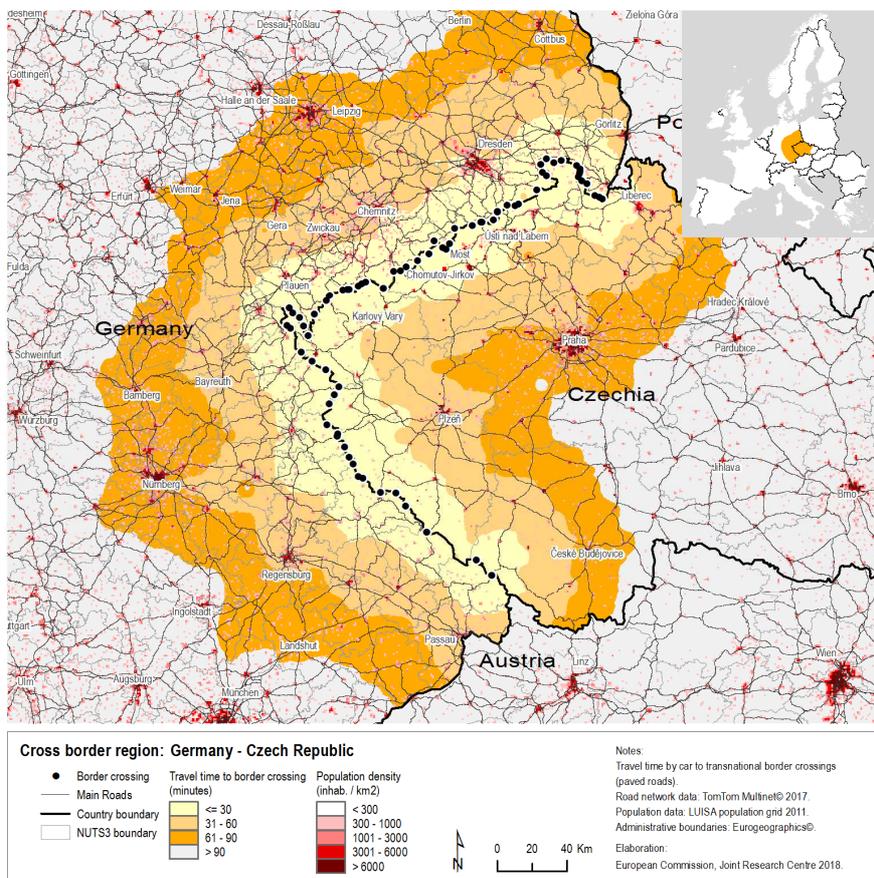
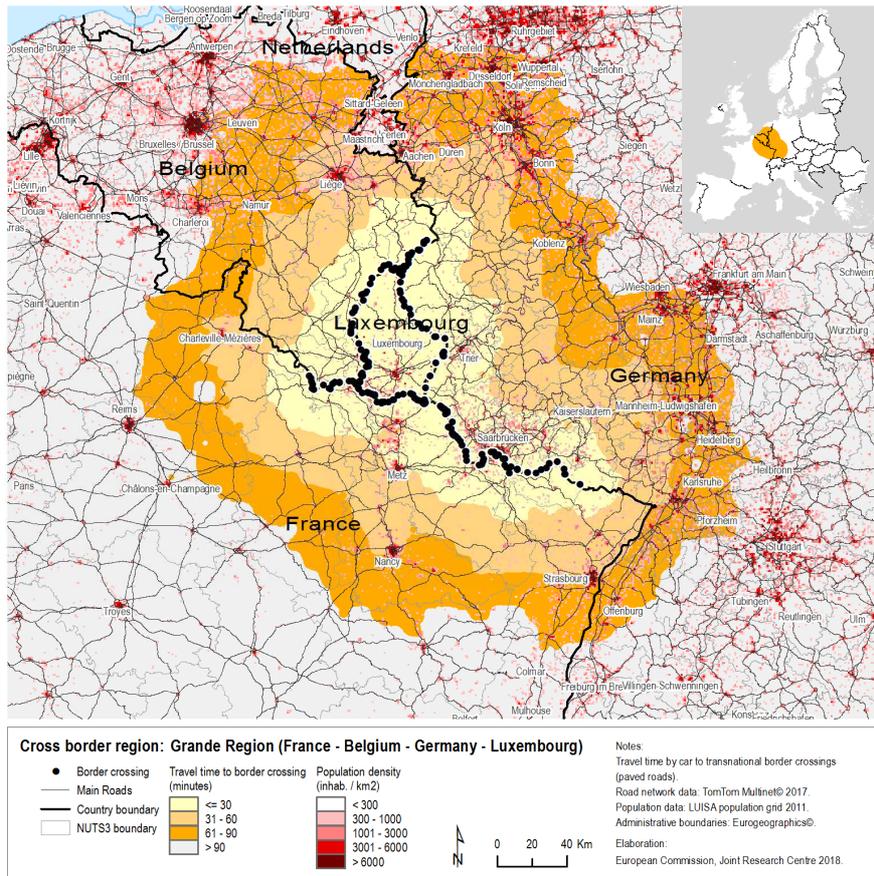


Figure 40: Area zones of 30-60-90-90+ minutes-drive from the border in Grande Region FR-BE-DE-LU (top) and Germany-Czech Republic (bottom) by 2017

6.6 Cluster 5: Faster declining borders – absolute population evolution 1961-2011 and drive-time (30-60-90 minutes) maps

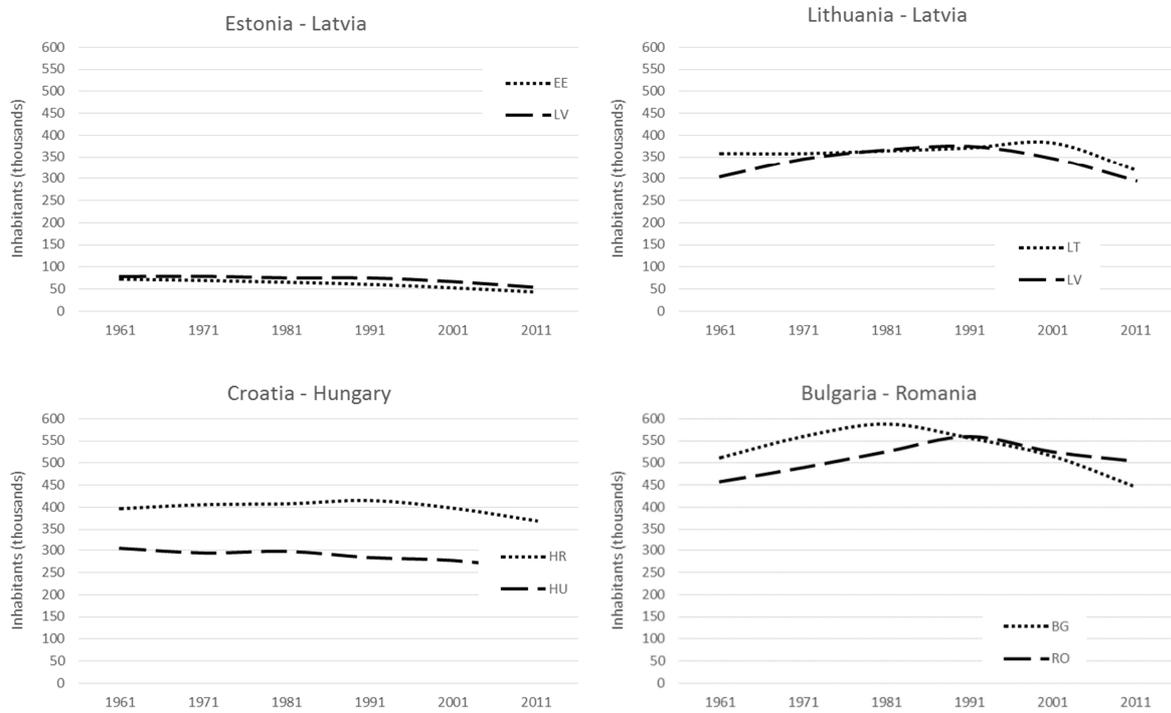


Figure 41: Population dynamics at country level and in the "30 minutes" drive-time border areas in Estonia-Latvia (top left), Lithuania-Latvia (top right), Croatia-Hungary (bottom left) and Bulgaria-Romania (bottom right) within 1961-2011, in thousand inhabitants (range 0-600)

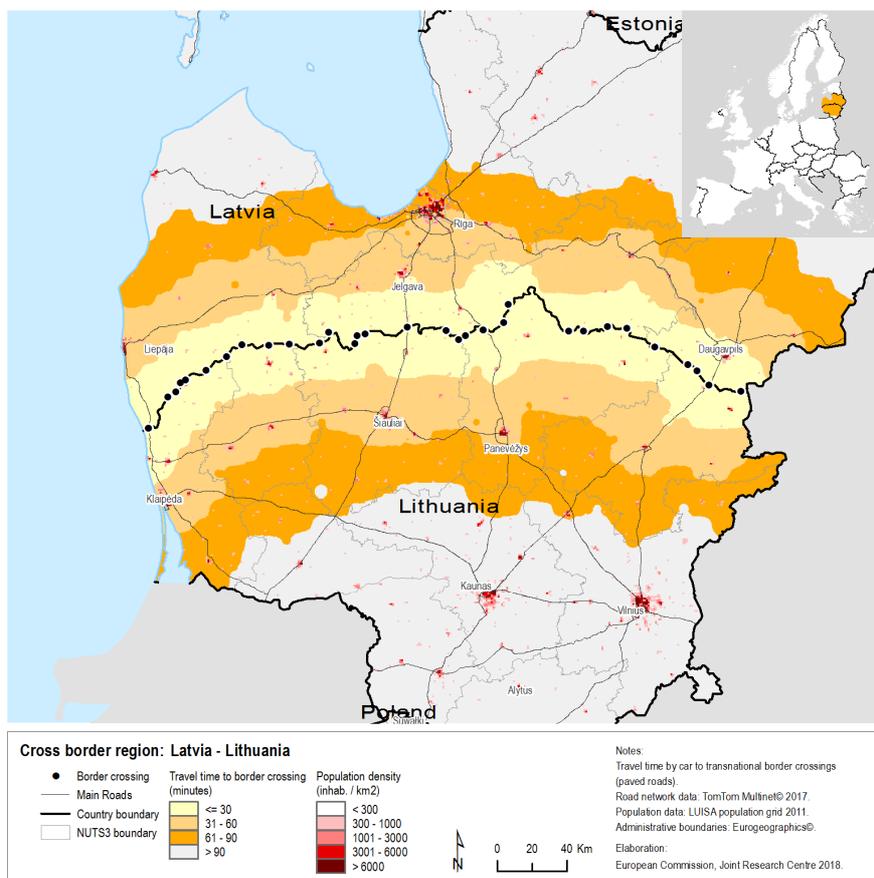
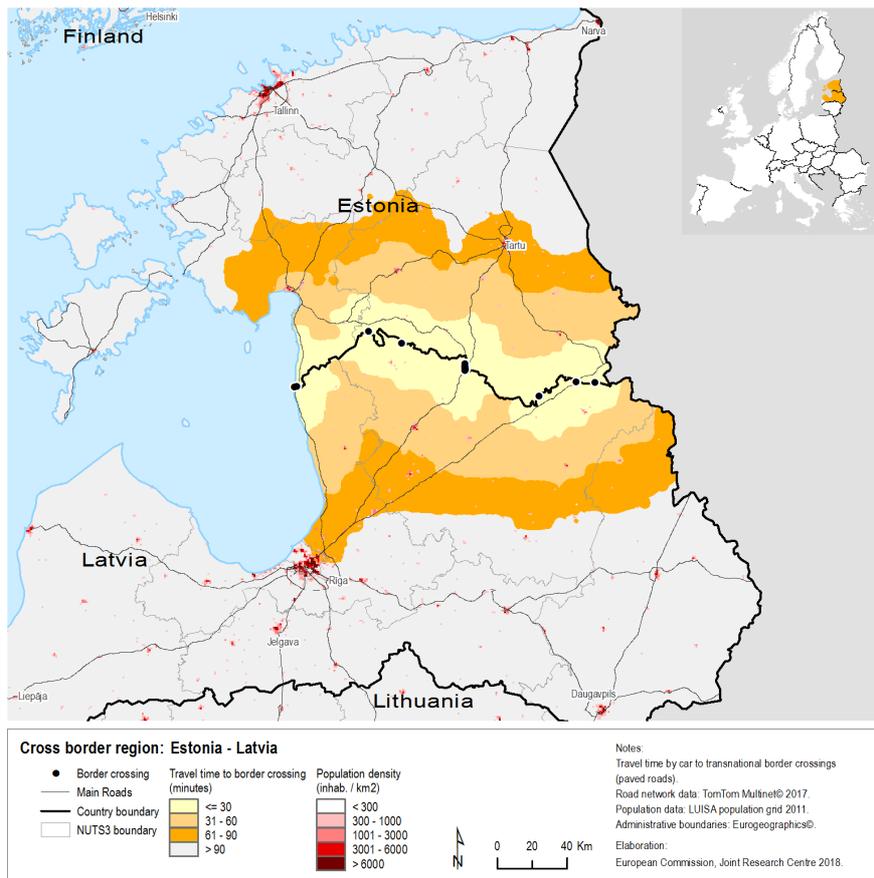


Figure 42: Area zones of 30-60-90-90+ minutes-drive from the border in Estonia-Latvia (top) and Latvia-Lithuania (bottom) by 2017

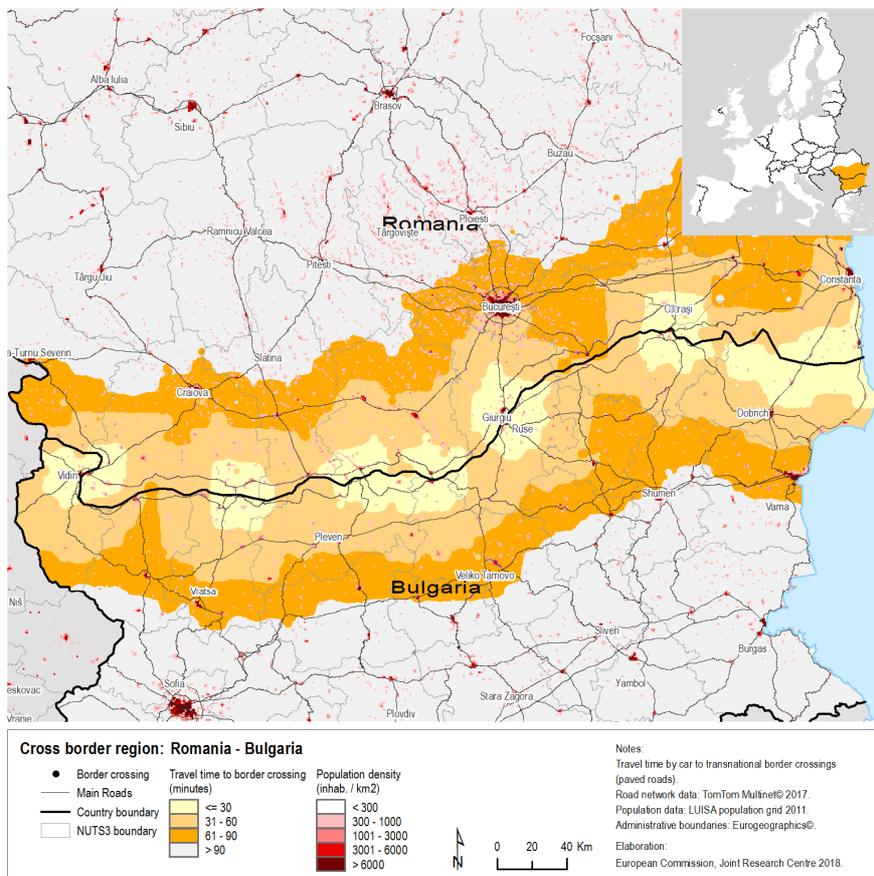
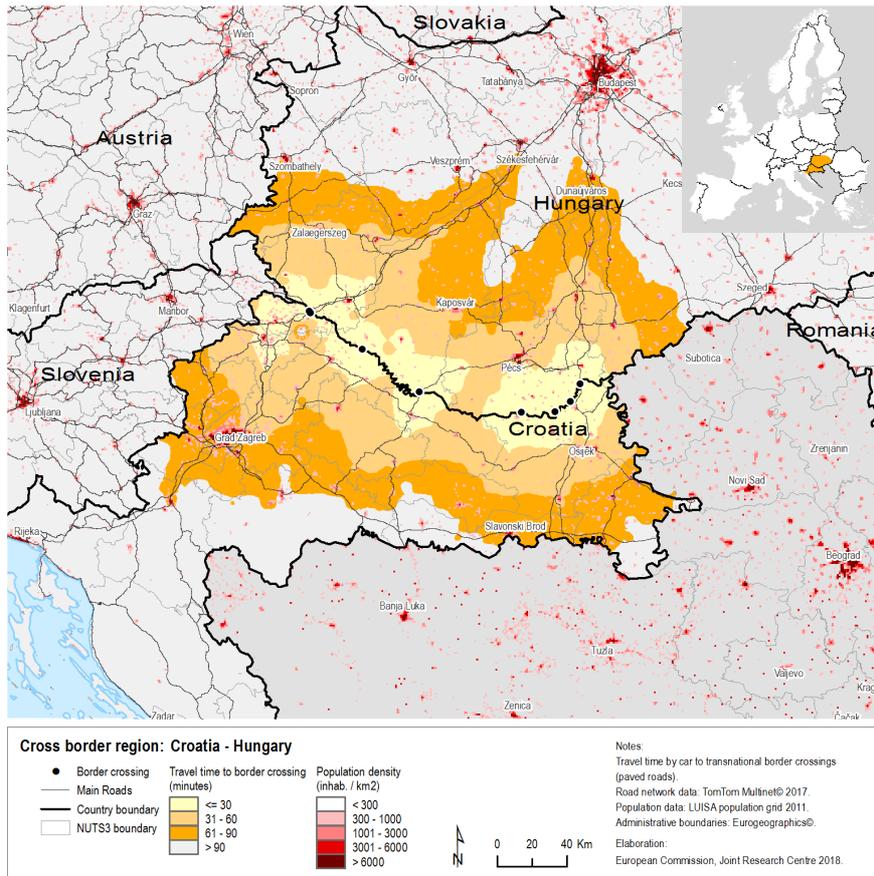


Figure 43: Area zones of 30-60-90-90+ minutes-drive from the border in Croatia-Hungary (top) and Romania-Bulgaria (bottom) by 2017

6.7 Cluster 6: Shrinking borders in growing countries – absolute population evolution 1961-2011 and drive-time (30-60-90 minutes) maps

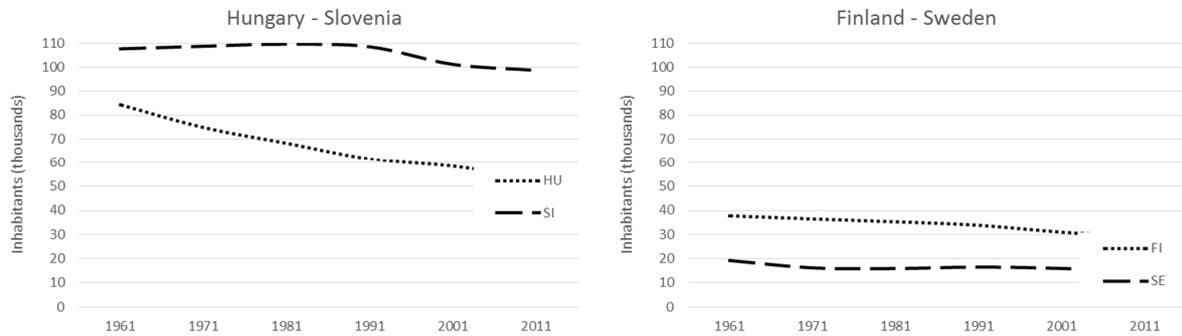


Figure 44: Population dynamics at country level and in the "30 minutes" drive-time border areas in Hungary-Slovenia (left) and Finland-Sweden (right) within 1961-2011, in thousand inhabitants (range 0-110)

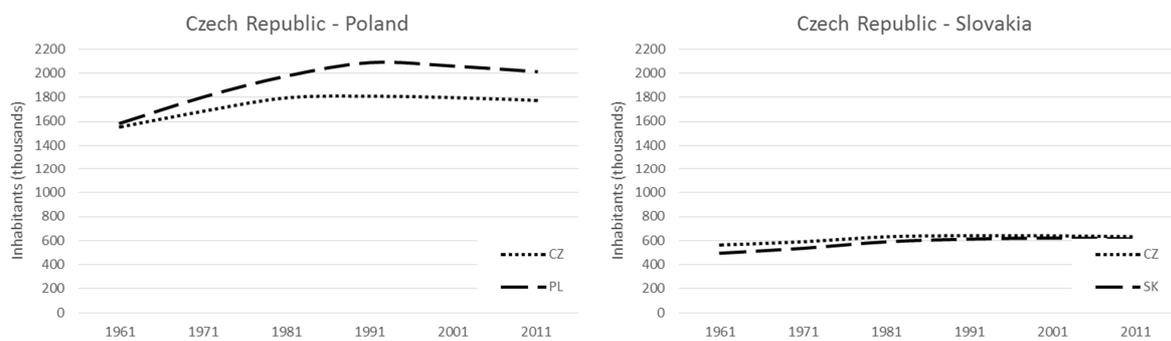


Figure 45: Population dynamics at country level and in the "30 minutes" drive-time border areas in Czech Republic-Poland (left) and Czech Republic-Slovakia (right) within 1961-2011, in thousand inhabitants (range 0-2200)

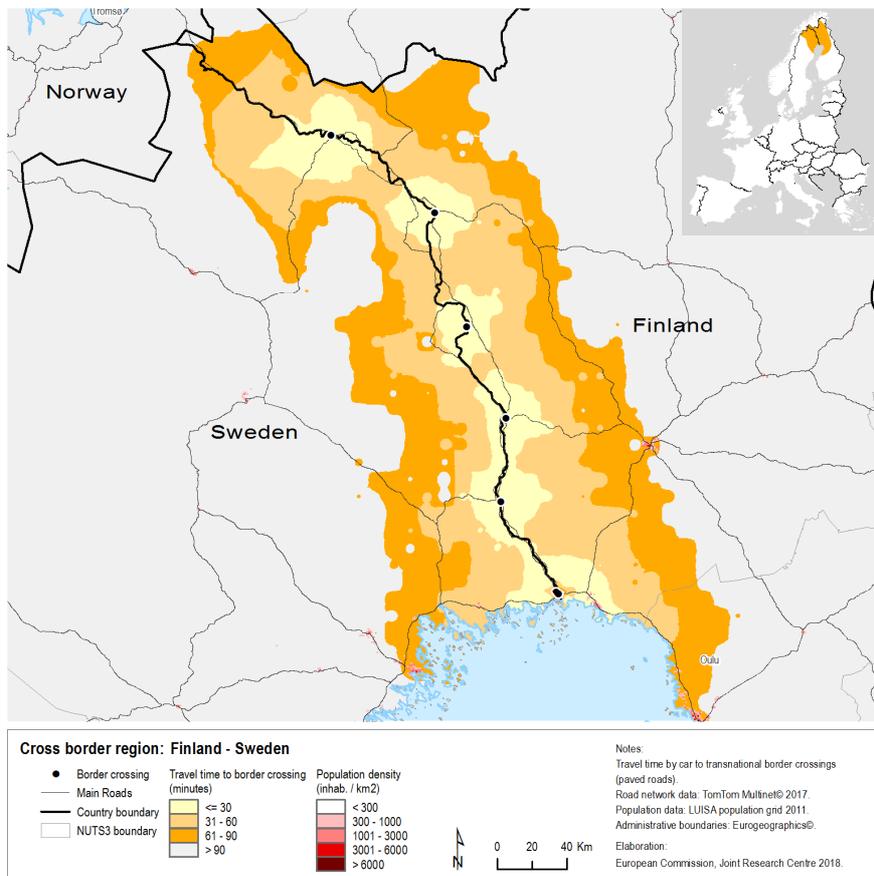
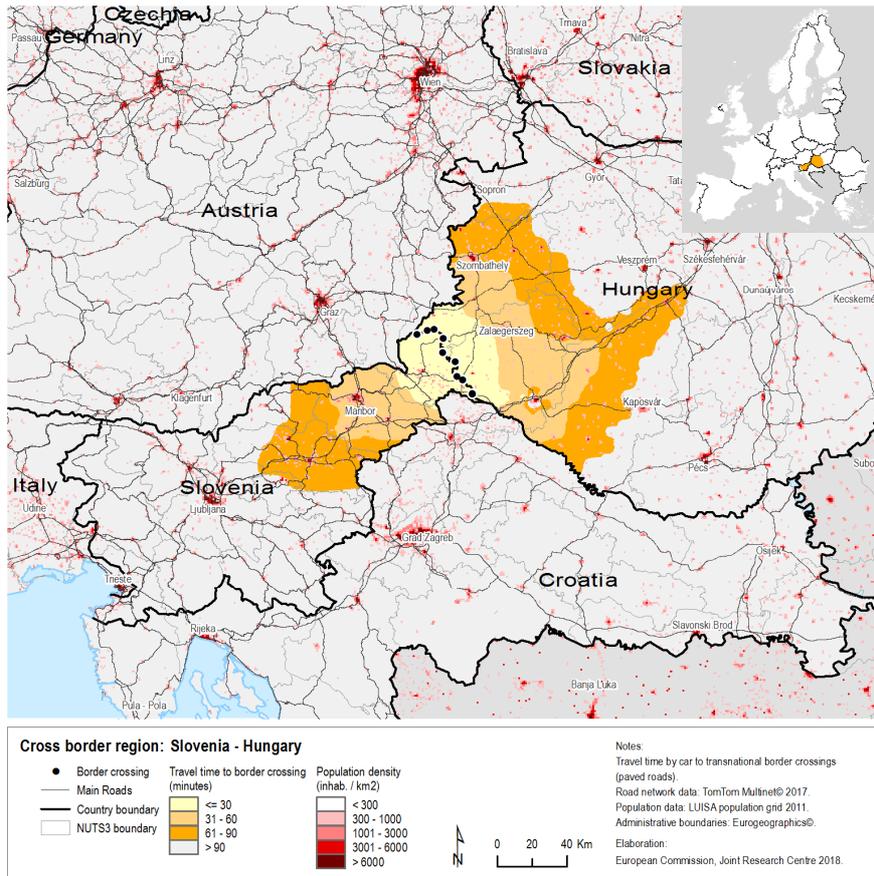


Figure 46: Area zones of 30-60-90-90+ minutes-drive from the border in Slovenia-Hungary (top) and Finland-Sweden (bottom) by 2017

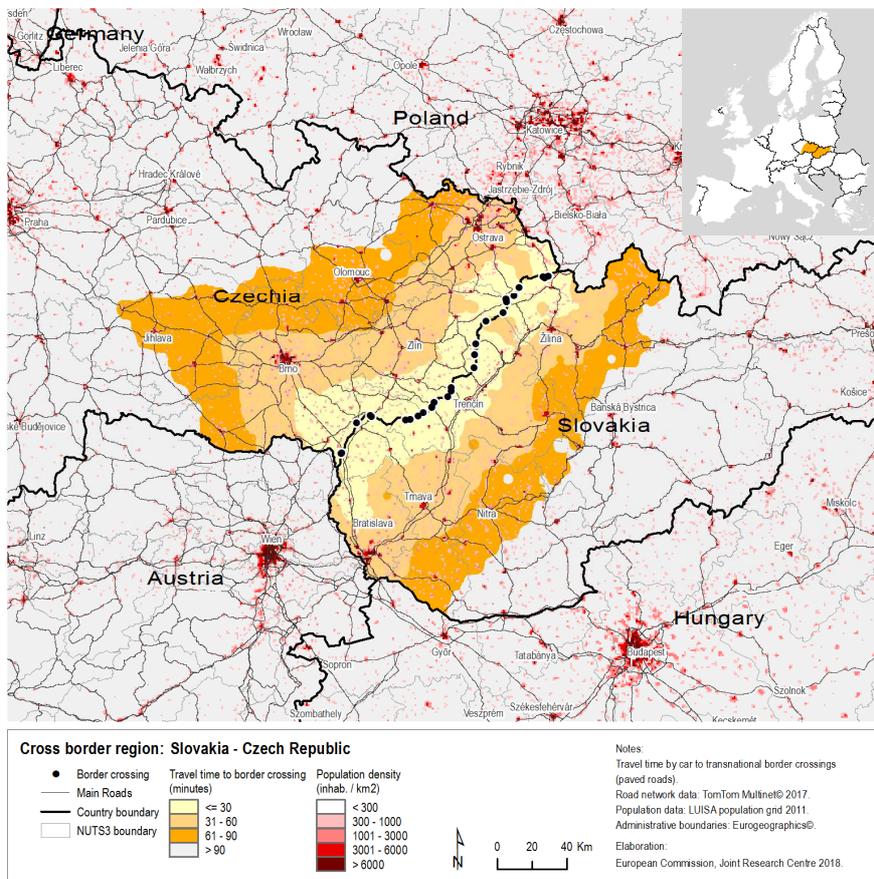
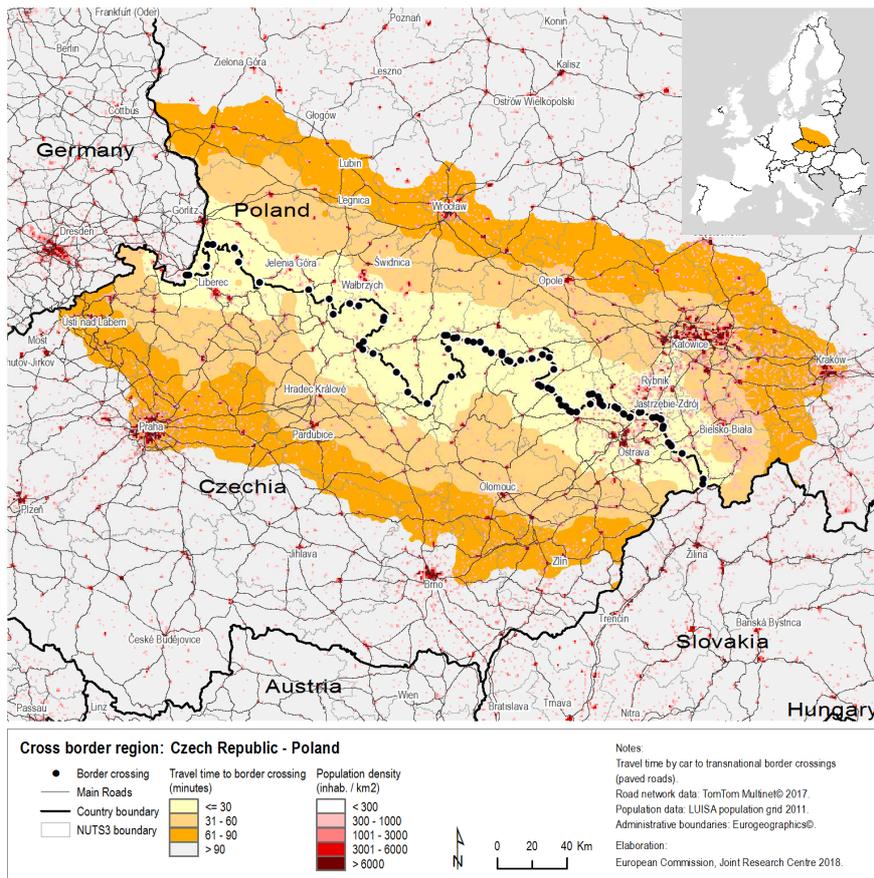


Figure 47: Area zones of 30-60-90-90+ minutes-drive from the border in Czech Republic-Poland (top) and Czech Republic-Slovakia (bottom) by 2017

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