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Abstract

The first chapter studies two major stages of European integration, the expansion of the European Union (EU) in 2004 and the Schengen Area in 2008, and their impacts on economic performance in subregions of Central and Eastern European (CEE) countries. Using European regional data at the NUTS3 level and a disaggregated synthetic control method, I construct counterfactuals for sub-regions of CEE countries. This approach allows me to assess regional treatment effects (RTEs) and to study the heterogeneous effects of European integration. I find that the benefits of EU and Schengen memberships to annual GDP per capita are approximately 10% less in border regions relative to interior areas. The results expose regional economic disparities, as border regions lost out relative to interior regions since European integration. Furthermore, integration facilitators in border regions, such as fewer geographical barriers, more service employment, and positive attitudes toward the EU, did not reduce economic disparities. The results show that the gap persists regardless of some complementarities. Thus, the main implication of this paper is that sub-regions of CEE countries are far from being fully converged and that European integration instead seems to have spurred sub-regional divergence.

The second chapter asks if spatial concentrations of economic activities have deep historical roots in European cities. This paper explores a unique quasi-natural experiment of opening borders within cities that were historically a single urban entity and were divided due to border shifts following major historical conflicts. I found that after inter-city borders were opened local economic activities, measured by remotely sensed nightlights, became more concentrated close to the pre-division city centers. This raises an important question of what type of border opening is more important in spurring agglomeration; the free movement of goods or of people? When looking into potential mechanisms behind the impact, using national business register databases, I find that proximity to former historical centers is more prominent, particularly after the allowance of the free movement of people as a part of the Schengen agreement in 2008, whereas gaining broader market access following the 2004 EU enlargement is less important. I account for two main channels. First, I show that firms

in the consumption sectors are more exposed to the free movement of people and are more likely to start operating closer to historical city centers than firms in the production sectors, which are less affected by local market potentials. Second, I show that cities where cultural and language differences are not barriers to cross-border cooperation are more influenced by the free movement of people than cities where these barriers still exist. Hence, spatial agglomerations near pre-division city centers are more apparent in almost borderless cities.

The third chapter evaluates the potential economic cost of controlling European borders during the pandemic. I use unconventional data sources such as NASA's Black Marble Nighttime Lights (NTL) products to provide insights into the socioeconomic impact of border restrictions on European municipalities. I find heterogeneity in the effects on the economic consequences of border controls. My results suggest that the impacts of travel limitations vary across cities; cross-border cities tend to lose relative to interior cities, particularly small border cities. Moreover, I find a larger decline in NTL radiance in border municipalities of new member states compared to old member states. Using the municipality-type subgroups, this paper concludes that industrial, consumer, and service-oriented border cities are adversely affected by temporary segregation. In addition, there was a significant reduction in NTL in municipalities where people oftentimes commute to foreign cross-border areas for shopping, leisure, and business purposes; where a large number of residents are employed; and where people have a high awareness of EU-funded cross-border activities and perceive living near the international border as economic potential rather than a barrier.

Abstrakt (CZ)

První kapitola zkoumá dvě významné události evropské integrace, konkrétně přijetí nových zemí do Evropské unie (EU) v roce 2004 a rozšíření Schengenského prostoru v roce 2008, a jejich dopad na ekonomickou výkonost regionu střední a východní Evropy (CEE). S využití evropských regionálních dat na úrovni NUTS3 a metody disagregované syntetické kontroly provádím kontrafaktuální analýzu regionů CEE zemí. Tento přístup umožňuje vyhodnotit regionální vliv a prozkoumat různorodost efektu evropské integrace. Zjišťuji, že přínos členství v EU a Schengenském prostoru přispívá k ročnímu HDP na obyvatele přibližně o 10% méně v okrajových regionech ve srovnání s vnitřními regiony. Výsledky ukazují regionální ekonomické nerovnosti, kdy okrajové regiony od počátku integrace ztrácejí ve srovnání s vnitřními regiony. Faktory usnadňující integraci v okrajových regionech, jakými jsou menší množství geografických překážek, vyšší zaměstnanost ve službách a pozitivní přístup k EU, nesnížily ekonomické rozdíly. Výsledky ukazují, že rozdíl přetrvává nezávisle na některých faktorech. Hlavním závěrem tohoto článku tedy je, že regiony CEE zemí jsou vzdáleny plné konvergenci a Evropská integrace naopak posiluje divergenci regionů.

Druhá kapitola se ptá, zda prostorové koncentrace ekonomických aktivit mají hluboké historické kořeny v evropských městech. Tato práce zkoumá unikátní kvazi-přirozený experiment otevírání hranic ve městech, která byla historicky jedinou městskou entitou a byla rozdělena kvůli posunům hranic po velkých historických konfliktech. Zjistila jsem, že poté, co byly otevřeny meziměstské hranice, se místní ekonomické aktivity, měřené dálkově snímanými nočními světly, více koncentrovaly v blízkosti center měst před rozdělením. To vyvolává důležitou otázku, jaký typ otevření hranic je důležitější pro urychlení aglomerace; volný pohyb zboží nebo osob? Při zkoumání potenciálních mechanismů za tímto dopadem pomocí národních databází obchodních rejstříků zjišťuji, že blízkost k bývalým historickým centrům je výraznější, zejména po umožnění volného pohybu osob v rámci schengenské dohody v roce 2008, zatímco nabývání širší přístup na trh po rozšíření EU v roce 2004 je méně důležitý. Počítám se dvěma hlavními kanály. Za prvé, ukazuji, že firmy ve spotřebních sektorech jsou více vystaveny volnému pohybu osob a je pravděpodobnější, že začnou

působit blíže k historickým městským centrům, než firmy ve výrobních sektorech, které jsou méně ovlivněny místním tržním potenciálem. Za druhé, ukazuji, že města, kde kulturní a jazykové rozdíly nejsou překážkou přeshraniční spolupráce, jsou více ovlivněna volným pohybem osob než města, kde tyto překážky stále existují. Prostorové aglomerace v blízkosti center měst před rozdělením jsou tedy patrnější ve městech téměř bez hranic.

Třetí kapitola hodnotí potenciální ekonomické náklady spojené s kontrolou evropských hranic během pandemie. Používám nekonvenční zdroje dat, jako jsou produkty NASA Black Marble Nighttime Lights (NTL), abych poskytla náhled do socioekonomického dopadu omezení hranic na evropské obce. Shledávám heterogenitu v dopadech na ekonomické důsledky hraničních kontrol. Moje výsledky naznačují, že dopady omezení cestování se v různých městech liší; přeshraniční města mají tendenci ztrácet ve srovnání s vnitrozemskými městy, zejména malými pohraničními městy. Navíc v příhraničních obcích nových členských států nacházím větší pokles záření NTL ve srovnání se starými členskými státy. S použitím podskupin městského typu tato práce dospívá k závěru, že průmyslová, spotřebitelská a na služby orientovaná pohraniční města jsou nepříznivě ovlivněna dočasnou segregací. Kromě toho došlo k výraznému snížení NTL v obcích, kde lidé často dojíždějí za nákupy, rekreací a podnikáním do cizích příhraničních oblastí; kde je zaměstnáno velké množství obyvatel; a kde lidé mají vysokou informovanost o přeshraničních činnostech financovaných EU a vnímají život blízko mezinárodních hranic jako ekonomický potenciál spíše než jako překážku.

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Introduction

This thesis consists of three interconnected chapters and falls under the broad banner of regional economics and economic geography, focusing on European integration and border studies. The overarching objective is to advance knowledge of the economic effects of European integration and provide insights into the dynamics of regional economies.

Chapter 1 focuses on the effects of European integration on the economic performance of Central and Eastern European (CEE) sub-regions. The research examines the impact of EU membership and Schengen Area accession on sub-regions and analyzes the regional economic disparities within CEE countries. By investigating the independent effects of European integration on each CEE sub-region and analyzing the economic inequalities between border and interior regions, the chapter contributes to understanding the heterogeneous results of European integration. It reveals that subregions within CEE countries have not converged fully, suggesting that European integration efforts have led to subregional divergence. This finding emphasizes the importance of addressing regional economic disparities within CEE countries.

Chapter 2 delves into historical roots and spatial concentrations in European cities. I utilize a unique quasi-natural experiment of border openings within historically divided border cities, which were once united in the past. By examining the effects of the free movement of people, proximity to historical centers, and reduced cultural and language barriers, the research provides insights into the drivers of economic concentration. I show that economic activities, measured by nighlights and registered firms, began to re-concentrate in the direction of the pre-division the allowance of free movement of people in 2008 due to the Schengen Agreement. My results suggest that integration policies can bring together what historically belongs together, internal city structures change, and the concentration of economic activities shifts to historical centers. The chapter expands the understanding of the factors shaping spatial patterns of economic activities within cities.

Chapter 3 focuses on the economic cost of border closures during the COVID-19 pandemic. This suggests that disruptions to economic integration, such as border closures, can adversely affect regional economies. The research examines the reintroduction of border controls as a preventive measure to curb the spread of the virus. I investigate the economic consequences of such measures, particularly in border municipalities. The study captures large-scale changes in socioeconomic activities using earth observation technologies and remotely sensed night-time lights (NTL) data. The chapter reveals significant declines in economic activity in cities near the border, indicating a negative impact on the regional economy. This chapter addresses the limited research on the economic costs of border controls during the pandemic and provides timely insights into the economic implications of temporary border closures.

The thesis employs various research methodologies, including disaggregated synthetic control methods, difference-in-differences (DD), and triple difference-in-differences (DDD). I have utilized the Annual Regional Database of the European Commission (ARDECO). Additionally, unconventional data sources enrich the thesis, such as DMSP-OLS remotely sensed nightlights and NASA's Black Marble products. Also, localized datasets on registered economic entities and cross-border cooperation surveys are incorporated, enabling a nuanced understanding of the economic effects of European integration.

The thesis provides important insights for policymakers involved in regional development, European integration, and pandemic management. It emphasizes the importance of border openings and the free movement of people in fostering economic concentration and agglomeration. Policymakers can prioritize initiatives that promote cross-border cooperation, reduce cultural and language barriers, and facilitate the movement of people and goods across borders. Furthermore, the thesis sheds light on the negative economic consequences of temporary border closures during the COVID-19 pandemic. Policymakers can use this knowledge to develop strategies for effectively managing future crises while minimizing the disruption to local economies.

CHAPTER 1

1 Checkmate! Losing with Borders, Winning with Centers. The Case of European Integration

1.1 Introduction

Joining the EU in 2004 and the Schengen Area in 2008 were key prerequisites for effective market integration of Central and Eastern European (CEE) countries. These were necessary steps in the course of European integration to eliminate barriers that hindered the free movement of goods, services, capital, and labor. One of the central components of the ongoing European integration process is that the reduction of international trading costs can influence the economic geography of each integrated country differently. Understanding regional economic inequalities caused by European integration is a complex undertaking. While aggregate disparities slowly disappear and European Union (EU) member states converge economically, there are still growing economic inequalities within new member states, with some sub-regions prospering and others struggling to sustain growth. To uncover who benefits and who loses from European integration, it is essential to identify inter-regional economic disparities. To the best of my knowledge, the heterogeneous effects of European integration at sub-regional levels and at different European integration stages, such as the expansion of the EU and Schengen Area, have not yet been studied. One of the main reasons such an analysis has not been performed is the lack of an appropriate methodology, particularly when it comes to finding proper counterfactuals for each sub-region. Using

European regional data and disaggregated synthetic control method, this paper contributes to the literature by estimating regional treatment effects (RTEs). For inferential analysis, I utilize in-space and in-time permutation-based methods, finding that disaggregated RTEs are significant. My results uncover the impact of EU and Schengen Area membership on sub-regional economic performance.

European integration might affect economic activities in border and interior regions. Based on new economic geography (NEG) models, regions close to borders may be affected differently by integration relative to interior areas due to a border's proximity to a foreign market (Puga, 1999; Redding, 2010; Redding and Rossi-Hansberg, 2017). Border regions have long been of special interest in the European integration context due to heightened competition, increasing foreign demand, and wider market access. Economic disparities between border and interior regions are particularly interesting in the European integration scenario. The empirical literature on European integration has considered border regions as treated and interior regions as control groups (Braakmann and Vogel, 2011; Brakman et al., 2012; Heider, 2019; Mitze and Breidenbach, 2018). They *a priori* assume that interior areas are much less affected by integration shocks. Those studies tend to bias the effects of European integration on border areas. I argue that interior areas are not a suitable comparison group for border regions in the case of European integration. Because interior regions were also affected by the shocks of joining the EU and the Schengen Area. As a counterfactual, I use sub-regions unaffected by European integration during the 2004 enlargement of the EU and the 2008 enlargement of the Schengen Area. After synthesizing every NUTS3 region of CEE countries using the disaggregated synthetic control method, I show that, in the course of European integration, annual GDP per capita in border regions lost more relative to interior areas by approximately €300, which is 10% of annual GDP per capita. Furthermore, I find that despite integration facilitators of border regions, such as fewer geographical barriers, more service employment, and positive attitudes toward the EU, border regions have developed less than interior regions due to European integration.

In estimating the effects of European integration, I address the following main questions: What would the level of per capita income in each sub-region be if the country it belongs to had not joined the EU and Schengen Area? Do all sub-regions benefit from economic integration or not? Are there significant regional economic disparities between border and interior regions after European integration? Do different types of integration facilitators reduce internal economic disparities, if any?

This paper contributes to the literature in two ways. This is the first study to examine the effects of reducing international trading costs on economic performance in each sub-region of CEE countries. This paper presents new estimates for the effects of European integration at the sub-regional level. Second, it extends the strand of empirical studies that use European integration as a quasi-natural experiment to analyze the role of wider market access on regional economic performances (i.e., among border and interior regions).

The rest of the paper is organized as follows: Section 2 reviews the literature; Section 3 explains the empirical approach, including the data and the disaggregated synthetic control method; Sections 4 and 5 introduce the results of RTEs and country-specific treatment effects; Section 6 explains estimation results; Section 7 covers the mechanisms and sensitivity analysis; and Section 8 concludes the paper.

1.2 Literature Review

To date, literature on the effects of European integration on internal economic geography has predominantly pursued two directions (for a detailed description of the related literature, see Table 1.1). One strand of the literature has estimated structural NEG models using simulation analysis and explored the effects of European integration on economic activities (Brülhart et al., 2004). These simulation studies have found positive integration effects in border regions. For example, Brülhart et al. (2004) found that broadened market access positively affected GDP per capita and manufacturing employment in border regions after the 2004 EU enlargement. In line with this study, Niebuhr (2008) provided a different simulation scenario. The author discovered a substantial positive impact of European integration on market potential and income per capita in European border regions relative to interior areas. However, the credibility of both studies depends on two main factors: the first is their assumptions in the simulation frameworks; the second is the unit of analysis, which was at the NUTS2 level in both studies. It is worth mentioning here that this level is large and could pose a problem if the research's primary focus were on inter-regional inequalities. Furthermore, Niebuhr and Stiller (2002) conducted a comprehensive review of the theoretical and empirical literature on the regional effects of European integration and showed that it was rare for European integration to have a positive effect in border regions. Accordingly, there is no clear-cut conclusion as to whether European integration has benefited border areas close to a foreign market or not.

Another strand of the literature has deemed European integration a quasi-natural experiment to evaluate changes in institutional and economic policies (Braakmann and Vogel, 2011; Brakman et al., 2012; Heider, 2019; Mitze and Breidenbach, 2018). These studies were inspired mainly by Hanson (2001) and Redding and Sturm (2008), who studied the effects of NAFTA in Mexican-US border cities and German reunification/division in East-West German border cities, respectively. Hanson (2001) studied the regional effects of trade integration on Mexican employment and argued that Mexican economic activities were re-oriented from the hinterlands to cities near the US border. In line with this study, Redding and Sturm (2008) deemed the division of Germany after the Second World War a quasi-natural experiment and argued that it negatively affected West German population growth in cities near the East-West German border. Inspired by these studies, the European integration literature has considered European integration a quasi-natural experiment and has studied whether border sub-regions have benefited from the integration process. For example, Brakman et al. (2012) argued that European integration positively affected the population growth rate in European NUTS3 border regions and cities. In line with this study, Heider (2019) examined the effect of the natural experiment of the 2004 EU enlargement on population growth in the border regions within "old" Member States. The results showed that populations increased in German cities along the border with Poland relative to interior regions of Germany after the 2004 EU enlargement. However, no statistically significant effect was found on population growth in the German border cities along the German-Czech border compared to the German interior areas. These results implied that considerable heterogeneous integration effects were at play. Other recent studies have looked at the economic impact of European integration by focusing on outcomes such as employment, wages, and GDP per capita. For instance, Brülhart et al. (2018) studied the impact of trade liberalization in the 1990s and found a positive effect on employment and wage growth in Austrian border regions compared to interior areas. Furthermore, Mitze and Breidenbach (2018) found a positive effect on regional economic growth in border regions due to the 2004 EU enlargement, using a space-time incremental impact analysis. However, the integration effect can also be negative for border regions. Indeed, cross-border interaction may result in "tunnel or corridor effects" for border regions after European integration. In such cases, border areas that locationally facilitate the free movement of goods, services, and people to central areas, so the economic activities are ultimately directed towards interior regions. Moreover, Petrakos and Topaloglou (2008) argued that border impediments such as physical and cultural differences were critical factors that undermined the economic benefits of integration in border regions in the course of cross-border interactions.

Overall, previous empirical studies have encountered several methodological challenges, and their results regarding the impact of European integration remain inconclusive. This paper addresses the methodological difficulties and studies the effects of European integration on economic performance using a disaggregated synthetic control method to uncover the impact of staggered increasing memberships in the EU and Schengen Area at the sub-regional level.

1.3 Data and Empirical Strategy

My study design and empirical approach are structured in three stages. First, I construct individual synthetic controls for each of the NUTS3 regions and estimate separate RTEs. This approach allows me to create estimated RTEs and to study the heterogeneous consequences of European integration in CEE NUTS3 regions. Second, I observe considerable heterogeneity of RTEs, revealing the winners and losers in European integration. Then, I question if within-country inequalities exist (e.g. between the border and interior regions). Third, I introduce integration facilitators, including fewer geographical barriers, more service employment, and positive attitudes toward the EU, which could trigger positive effects of European integration in border regions and reduce economic inequalities within CEE countries, if any.

1.3.1 Data

This paper employs a European regional database of 14 European countries and 437 NUTS3 regions from 1990 to 2015 (for detailed descriptive statistics of the main variables, see Table 1.A.1. The European regional data on GDP per capita, sectoral employment, sectoral gross value added (GVA), and population are taken from the Annual Regional Database of the European Commission's Directorate-General for Regional and Urban Policy (ARDECO) platform. The typology and size of NUTS3 regions are collected from the Geographic Information System of the Commission (GISCO) database. European borders at the NUTS3 level and international borders are taken from Eurostat shapefiles. To measure if a region is non-mountainous with fewer geographical barriers, I use the hill-shading procedure and calculate the elevation of hills or mountains using the shade and light of the areas displayed on the terrain maps of the NUTS3 regions of CEE. These terrain maps store illumination values for each cell in raster data, and every single pixel takes a value that ranges between 0 (the lowest-black color) to 255 (the highest-white color). The terrain maps were collected from the European Environment Agency (EEA). In addition, to measure public perceptions of the EU, I use data on EU membership from referendum held one year before countries joined the EU in 2003. Referendum data are at the NUTS3 level, collected from the European Election and Referendum Database.

1.3.2 Disaggregated Synthetic Control Approach

To identify the effects of European integration on regional economic performance, one needs a valid counterfactual (i.e., what would have happened to economic growth in NUTS3 regions had their countries not joined either the EU or the Schengen Area). Measuring these effects requires the estimation of the counterfactual outcome from comparably similar sub-regions.

Table 1.1: Literature Survey on the Effects of the European Integration in Border Regions

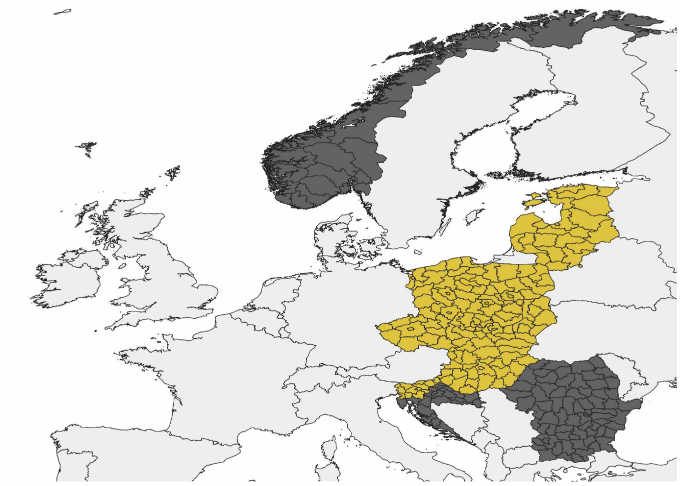
Paper By	Main Results	Treated	Comparision Group	Methods
Simulation Studies				
Brülhart et al. (2004)	(+)	Border regions in EU-15	Interior Regions	Simulation Analysis
Brülhart and Koenig (2006)	(+)	Border regions in NMS-10	Interior Regions	Simulation analysis
Niebuhr (2008)	(+)	Border regions in NMS-10	Interior Regions	Simulation Analysis
Quasi-Experimental Studies				
Braakmann and Vogel (2011)	(-, NE)	German's Eastern border regions	Interior regions	Difference in Difference
Brakman et al. (2012)	(+)	Border regions in EU	Interior regions	Difference in Difference
Heider (2019)	(+)	German's Eastern border regions	Interior regions	Triple Difference
Mitze and Breidenbach (2018)	(+, NE)	Border regions in EU	Interior regions	Spatial-time incremental difference in difference model
This study	**Stage I:** (heterogeneous effects)	All sub-regions in CEE countries	Non-EU & Non-Schengen regions	Disaggregated Synthetic Control Method
	Stage II: (-)	Border regions in CEE countries	Interior regions in CEE countries	Cross-sectional OLS

Notes: Table represents the primary literature survey on the effects of the European integration. The first column refers to - authors; the second column - main results of the research, (+) denotes the positive effects of European integration in border regions, (-) denotes the negative effects, (NE) denotes the insignificant effect; the third & fourth columns show treated and the control group, respectively (where NMS-15 stands for New Member States); and the last column explains used methodologies.

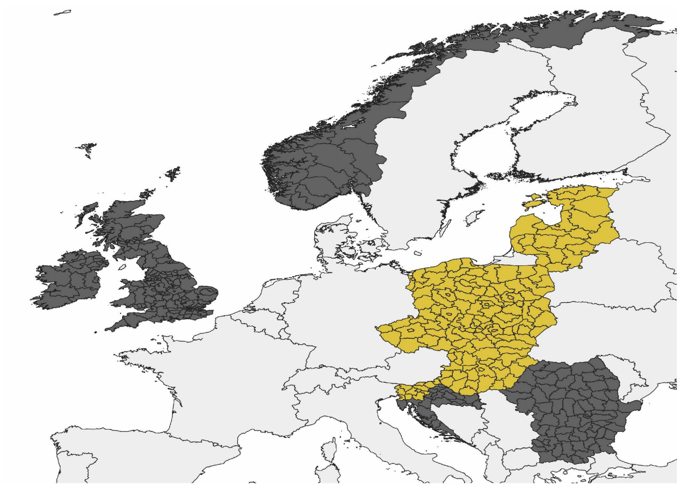
Source: Author's construction.

Figure 1.1: Treated and Control NUTS3 regions

(a) European Union



(b) Schengen Area



Notes: Figure (a) represents joining the EU in 2004, treated CEE NUTS3 regions (yellow) and untreated NUTS3 regions in Bulgaria, Romania, Croatia, and Norway (gray). Figure (b) represents joining the Schengen Area in 2008, treated CEE NUTS3 regions (yellow), and untreated NUTS3 regions in Bulgaria, Romania, Croatia, Ireland, and the United Kingdom (gray). The rest of the area is out of the sample (white).

Source: Author's elaboration based on GISCO shapefiles.

In this study, I use the disaggregated synthetic control method to select the most comparable regions (Abadie and Gardeazabal, 2003). Instead of directly comparing the outcomes in regions influenced by European integration and unaffected regions, the synthetic control method constructs a counterfactual group from a weighted average of the non-treated areas, or the so-called "donor pool" (Abadie et al., 2010).

The main advantage of building regional synthetic controls is that the pre-intervention characteristics of the treated sub-regions are accurately approximated by a combination of untreated sub-regions rather than by any single sub-region in Europe. These sub-regions, which were not affected by European integration, are chosen to match as closely as possible in terms of the pre-treatment characteristics of the sub-regions which underwent the integration process (i.e., joining the EU and Schengen Area). As shown in Figure 1.1, the treated group comprises 146 NUTS3 regions in the Czech Republic, Poland, Hungary, Slovenia, Slovakia, Lithuania, Latvia, and Estonia. To study the effects of two different phases of European integration, joining the EU and joining the Schengen Area, I use two separate control groups. In the case of the 2004 enlargement of the EU, the control group consists of 89 non-EU NUTS3 regions of Bulgaria, Romania, Croatia, and Norway (see Figure 1.1). Meanwhile, in the case of the 2008 enlargement of the Schengen Area, the control group includes 245 non-Schengen NUTS3 regions of Bulgaria, Romania, Croatia, Ireland, and the United Kingdom (see Figure 1.1).

It is worth mentioning that significant progress has been made in the field of econometrics related to Difference-in-Differences and Synthetic Control methods in recent years (Roth et al., 2023). These advancements have been achieved by relaxing crucial assumptions, including those related to the presence of multiple time periods (variations in treatment) and potential violations of parallel trends (using treated units from different time periods in the control group). However, in this paper, I am adopting a conventional approach to quantify average regional treatment effects. This approach involves two distinct time periods, wherein there exists a group of treated regions that have undergone a specific treatment of interest in the second time period and comparable regions that have not received the treatment in either period. So, I focus on countries that have never undergone any form of treatment, whether it involves becoming a European Union member or joining the Schengen area. These sub-regions are "never treated". Importantly, I cannot use "not yet countries" due to the absence of the NUTS3 territorial scale, which is recognized only by the European Union, e.g., potential candidates for European Union membership: Turkey (in 1999), North Macedonia (in 2005), Montenegro (in 2010), Serbia (in 2012), Albania (in 2014), Moldova (in 2022), Ukraine (in 2022), Bosnia and Herzegovina (in 2022), and Georgia which officially launched membership application in 2022. In these countries, it poses a challenge to determine the appropriate spatial unit of analysis. This can lead to difficulties in the identification process. Considering all the factors mentioned, I limit my donor pool to sub-regions that have not undergone any form of treatment prior to the treatment year.

Synthetic control estimators were initially introduced for settings in which an aggregate unit was exposed to the intervention, such as a city, a state, or a country (Abadie and Gardeazabal, 2003; Abadie et al., 2010). More recently, synthetic control methods have been used with multiple units (Abadie and L'hour, 2021; Abadie, 2021). Some relevant studies have used a disaggregated synthetic control method with a large number of units (e.g., 525 firms in Acemoglu et al. (2016), 13 states in Dickert-Conlin et al. (2019), 29 states in Dube and Zipperer (2015), 24 hospitals in Kreif et al., 2016 and 44 German districts in Osikominu et al., 2021). I use a disaggregated synthetic control approach to estimate the effects of European integration of 146 NUTS3 regions of CEE countries (for a detailed illustration of individual 146 synthetic controls, see Figure 1.B.1 and Figure 1.B.2).

A synthetic control method relies on a weighted combination of control units. Weights are chosen to minimize the distance between synthetic and treated units in the pre-treatment period. In Equation 1.1, multiple treated NUTS3 regions are represented by i and control NUTS3 regions by j, whole sample size by m, and the total number of treated units by n (i.e., 146 NUTS3 regions of CEE countries). Let X_i be a matrix that collects pre-treatment predictors of economic performance for the treated NUTS3 regions $[X_1....X_n]$. Predictors of regional economic performance are GDP per capita in pre-treatment periods, GVA share in the industrial sector, GVA share in the agriculture sector, employment share in the industrial sector, population (log) and the size of NUTS3 regions (log) (for more details, see Table

1.2). A matrix of predictors of the same variables for all possible control NUTS3 regions in the pre-treatment period is X_0 and in the post-treatment, is represented by $[X_{n+1}....X_m]$. Weights are displayed by $W_{i,j} = w_{i,n+1}, ..., w_{i,m}$ where $w_{i,n+1}$ is the weight of untreated $n+1$ in the synthetic control of unit i. Individual weights are non-negative, and the total weight is added to one to avoid extrapolation problems:

$$min_w (X_i - X_0 W_i)'(X_i - X_0 W_i) \tag{1.1}$$

$$w_i \geq 0$$

$$w_{i,n+1} + ... + w_{i,m} = 1 \quad \forall i = 1, 2, ..., n$$

Once the synthetic control model optimally chooses a set of weights, I estimate the effects of European integration on the economic performance in each NUTS3 region of CEE countries, denoted as $\hat{\alpha}_i$, over the period $t \in T_0 + 1, \dots, T_1$ for an intervention that occurred in the time T_0. The estimated treatment effect is the difference between the observed value of the treated and simulated synthetic units. Equation 1.2 represents estimated RTEs, $\hat{\alpha}_i$:

$$\hat{\alpha}_i = Y_i - \sum_{j=n+1}^{m} w_{i,j} * Y_j \tag{1.2}$$

The estimated effect in Equation 1.2 measures the post-treatment difference between the outcome of the treated units, Y_i, and the synthesized control units as an optimal average of all control units in the donor pool, $\sum_{j=n+1}^{m} w_{i,j} * Y_j$. The selection of pre-treatment characteristics has a significant impact on the weights and composition of the synthetic control (i.e., on $w_{i,j}$). To find the optimal weight distribution, I select the specification for which the pre-treatment characteristics generate the smallest mean squared prediction error (Abadie and Gardeazabal, 2003).

1.4 Empirical Results

1.4.1 Regional Treatment Effects (RTEs)

After estimating all individual treatment effects for each of the 146 NUTS3 regions of CEE countries, Figure 1.3 shows how European integration has affected GDP per capita at constant prices in sub-regions. The results indicate that joining the EU and Schengen Area brought about uneven regional effects. The most positive regional treatment effect is presented by a green color and the most negative by a red color. Further, Figure 1.3 illustrates some level of clustering of RTEs: negative integration effects are more clustered after the 2004 enlargement of the EU than after the Schengen expansion in 2008[1].

Next, I pool the RTEs from each of the 146 NUTS3 regions; in Figure 1.2, the dashed grey lines represent the individual treatment effects. These are the gaps between treated and synthetic controls for each NUTS3 region. Figure 1.2 shows that the gap in the pre-treatment period is close to zero; in other words, I have synthetic controls with perfect pre-treatment fit where $\hat{\alpha}_{it}$ before T_0 intervention is close to zero. In the post-treatment period, some areas have positive and others have negative RTEs. Both Figures 1.2 and Figure 1.3 illustrate considerable heterogeneity of the effects of European integration in NUTS3 regions following the enlargement of the EU in 2004 and the Schengen Area in 2008.

I utilize two different permutation-based methods of inference analyses for the disaggregated synthetic control method. These are in-time and in-space permutation methods suggested in Abadie et al. (2010), Abadie and L'hour (2021) and Abadie (2021).

[1] Table 1.A.1 shows that, on average, RTEs as a result of EU enlargement in 2004 are negative in border regions and positive in interior regions. On average, RTEs are positive in both border and interior regions after the expansion of the Schengen Area in 2008. However, the magnitude of the mean effects in the interior regions is higher.

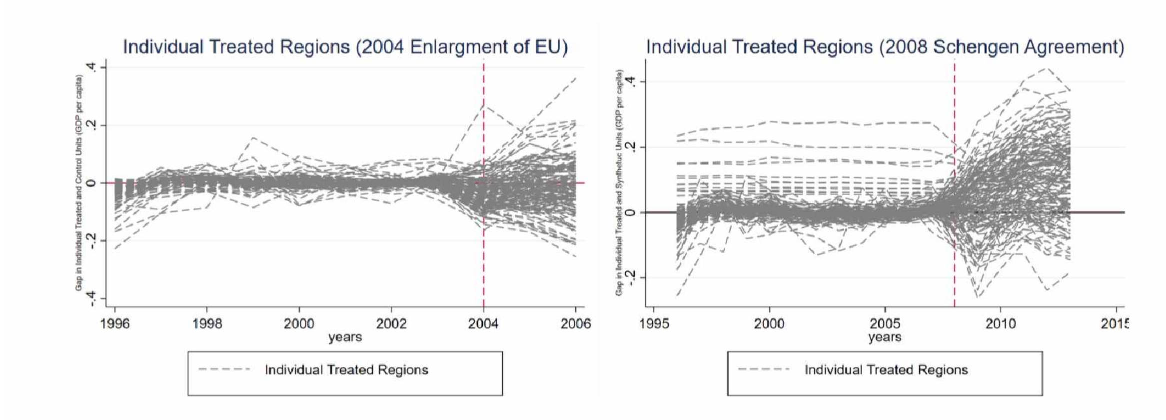
Table 1.2: Predictors of Regional Economic Performance (Disaggregated synthetic control method)

Treatment	Years	Treated Group (NUTS3)	Donor Pool (NUTS3)	Predictors
2004 EU	1996-2006	Czech Republic (14), Estonia (5), Hungary (20), Latvia (6), Lithuania (10), Poland (72), Slovakia (8), Slovenia (12)	Romania (42), Bulgaria (28), Croatia (21), Norway (12)	GDP per capita dummies in pre-treatment periods , GVA share in industry sector , GVA share in agriculture sector, Employment share in industrial sector, Population (log), NUTS3 size (log)
2008 SA	1996-2013	Czech Republic (14), Estonia (5), Hungary (20), Latvia (6), Lithuania (10), Poland (72), Slovakia (8), Slovenia (12)	Romania (42), Bulgaria (28), Croatia (21), Ireland (8), United Kingdom (173)	GDP per capita dummies in pre-treatment periods , GVA share in industrial sector, GVA share in agriculture sector, Employment share in industrial sector, Population (log), NUTS3 size (log)

Notes: Table represents two phases of European integration, expansion of the EU and the Schengen Area. Treated groups include 146 NUTS3 regions in eight CEE countries. The donor pool includes 89 NUT3 regions of non-EU countries and 245 NUTS3 regions of non-Schengen countries. The last column presents predictors of regional economic performance. They are used to measure RTEs using disaggregated synthetic control method.

Source: Author's construction.

Figure 1.2: Regional Treatment Effects 1996-2013



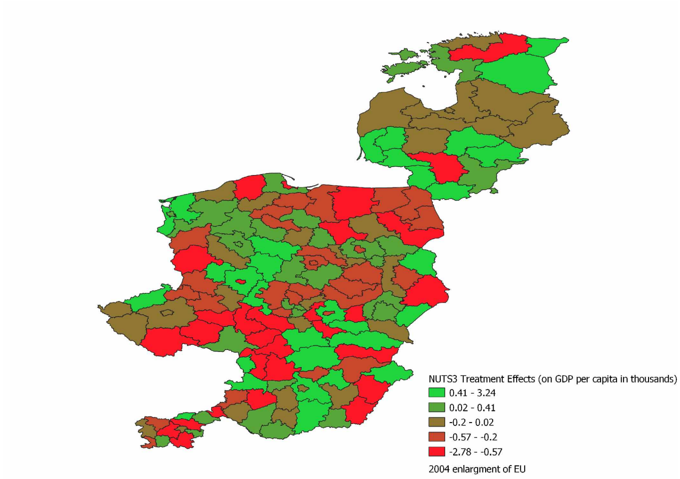
Notes: The left side of Figure represents a gap in treated and synthetic controls as a result of joining the EU in 2004, and the Right side of Figure 3 represents a gap in treated and synthetic controls as a result of joining the Schengen Area in 2008.
Source: Author's elaborations.

I permute the treatment status across space and across time to generate the placebo distribution of treatment effects under the null hypothesis, $H_0 = 0$: *no effects of European integration.*

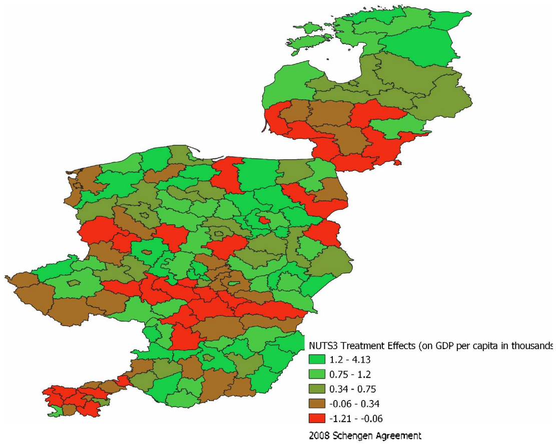
If the distribution function of treatment effects computed by permutations and the distribution of actual RTEs differ, then it is against the null hypothesis, and disaggregated RTEs are deemed significant.

My inferential framework is based on two permutation methods. First, regarding the in-time permutations, I permute the treatment status for all NUTS3 regions of CEE in the pre-treatment period. To generate the placebo distribution of treatment effects, I compute the synthetic control estimates in the pre-treatment year - 1998. The European agreements came into force in 1998, which may mean that there was an anticipation effect; membership negotiations had already begun, leading to some level of integration even before these countries joined the EU in 2004 (Campos et al., 2019). Under the placebo scenario in 1998, CEE countries received pre-integration aid during the pre-accession period so as to facilitate their integration into the EU. Hence, I permute intervention time so that the 146 NUTS3 regions received treatment in 1998; thus, I generate placebo treatment effects as if the CEE countries joined the EU and Schengen Area in 1998.

Figure 1.3: Regional Treatment Effects in CEE Countries



(a) European Union



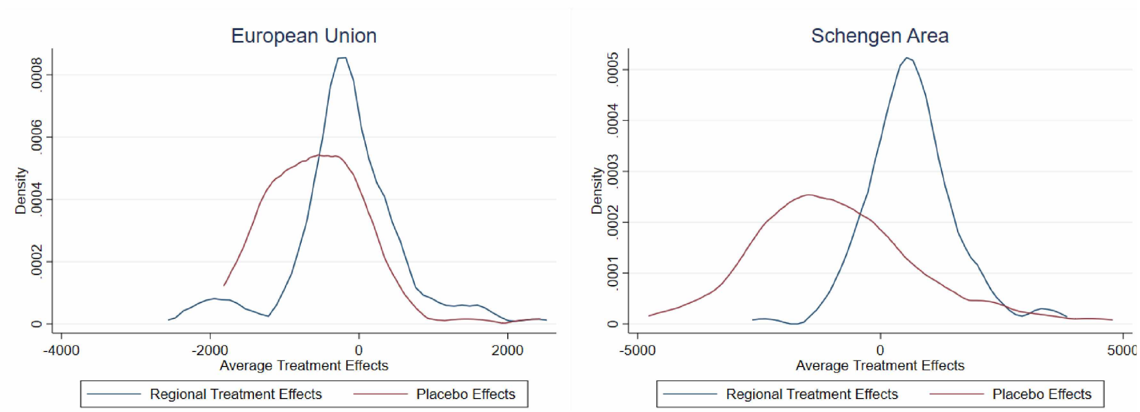
(b) Schengen Area

Notes: *The left* side of the figure shows the effects of the 2004 EU Enlargement on GDP per capita (at constant prices in thousands €) in 146 CEE NUTS3 regions. *The right* side of the figure shows the effects of the 2008 Schengen Agreement on GDP per capita (in thousands) in 146 CEE NUTS3 regions.

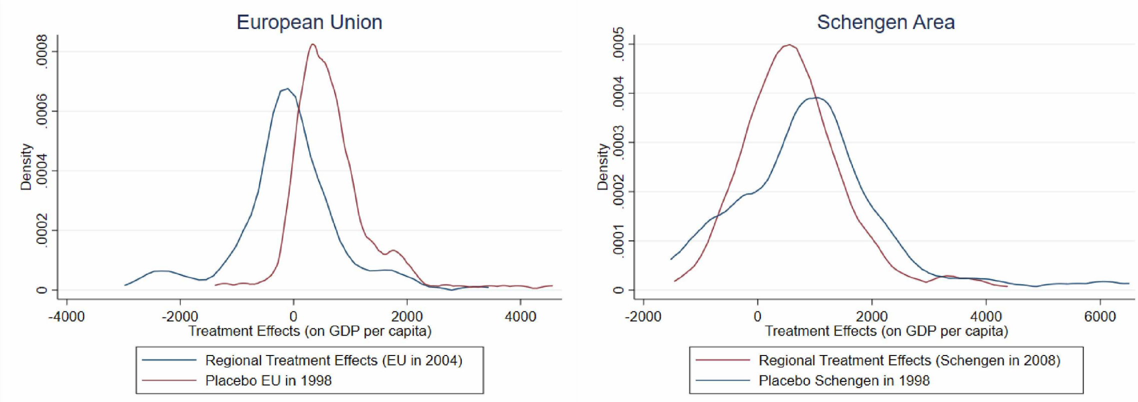
Source: Author's elaboration.

Figure 1.4: Distributions of Regional Treatment and Placebo Effects

(a) Permutations in Space



(b) Permutations in Time



Notes: Permutations in space and in time.

The left side of Figures (a) and (b) displays the kernel density function of regional treatment effects as a result of joining the EU in 2004 (blue line) and the kernel density function of placebo effects when I generated in space and in time permutations of treatment assignments (red line), respectively. *The right* sides of Figures (a) and (b) display the kernel density function of regional treatment effects as a result of joining the Schengen Area in 2008 (blue line) and the kernel density function of placebo effects when I generated in-space and in-time permutations of treatment assignment (red line), respectively.

Source: Author's elaborations.

Second, regarding in-space permutations, I construct permutation distributions by reassigning the treatment status (i.e., joining the EU and Schengen Area) to each NUTS3 region in the donor pool and estimating placebo effects in every iteration. Then, I compare in-space permutation distribution to the distribution of estimated RTEs. If the distributions of in-space permutations and actual RTEs differ, then the integration effect in the given NUTS3 region

Table 1.3: Inference on the Distribution of Regional Treatment Effects

(a) Permutations in Space

EU	Differences	P_value
K-S Test in 2004	0.1858	0.042
K-S Test in 2005	0.4195	0.000
K-S Test in 2006	0.3782	0.000
Schengen Area	Differences	P_value
K-S Test in 2008	0.5065	0.000
K-S Test in 2009	0.4709	0.000
K-S Test in 2010	0.5603	0.000
K-S Test in 2011	0.7063	0.000
K-S Test in 2012	0.6159	0.000
K-S Test in 2013	0.5545	0.000

(b) Permutations in Time

EU	Differences	P_value
K-S test in 1998 vs. in 2004	0.5616	0.000
Schengen Area	Differences	P_value
K-S test in 1998 vs. in 2004	0.2082	0.003

Notes: Table reports results of Kolmogorov-Smirnov tests of permutation in space and in time, respectively. The columns labeled *Differences* refer to the most significant differences between placebo and actual treatment effect distribution. The column labeled *P-value* refers to the asymptotic p-value, which is computed to the equality of placebo and actual treatment effect distribution. *Source:* Author's calculations.

is considered significant.

I conduct a series of placebo estimations by applying a synthetic control method to estimate the effect of joining the EU in 2004 and the Schengen Area in 2008 on every NUTS3 region in the donor pool. In each iteration, I reassign the treatment to one of the 89 NUTS3 regions in Bulgaria, Romania, Croatia, and Norway and the 245 NUTS3 regions in Bulgaria, Romania, Croatia, Ireland, and the United Kingdom. All treated NUTS3 regions are shifted to the donor pool. Then, I proceed as if one of the countries to which one of the NUTS3 regions belongs in the donor pool became a member of the EU in 2004 and the Schengen Area in 2008 instead of the Czech Republic, Hungary, Poland, Slovenia, Slovakia, Latvia, Lithuania, and Estonia. Then, I compute the estimated placebo treatment effects associated with each placebo iteration.

The distribution of treatment effects can be compared to the in-space and in-time permutations distribution, as shown in Figure 1.4 (a) and (b). These figures provide a visual illustration of in-space, in-time permutations, and actual RTE distributions. For both interventions, joining the EU and the Schengen Area, the treatment effect distribution lies on both sides of the tail; it has a bell-shaped curve. The effects of European integration are positively and negatively skewed, suggesting that there are winners and losers among NUTS3 regions.

Further, I compute Kolmogorov-Smirnov statistics to test for the equality of the placebo treatment effects and RTE distributions. Table 1.3 (a) and (b) present the Kolmogorov-Smirnov test, a non-parametric test of the equality of two sample distributions. The test indicates that actual and placebo distributions of treatment effects have a p-value of zero, confirming the non-equality of the distributions of actual and placebo treatment effects in every post-treatment year.

1.4.2 Country Treatment Effects

In this section, I aggregate RTEs at the country level. Figure 1.5 presents the effects of CEE joining the EU. After aggregating individual treatment effects, I found that joining the EU had a positive effect with respect to the 2008 global financial crisis in Estonia, Lithuania, Latvia, and Slovakia. Insignificant effects are found for the Czech Republic, and an adverse effect was detected for Poland, Hungary, and Slovenia.

Figure 1.6 illustrates the effects of joining the Schengen Area, which are almost entirely positive among CEE countries. However, for Baltic states, slightly adverse or insignificant effects are detected until 2009, with positive impacts thereafter. This could be attributable to the global financial crisis, which lasted from mid-2007 to early 2009; these countries' membership in the Schengen Area in 2008 co-occurred with a global recession. In Europe, the Baltic states were the most negatively impacted by the global financial crisis (Staehr, 2013).

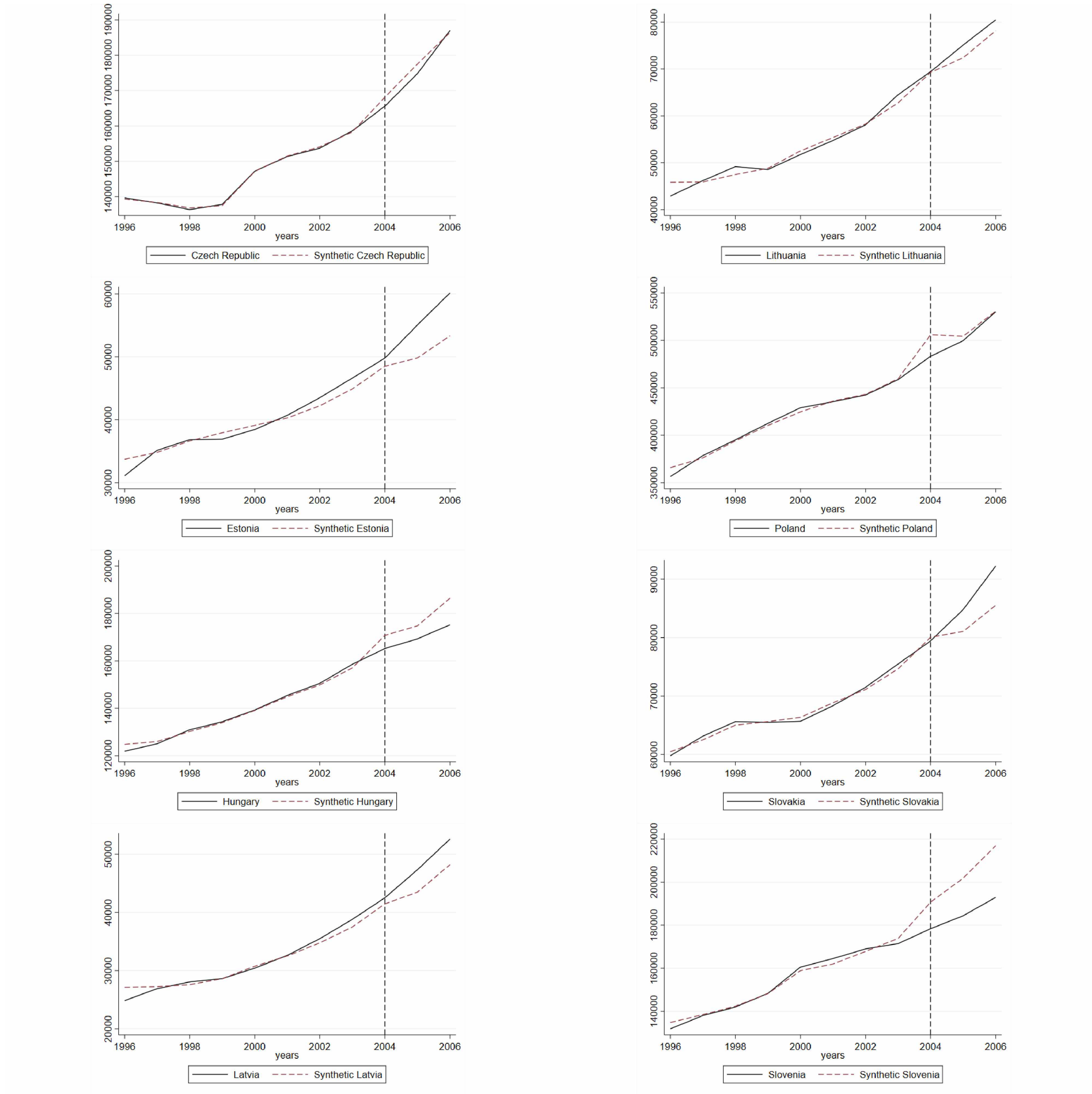
Aggregate estimations align with the findings of Campos et al. (2019), who studied the effects of European integration on GDP per capita using a synthetic control method at the country level. My results are consistent with their findings, confirming the significance of estimated individual/regional treatment effects. Campos et al. (2019) found that GDP per capita increased with EU membership in Estonia, Hungary, Latvia, and Lithuania. However, the effects tended to be slightly negative for Poland and Hungary and insignificant for Slovenia[2].

1.4.3 Border vs. Interior Treatment Effects

The disaggregated synthetic control methodology with multiple treatment units resulted in 146 NUTS3-level treatment effects. To understand the cause of treatment heterogeneities across integrated regions, I examine whether local characteristics of the NUTS3 regions influence the RTEs in the post-treatment period (e.g., the key determinant is if a region is close to an international border, or not). Using cross-sectional ordinary least square (OLS) regression, I exploit the European integration set-up for the following estimation model:

[2]The main reason for these differences in the case of Slovenia might be the chosen donor pool in Campos et al. (2019). It is worth noting that the relative weights in the donor pool for Slovenia are 43.4%, South Korea, 24.5% Chile, 20.9% Canada, 11.1% Colombia, and 0.1% Thailand in Campos et al. (2019). However, all regions in the donor pool I use are European sub-regions, which are comparable controls. The synthetic control method should use control units that are similar to the treated unit Abadie (2021), because, in the case of a poor donor pool, high weights may be allocated to units with better fits, which results in over-fitting of the model.

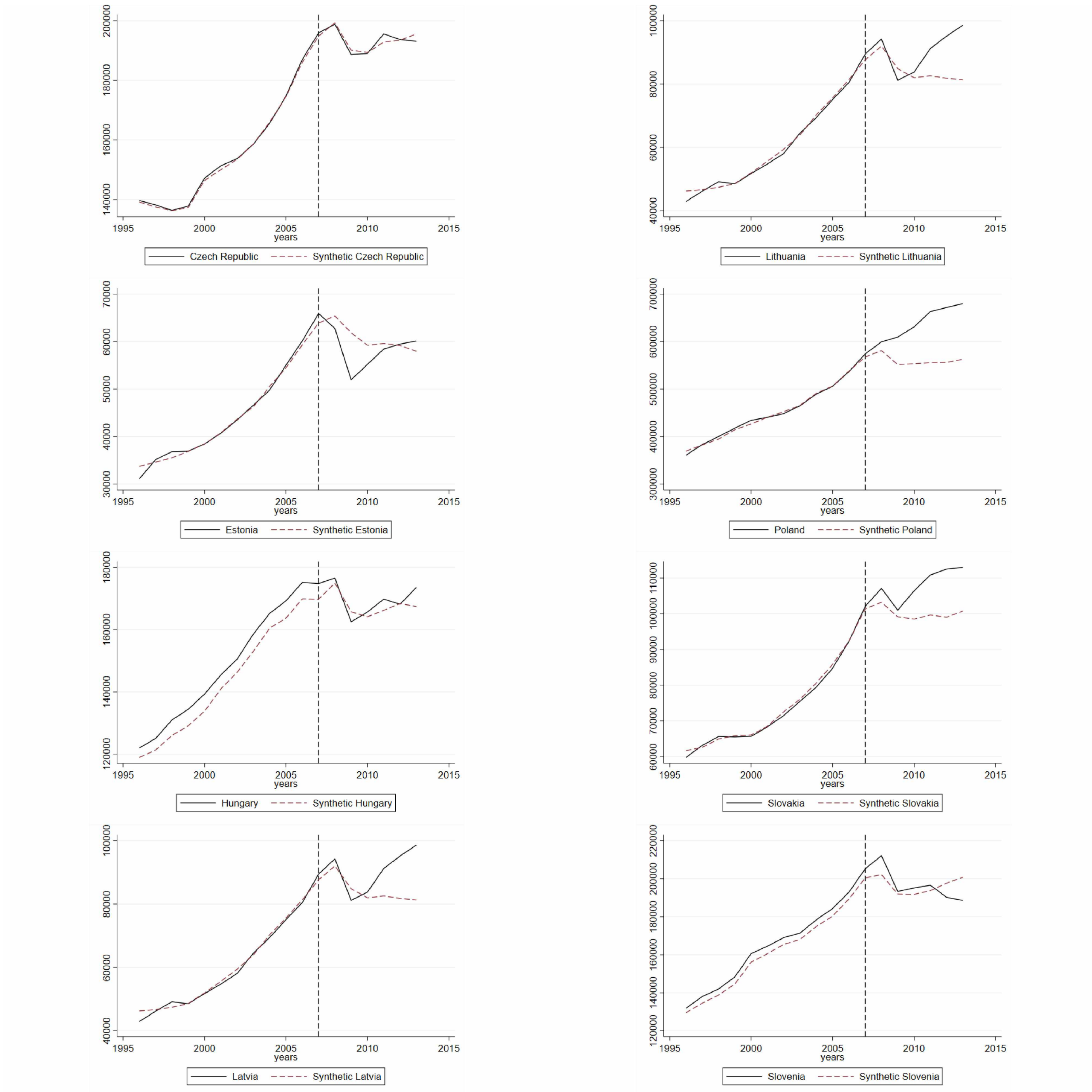
Figure 1.5: EU - Actual and Synthetic CEE Countries. Country-Specific Treatment Effects



Notes: Figure shows the effects of CEE countries joining the EU. The solid line denotes actual GDP per capita (2005 constant prices, €), in the Czech Republic, Hungary, Poland, Slovenia, Slovakia, Lithuania, Latvia, and Estonia. The dashed line represents the synthetic country - GDP per capita in CEE. The gap after 2004 shows the dynamic effects of the EU in CEE countries.

Source: Author's elaborations.

Figure 1.6: Schengen Area - Actual and Synthetic CEE countries. Country-Specific Treatment Effects



Notes: Figure shows the effects of CEE countries joining the Schengen Area. The solid line denotes actual GDP per capita (2005 constant prices, €), in the Czech Republic, Hungary, Poland, Slovenia, Slovakia, Lithuania, Latvia, and Estonia. The dashed line represents the synthetic country - GDP per capita in CEE. The gap after 2008 shows the dynamic effects of the Schengen Area in CEE countries.

Source: Author's elaborations.

Table 1.4: Regional Effects of Joining the EU and Schengen Area

	(1)	(2)	(3)
EU	RTE	RTE	RTE
Land Border	-0.277***		
	(0.060)		
Internal Border		-0.240**	
		(0.072)	
External Border			-0.364**
			(0.104)
Country Fixed Effects	YES	YES	YES
Observations	146	130	68
Adjusted R^2	0.412	0.330	0.470

	(1)	(2)	(3)
Schengen Area	RTE	RTE	RTE
Land Border	-0.354*		
	(0.151)		
Internal Border		-0.283*	
		(0.120)	
External Border			-0.592*
			(0.279)
Country Fixed Effects	YES	YES	YES
Observations	146	130	68
Adjusted R^2	0.381	0.392	0.350

Notes: Cross-sectional regional data consisting of eight CEE countries and 146 NUTS3 regions. *Estimation method:* OLS. *Dependent variable:* estimated RTE - regional effects of joining the EU and Schengen Area on GDP per capita. Robust standard errors in parentheses. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. *Source:* Author's calculations.

$$RTE_i^{2004} = \alpha_{eu} Border_i + X_i + D_c + \epsilon_i \tag{1.3}$$

$$RTE_i^{2008} = \alpha_{sch} Border_i + X_i + D_c + \epsilon_i \tag{1.4}$$

where RTE_i^{2004} and RTE_i^{2004} are the effects of the 2004 enlargement of the EU and 2008 Schengen expansion in NUTS3 region i, respectively; $Border_i$ is a dummy variable and equals one if it is a NUTS3 region with a land border, or is a region where more than half of the population lives within 25 kilometers of such a border; α_{eu} and α_{sch} show how the EU and Schengen Area outcomes differ in border versus interior regions; X_i denotes a set of observable characteristics including geographical factors, sectoral structure, and public perceptions about the EU; in order to capture unobserved country heterogeneity, I include country fixed effects represented by D_c, and ϵ_i is an error term estimated using heteroscedasticity-consistent robust standard errors.

The results in Table 1.4 column 1 indicate that, on average, joining the EU and Schengen Area negatively influenced border regions, compared to interior regions. The unconditional gap between the border and interior regions is significantly negative. If the region has land borders, the economic benefit of joining the EU declines by €277, and the benefit from entering the Schengen Area reduces by €354 per capita annually (i.e., approximately 10% of annual GDP per capita). It is worth noting that after dropping interior NUTS3 regions where the largest capital cities, Prague and Budapest, are located (e.g., 25 km from the land border), the baseline results are moderately robust (see Table 1.A.2).

I divide land borders into two categories: internal EU borders - (i.e., borders on neighboring fellow EU member sub-regions); and external EU borders (i.e., borders on neighboring non-EU member sub-regions). The unconditional gap between internal borders and interior regions due to the 2004 EU enlargement and the 2008 Schengen expansion is negative. So, internal border regions lose from European integration. Similarly, there is significant inequality between external EU border regions and interior regions, but the magnitude is higher when I compare external EU border regions and interior regions. In Table 1.4, the regional economic disparity between external border regions and interior regions is approximately 50% higher than the regional economic inequality between internal border regions and interior regions.

Heterogeneous effects in CEE sub-regions show that there are indeed winners and losers as a result of European integration. On average, border regions lose more from integration than interior regions. To analyze this more deeply, I investigate if border regions become "winners" when different types of integration facilitators complement European integration.

1.5 Mechanisms and Sensitivity Analysis

This study shows that, on average, joining the EU and Schengen Area had a lower effect on GDP per capita in border sub-regions than in interior regions. However, where border regions interact with integration facilitators, existing regional economic disparity within CEE countries may be reduced. Different types of proximities have important roles in cross-border cooperation because they can serve as impediments to, or facilitators of, social interactions (Boschma, 2005; Torre, 2008). Related literature has introduced three main categories of proximity: physical, relational, and sectoral (Shaw and Gilly, 2000; Torre, 2008; Boschma, 2005).

First, physical proximity is related to the geographical dimension, particularly to road conditions, time distance, transaction types, and transportation costs. It may be challenging to trade and enjoy free mobility in mountainous border areas. A lack of good roads in high-altitude regions complicates market access and hinders the free movement of goods, services, and people. Several studies have emphasized the importance of addressing tangible barriers in border regions to accelerate the economic integration process (Petrakos and Topaloglou, 2008; Capello et al., 2018). Second, relational proximity concerns the non-tangible dimension. It covers social and cultural proximities that affect social decisions and public opinions (Torre, 2008). One intangible barrier, negative attitudes toward the EU, can stem from cultural and historical dissimilarities between local and neighboring foreign sub-regions in the EU. Crucially, residents in sub-regions of CEE countries may support integration into the EU for economic and cultural reasons. Public opinion plays a salient role in determining whether countries integrate into the EU or not, so public perceptions about the EU are essential; they can hinder or accelerate the integration process (Bølstad, 2015; Brack and Startin, 2015). A great example of the importance of voters was a referendum in June 2016, in which residents of the United Kingdom voted to leave the EU (Brexit). So, where there is a lack of positive attitudes towards the EU in border regions, trade faces an invisible frontier. In general, the concept of European integration refers to the importance of removing barriers, particularly to cross-border services. With this in mind, the third facilitator is sectoral proximity. Service industries include transport, legal, accommodation, food, health, and tourism services; they require face-to-face interactions between buyers and sellers. Proximity to services is related to trading in the service sector across borders, while free movement of wholesale, retail, transport, accommodation, food, information, and communication is important in cross-border interactions. European integration guarantees the free movement of services; that is why the service sector is a salient factor in the integration process and enables direct intercommunication between locals and foreigners. In cross-border relations, it is important to have well-developed services along borders so that nationals and foreigners in border regions can benefit from opportunities accessible on both sides of the given border. For this reason, physical proximity, relational proximity, and sectoral proximity may shape the economic advantages gleaned in border regions relative to interior areas.

My findings indicate that a higher degree of integration, such as through joining the EU and the Schengen Area, leads to greater inter-regional inequalities. Thus, it triggers a divergence among RTEs in NUTS3 regions. The heterogeneity of RTEs suggests the importance of local characteristics and tangible and intangible factors, specifically geography and pre-integration conditions. These are important dimensions that shape economic outcomes together with economic integration. In the modified model in Equation 1.5, I introduce integration facilitators that may enhance the positive effect of European integration in border regions and reduce the economic gap between border regions and interior regions. I estimate the following modified model:

$$RTE_i = \beta_1 Border_i + \beta_2 Border_i \times Facilitator_i^k + \beta_3 Facilitator_i^k + D_c + \epsilon_i \qquad k \in 1, 2, 3 \tag{1.5}$$

where RTE_i represents the effects of joining the EU and Schengen Area in NUTS3 region i; $Border_i$ is a dummy variable and equals one if the NUTS3 region is a land border. And, interactions between $Facilitator_i^k$ and $Border_i$ represent integration facilitators in border regions. The first is a physical or geographical facilitator ($k = 1$): these areas have fewer physical barriers (e.g., they are low-altitude border regions). The second is a sectoral facilitator ($k = 2$), referring to border regions with a high share of service employment before they joined the EU and the Schengen Area in wholesale, retail, transport, accommodation, food services, information, and communication. The third is a relational facilitator ($k = 3$), referring to areas with border regions where the public voted to join the EU in a referendum.

Table 1.5: Regional Effects of Joining the EU and Schengen Area

	EU			Schengen Area		
	(1)	(2)	(3)	(1)	(2)	(3)
	RTE	RTE	RTE	RTE	RTE	RTE
Average Hill Shades (from high to low)	-0.007	-0.006	-0.018**	0.018**	0.020**	0.002
	(0.015)	(0.015)	(0.006)	(0.005)	(0.007)	(0.009)
Employment in Service Sector (2003)	4.344**	3.743*	4.863*	4.555***	5.005***	7.431**
	(1.828)	(1.694)	(2.072)	(1.274)	(1.054)	(2.844)
Pro-EU Attitudes (2003)	-0.002	0.001	0.000	-0.002	-0.004	0.003
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.005)
Land Border	-0.189**			-0.312*		
	(0.066)			(0.146)		
Internal Border		-0.222**			-0.292*	
		(0.065)			(0.143)	
External Border			-0.087			-0.165
			(0.109)			(0.241)
Country Fixed Effects	YES	YES	YES	YES	YES	YES
Observations	140	125	66	140	125	66
Adjusted R^2	0.327	0.245	0.404	0.435	0.466	0.478

Notes: Cross-sectional regional data consisting of eight CEE countries and 146 NUTS3 regions. *Estimation method:* OLS. *Dependent variable:* estimated RTE - regional effects joining the EU and Schengen Area on GDP per capita. Robust standard errors are in parentheses. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. *Source:* Author's calculations.

In addition to baseline results, Table 1.5 shows the conditional means, where I control for different local characteristics, including the altitude of the region, public perceptions about the EU, and the employment share in the service sector before the country joined the EU. I find that the gap after European integration becomes significantly negative between border regions and interior regions in CEE countries, *ceteris paribus*. Similarly, the gap is negative between internal borders and interior areas. The results in Table 1.5, column 2 match the findings in Table 1.4 column 2. This implies that the differences between the border regions and interior regions result purely from the locational border effect. However, if I compare results from Table 1.4, column 3 to those in Table 1.5 column 3, the gap is insignificant between external borders and interior regions, *ceteris paribus*. This suggests that inequality is not determined by geographical location or the border effect and could be explained by regional or economic characteristics.

As European integration has affected border regions less than interior regions, I question whether there are variations between boundary locations and if some facilitators can offset the negative effect. Interestingly, the negative integration effect in border regions versus that in their interior counterparts is so strong that the negative border effect persists even when I apply integration facilitators. There is no significant relationship between the interaction terms in Table 1.6.

This paper has three main findings. First, I construct RTEs using a disaggregated synthetic control methodology. The results indicate the heterogeneity of the effects of European integration. As illustrated in Figure 1.3, in the RTEs map, some regions have been positively affected by European integration, while others have not. Second, this study shows significant evidence of inequality between border regions and interior regions within CEE countries after integration. Border regions, on average, lose out from integration compared to interior regions. Specifically, internal border regions that directly neighbor former EU sub-regions lose relative to interior regions. In contrast, external border regions that directly neighbor non-EU sub-regions lose not because of their location but due to economic conditions. Third, I introduce different types of trade facilitators, but even with such complementarities, the gap between border regions and interior regions within CEE countries persists.

I can conclude that the positive effects of European integration are found more in interior regions rather than in border regions and that such economic integration has exacerbated significant within-country inequalities.

Table 1.6: The Effect of European Integration Complemented with Facilitators in Internal EU Borders

	European Union			Schengen Area		
European Union	(1)	(2)	(3)	(1)	(2)	(3)
	RTE	RTE	RTE	RTE	RTE	RTE
Internal Border	-0.276	0.080	-0.306	0.267	1.383*	1.609
	(1.150)	(0.489)	(0.794)	(1.317)	(0.720)	(0.872)
Average Hill Shades (from high to low)	-0.006	-0.006	-0.006	0.023***	0.021**	0.021**
	(0.013)	(0.015)	(0.015)	(0.003)	(0.007)	(0.006)
Employment in Service Sector (2003)	3.739*	4.262**	3.750*	5.043***	7.882***	4.844***
	(1.743)	(1.452)	(1.751)	(1.018)	(2.107)	(0.993)
Pro-EU Attitudes (2003)	0.001	0.001	0.001	-0.004	-0.007	0.002
	(0.003)	(0.003)	(0.005)	(0.003)	(0.004)	(0.005)
Internal Border × Average Hill Shades	0.000			-0.003		
	(0.006)			(0.007)		
Internal Border× Employment in Service Sector		-1.407			-7.799	
		(2.457)			(4.304)	
Internal Border × Pro-EU Attitudes			0.001			-0.025
			(0.011)			(0.014)
Constant	0.121	-0.006	0.100	-4.189***	-4.241***	-4.221***
	(2.158)	(2.297)	(2.214)	(0.394)	(1.101)	(1.036)
Country Fixed Effects	YES	YES	YES	YES	YES	YES
Observations	125	125	125	125	125	125
Adjusted R^2	0.239	0.240	0.239	0.461	0.500	0.475

Notes: Cross-sectional regional data consisting of eight CEE countries and 146 NUTS3 regions. *Estimation method:* OLS. *Dependent variable:* estimated RTE - regional effects of joining the Schengen Area on GDP per capita. Robust standard errors are in parentheses. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. *Source:* Author's calculations.

1.6 Conclusion

There is a heated debate about a growing spatial disconnect of economic performance in CEE countries, with some regions growing and others lagging in the aftermath of their European integration. This study adds to the growing body of research indicating "winners and losers" of European integration. Using European regional data and disaggregated synthetic control method, this paper is one of the first to attempt to thoroughly examine the effects of joining the European Union in 2004 and the Schengen Area in 2008 at the sub-regional level. I obtain precise estimates for every RTEs as a result of European integration. I find that the positive effects of European integration on annual GDP per capita are approximately 10% less in border regions relative to interior regions. Perhaps the main reason previous studies on European integration reached inconclusive results was that these studies treated interior regions as counterfactual. In this paper, I address these concerns and contribute to the literature by proposing a refined counterfactual scenario. This strategy allows me to derive new evidence on economic disparities between border and interior regions. The main results show that becoming a member of the EU or Schengen Area has an unequal impact on economic performance in sub-regions of CEE countries. Using RTEs, I find that border regions are losers from their countries joining the EU and the Schengen Area relative to interior regions. The results are consistent when I drop from the sample interior sub-regions where the largest capital cities, such as Prague and Budapest, are located. Further, this paper provides additional evidence that integration facilitators, including fewer geographical obstacles, more service employment, and positive public perceptions about the EU, do not obviate the loss in border regions. Further research is needed to fully understand why border regions have relatively negative outcomes from EU accession and expansion of the Schengen Area. Future work will focus on case studies of border regions at a granular level to uncover specific mechanisms and channels through which European integration affects the internal structure of border regions.

1.7 Appendix A: Descriptive Statistics

Table 1.A.1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
GDP per capita in constant prices R	10103.105	11012.156	1628.120	96850.422
Industry Share of GVA at constant prices	0.278	0.106	0.046	0.774
Agriculture share of GVA at constant prices	0.072	0.060	0.000	0.562
Employment in industry (share of total employment)	0.249	0.088	0.041	0.576
Population (log)	12.781	0.652	10.777	14.594
Regions size (log) (in km2)	8.712	0.834	5.886	10.872
Distance to the nearest border (from nuts3 centroid) (in km)	92.006	76.913	6.049	333.495
Road Distance to nearest foreign region's centroid (in km)	196.239	129.906	15.110	780.530
Share of population voted in favor in referendum (2003)	55.671	28.272	10.919	96.090
Employment share in the service sector (2003) wholesale, retail, transport, accommodation, food, information, and communication	0.208	0.052	0.101	0.359
Average hill shades	174.350	11.736	110.964	183.496
Land border (dummy)	-	-	0	1
Estimated Regional Treatment Effects on GDP per capita in thousands (European Union)				
Border (N=94)	-0.218	0.934	-2.782	2.326
Interior (N=52)	0.109	0.847	-2.042	3.236
Estimated Regional Treatment Effects on GDP per capita in thousands (Schengen Area)				
Border (N=94)	0.4045	0.748	-1.21	3.614
Interior (N=52)	1.099	1.017	-1.117	4.125

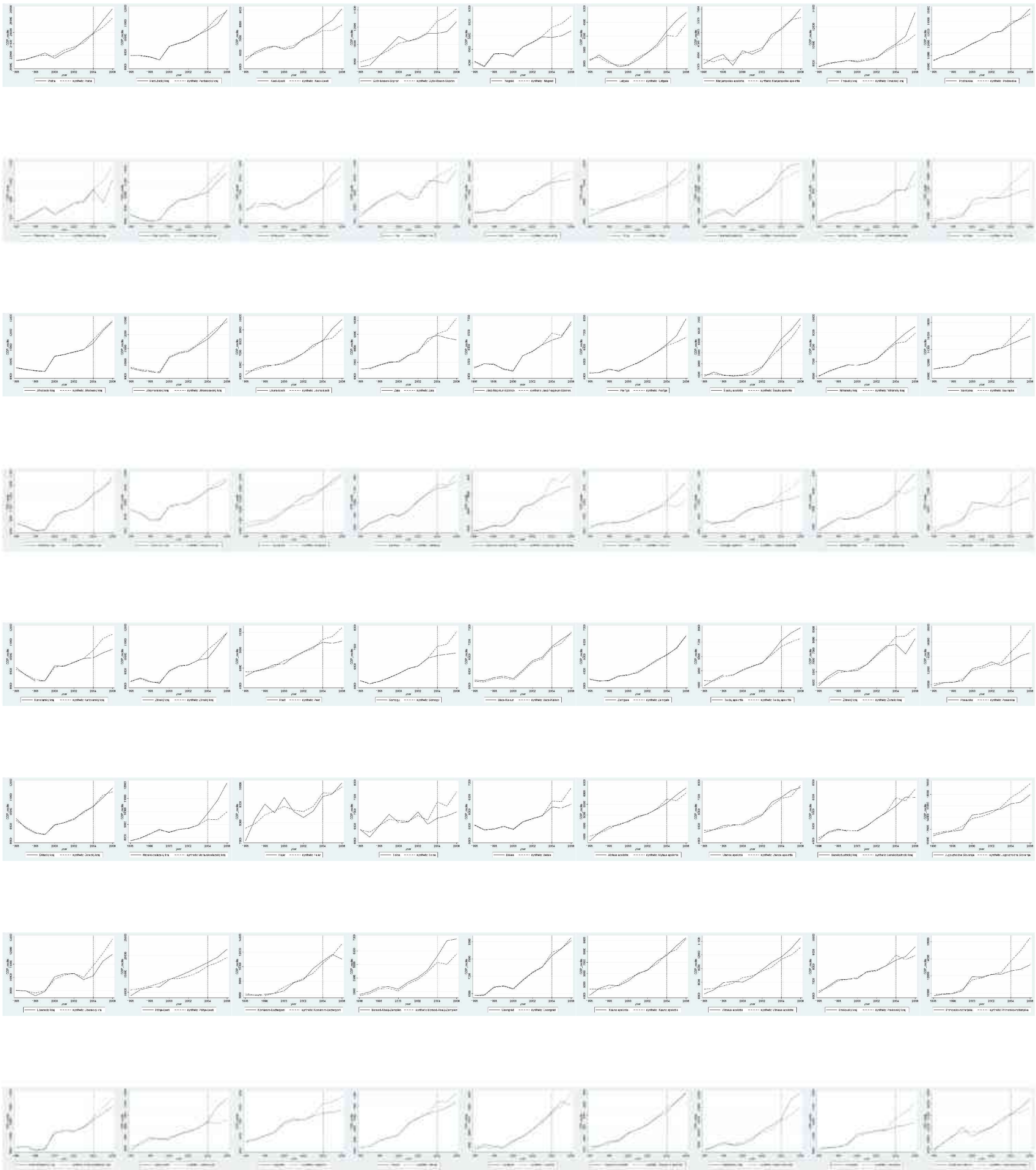
Table 1.A.2: Regional Effects of Joining the EU and Schengen Area (excluding NUTS3 Interior Regions of Prague and Budapest)

	(1) RTE (EU 2004)	(2) RTE (Schengen 2008)
Land Border	-0.200**	-0.344*
	(0.078)	(0.086)
Country Fixed Effects	YES	YES
Observations	144	144
Adjusted R^2	0.451	0.417

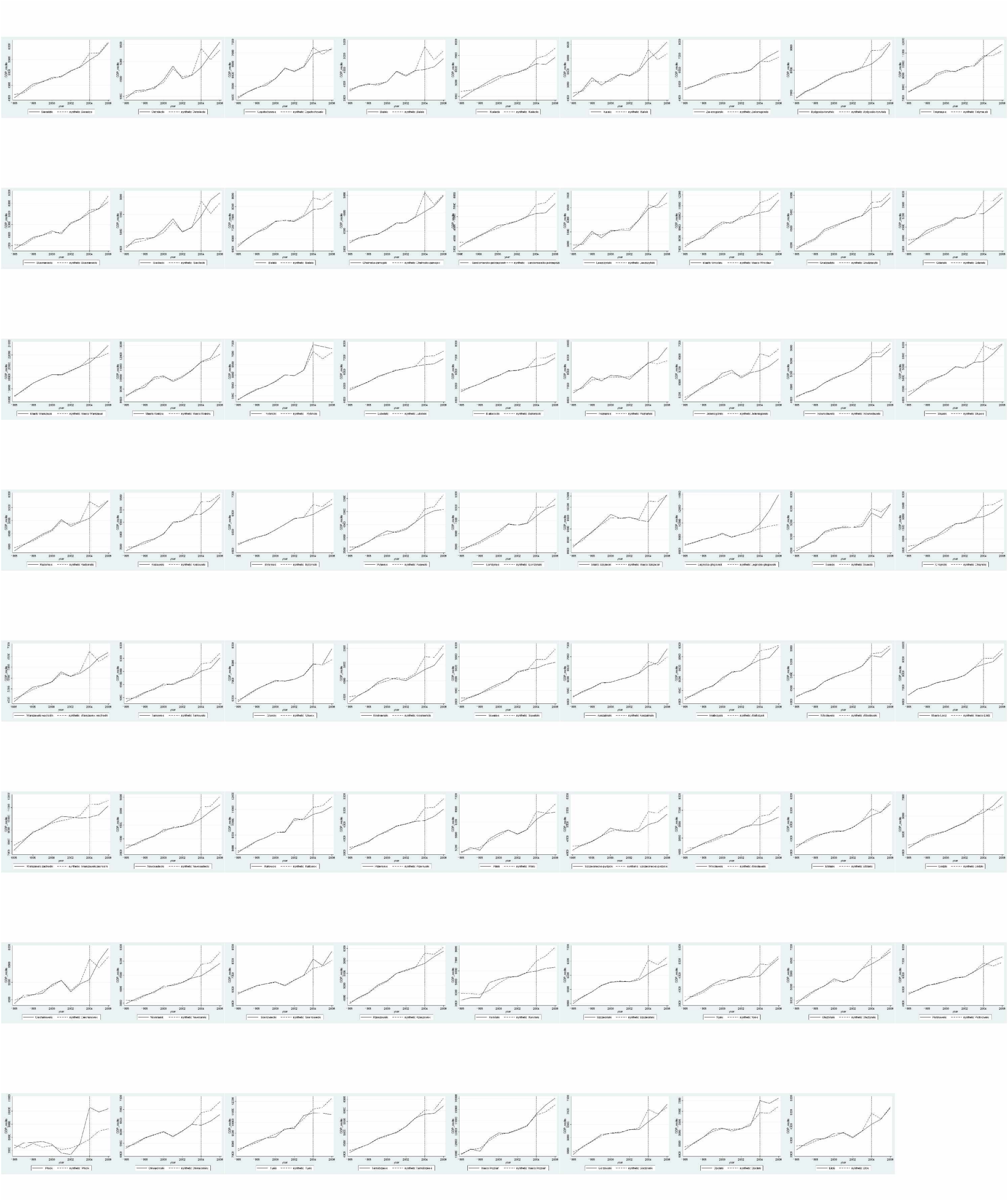
Notes: *Estimation method:* OLS. *Dependent variable:* estimated RTE - regional effects of joining the EU and Schengen Area on GDP per capita. Robust standard errors are in parentheses. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. *Source:* Author's calculations.

1.8 Appendix B: Individual Regional Synthetic Controls

1.B.1. Disaggregated Synthetic Controls of EU



cont. 1.B.1. Disaggregated Synthetic Controls of EU



1.B.2. Disaggregated Synthetic Controls of Schengen Area

cont. 1.B.2. Disaggregated Synthetic Controls of Schengen Area

CHAPTER 2

2 Bringing Together What Belongs Together: The Case of Divided Border Cities in Europe

2.1 Introduction

"One city, two states" - the motto of Valga-Valka

The concentration of economic activities within cities has been a subject of interest in urban economics for many years. The concentration of economic activities within cities is a complex phenomenon that can be influenced by a combination of natural factors (first-nature geography) and human interactions (second-nature geography). First-nature geography refers to the inherent characteristics of a location, such as its access to natural resources, climate, topography, and other physical features. These natural advantages can attract economic activities to specific areas. Second-nature geography, on the other hand, focuses on the social and economic interactions that arise from the proximity of firms, people, and infrastructure within urban areas. When businesses and individuals are located close to each other, it can lead to benefits such as knowledge spillovers, reduced transportation costs, labor market efficiencies, and networking opportunities. These agglomeration effects can further enhance the concentration of economic activities in cities. However, distinguishing between the effects of first-nature and second-nature geography can be challenging because they often interact and reinforce each other. For example, a city with favorable natural amenities (first-nature geography) might attract a highly skilled workforce and innovative firms (second-nature geography), leading to a self-reinforcing cycle of economic concentration. Researchers in urban economics strive to disentangle these factors to understand the drivers of economic agglomeration better and to formulate effective urban planning and policy strategies.

This paper aims to address the challenge of finding exogenous variations that are uncorrelated with locational fundamentals by examining a unique quasi-natural setting of removing borders along divided European historical border cities that were once united in the past. I show that local economic activities, measured by remotely sensed nighttime lights (NTL) and by the number of newly established firms, concentrated denser and closer to the pre-division 20th-century centers as Schengen has abolished border barriers and facilitated the free movement of people across Europe. This paper takes a comprehensive and multinational perspective by examining 22 European historical cities in 10 European countries. It aims to provide a high-resolution analysis by utilizing localized data specific to each historically divided city.

Divided historical border cities in Europe were one urban unit before the World Wars, and after major international border shifts, cities came apart. For example, the historical German city Frankfurt (Oder) was divided into an East German city - Frankfurt (Oder), and a Polish city - Slubice; the latter was a German suburb called Dammvorstadt until 1945. The lack of cooperation between East Germany and Poland during the communist era created obstacles to cross-border interactions and economic integration. The division of Frankfurt (Oder) and Slubice resulted in economic activities being dispersed away from the pre-division centers due to the restricted movement and limited cooperation between the two separated cities. However, the Eastern enlargement of the European Union in 2004 and Poland's subsequent entry into the Schengen Area in 2008 further facilitated the stepwise development of cross-border cooperation and the free movement of goods, people, and services between the two cities[1]. After joining Schengen, all border barriers were lifted, enabling divided cities to work together freely once again. I show that economic activities began to re-concentrate toward the pre-division centers. My results suggest that integration

[1]It was difficult to freely cross the internal borders between the cities until Poland joined the Schengen Area in 2008.

policies can bring together what historically belongs together, internal city structures change, and the concentration of economic activities shifts to historical centers.

My paper builds on the large literature on the effect of quasi-natural experiments on the location of economic activity within cities, particularly from a historical perspective. One strand of literature has explored technological inventions in transportation or transportation extensions, e.g., Baum-Snow et al. (2005) examines the effects of urban rail transit expansions in sixteen major U.S. cities; Brooks and Lutz (2019) study the period when streetcars dominated urban transit in Los Angeles county and explore the effects of transportation infrastructure on economic concentration; Heblich et al. (2020) focus on the invention of steam railways in London and analyzes the impacts of transportation innovations on economic clustering. Another strand of literature studies the role of historical policies and historical events within cities, including Arzaghi and Henderson (2008), which investigated the factors influencing the spatial distribution of advertising agencies in Manhattan. They focused on the role of networking externalities and agglomeration economies in shaping the location decisions of advertising agencies; Rossi-Hansberg et al. (2010) examined the impact of urban revitalization policies on housing externalities in Richmond, Virginia. They focused on concentrated revitalization programs that aimed to improve specific neighborhoods within the city, and Ahlfeldt et al. (2015) examined the economic consequences of the division and subsequent reunification of Berlin, Germany. It seems as if there is some consensus on understanding the sources and dynamics of economic concentration within the cities. However, the area is still under-researched. The existing literature often focuses on specific cities, which may limit the generalizability of the findings. Each city has its unique characteristics, historical background, and economic structure, which can lead to different channels of agglomeration forces at play.

This paper contributes to the stream of literature by exploring a unique quasi-natural experiment of opening borders within cities, which used to be one city in the past and were divided following major historical conflicts. The closest to my work is a study by Ahlfeldt et al. (2015), where authors study how the reunification of Berlin affected the city's economic landscape, including the role of historical city centers and their transformation in the postreunification era. My central contribution is assessing border effects for a different type of border (e.g., with its different historical and institutional circumstances) than the imposition and removal of the Iron Curtain. In contrast to their study, my paper which studies cities that were split into two different countries with different languages and cultures, allows me to shed some light on different mechanisms and channels.

My paper's setting of multiple border cities and detailed NTL and business register data allows me to study different underlying economic mechanisms and channels of agglomeration forces, something that has not been studied yet, to the best of my knowledge. The paper has the main findings in the following three aspects.

First, the implementation of the free movement of people policy in 2008 had a significant impact on reorienting economic and human activities towards pre-division city centers. However, the "borderless market" or free movement of goods, services, and capital in 2004 did not have the same effect. This indicates that factors other than the movement of goods and capital, such as the direct engagement and interaction of people, play a more significant role in driving economic concentration near historical centers.

Second, city heterogeneity allowed me to investigate the role of language and cultural closeness between divided city pairs. While historical centers tend to be hubs of social activities, language similarity should enhance participation and integration into cross-national networks. Therefore, I show that businesses are more likely to concentrate on areas where they can effectively communicate and engage with the local and foreign markets. I show that economic activities concentrate closer to former historical centers in city pairs where lexical similarities are high between languages in divided cities and cultural and language differences are not barriers to cross-border cooperation.

Third, using a data set on registered firms in divided border cities, I show that the consumption-oriented sectors concentrate near pre-division centers. Firms in the consumption sector facilitate greater interaction and connectivity among local and foreign people. I show that restaurants, cafes, and cultural and entertainment venues started operating in a close radius of former historical centers after removing all types of borders in divided cities. Customers from both sides of the formerly united city can come to these areas, leading to increased physical movement and social interactions. This increased human mobility could create shared spaces, fostering a sense of togetherness and community within the divided city.

This paper also contributes to the European integration literature. While there has been researched on the broader impacts of EU integration on regional development and urbanization patterns *across* European cities (Brakman et al., 2012; Brülhart et al., 2018; Heider, 2019), the concentration and spatial distribution of economic activities *inside* cities in the course of European integration have not been studied before.

The rest of the paper is organized as follows: Section 2 introduces the history of the study area with a particular focus on city division and historical city centers; Section 3 explains the data; Section 4 presents the empirical framework and main results; Section 5 discuss the channels; Section 6 concludes the paper.

2.2 Historty of Study Area

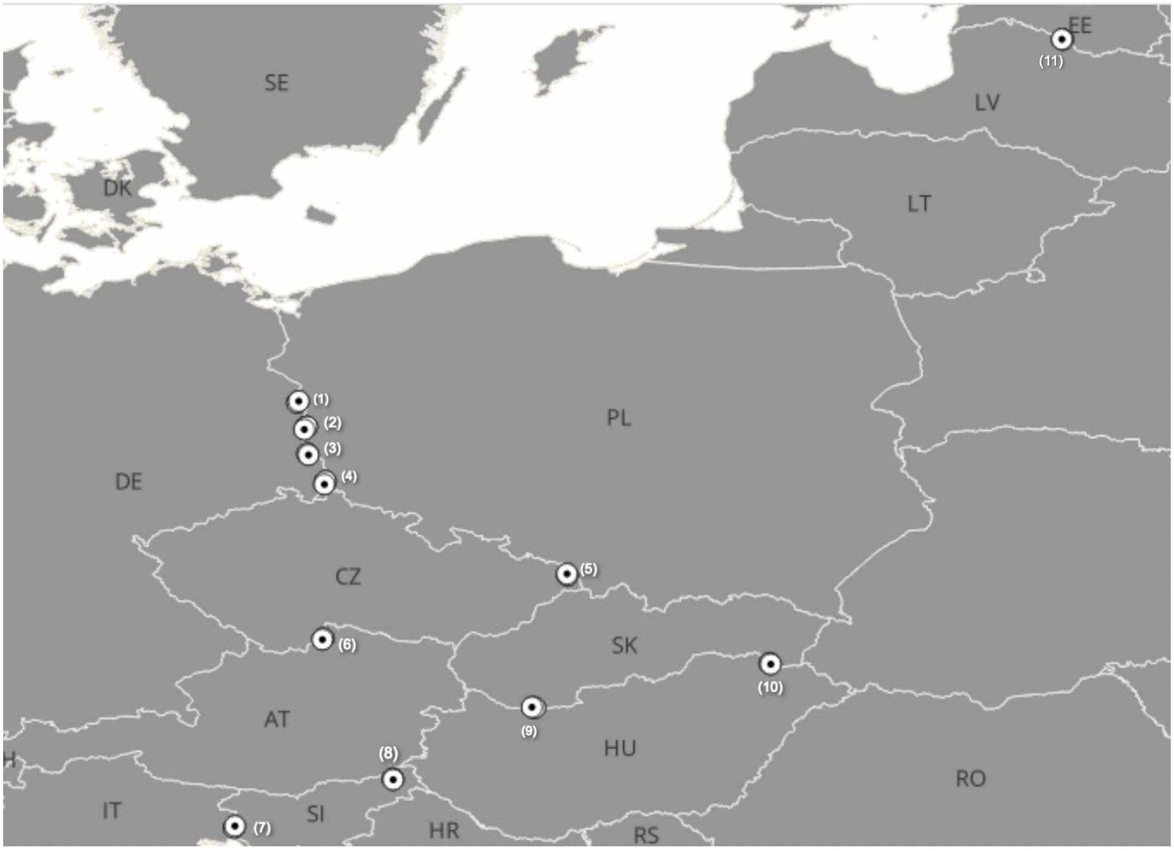
2.2.1 City Division

The geographical division of some European cities occurred mainly after two major shocks, World Wars I and II. WWI brought about the collapse of multinational empires - the Russian, Ottoman, Austro-Hungarian, and German. Consequently, new borderlines were drawn in Europe, and some European cities were divided into separated city parts due to conflicts and border shifts. Cities that were united at the beginning of the 20th century and later divided are located along the borders of Austria-Slovenia, Hungary-Slovakia, Poland-Czechia, Austria-Czechia, and Latvia-Estonia. These city locations are illustrated in Figure 2.1, and a detailed description is provided in Table 2.1.

After World War I (1914-1918), there were significant territorial adjustments and the creation of a new nation. After years of conflict between countries, in total, 12 historical border cities were divided. As for World War II (1939-1945), there were also significant territorial changes and political shifts. Therefore, ten historical border cities were divided due to this tension.

During the first half of the 20th century, other newly founded republics of Estonia and Latvia entered into a conflict over the historical city of Walk. In 1919, the city was divided; the Estonian part was called Valga, and the Latvian side, Valka. The Baltic states were invaded and occupied from June 1940 until 1990 by the Soviet Union[2]. In 1991, Latvia and Estonia declared independence.

Figure 2.1: Divided Border Cities in Europe



Source: Author's elaboration based on GISCO shapefiles.

Notes: Circles on the map illustrate 22 divided cities in 10 European countries, i.e., Germany (DE), Poland (PL), Czechia (CZ), Slovenia (SI), Slovakia (SK), Austria (AT), Hungary (HU), Italy (IT), Estonia (EE), and Latvia (LV). Divided cities are (1) Frankfurt (Oder) - Slubice, (2) Zgorzelec - Gorlitz, (3) Guben - Gubin, (4) Leknica - Bad Muskau, (5) Ceske Teshin - Cieszyn, (6) Gmund - Ceske Velenice, (7) Nova Gorica - Gorizia, (8) Bad Radkersburg - Gornja Radgona, (9) Komarom - Komarno, (10) Satoraljaujhely - Slovenske Nové Mesto, (11) Valga - Valka

After WWI, the newly created independent states of Poland and Czechoslovakia engaged

[2]The historical city of Walk was *united* in the Soviet Union.

in conflict over the area of the city of Teschen. Because the highest authorities in both nations could not reach a consensus, the city of Teschen was divided into a Polish part, Cieszyn, and the Czechoslovak area became Cesky Tesin in 1919. Further, until 1918, Ceske Velenice was part of the Austrian city of Gmund. At the end of WWI, following the Treaty of Saint-Germain-en-Laye (1919), the territory officially became part of Czechoslovakia - a new Czech city. Similarly, Gornja Radgona, which is located on the northern edge of Slovenia, was historically a part of the Austrian city of Bad Radkersburg - a divided city on the other side of the Mura River. They were divided in 1919 when the state of Styria was divided into Austria and Slovenia. Further, in the same period, the city of Komárom was divided along the national border between Hungary and Czechoslovakia (today, Slovakia), creating the city of Komarno in Slovakia and Komarom in Hungary.

Table 2.1: Divided Cities in Europe

Historical City	Divided City (A)	Divided City (B)	Rise of Borders	Fall of Borders	20th century centers
Frankfurt	Frankfurt (Oder) (DE)	Slubice (PL)	1945	2008	Museum Viadrina (DE)
Gorlitz	Gorlitz (DE)	Zgorzelec (PL)	1945	2008	Historical & Cultural Museum (DE)
Guben	Guben (DE)	Gubin (PL)	1945	2008	City & Industry Museum (DE)
Bad Muskau*	Bad Muskau (DE)	Leknica (PL)	1945	2008	Schlobvorwerk (DE)
Gorizia	Gorizia (IT)	Nova Goricia (SI)	1945	2008	Palazzo Lantieri (IT)
Bad Radkersburg*	Bad Radkersburg (AT)	Gornja Radgona (SI)	1919	2008	Frauenkirche Bad Radkersburg (DE)
Komarom	Komarom (HU)	Komarno (SK)	1919	2008	Gyorgy Klapka Museum (HU)
Satoraljaujhely*	Satoraljaujhely (HU)	Slovenske Nove Mesto (SK)	1919	2008	Kazinczy Ferenc Muzeum (HU)
Teschen	Cieszyn (PL)	Cesky Tesin (CZ)	1919	2008	Museum of Cieszyn Silesia (PL)
Gmund	Gmund (AT)	Ceske Velenice (CZ)	1919	2008	Schloss (Castle) Gmund (AT)
Walk	Valka (LV)	Valga (EE)	1919	2008	Valga Museum (EE)

Source: Author's elaboration.

Notes: The first column shows the names of historical cities. The second and third columns present the names of cities after they were divided. The fourth column shows the year a city was divided and intra-city borders were established. The fifth column indicates when border controls were lifted. The sixth column displays the names of all historical centers - historical museums, plazas, churches, and city halls. I dropped some divided European cities from the sample due to their small sizes, including Laufenburg (Laufenburg, Germany and Laufenburg, Switzerland) and Rheinfelden (Rheinfelden, Germany and Rheinfelden, Switzerland). During the Soviet era, Valga and Valka were once united and then separated again in 1992 when the Soviet Union was dissolved. Cities denoted by an asterisk (*) are not part of the sample due to their small size.

At the end of World War II, Europe underwent further significant changes to the locations of its internal international borders. For example, in 1945, after the defeat of Nazi Germany, the Oder–Neisse line became Poland's western and Germany's Eastern border. At the end of WWII, a new international border was established between Germany and Poland, dividing four historical border cities. Thus, four new border city pairs emerged along the new borderline, including Frankfurt (Oder)-Slubice, Gubin-Guben, Gorlitz-Zgorlec, and Bad Muskau-Leknica.

In 1947, after WWII, Italy signed a peace treaty with Yugoslavia (today, Slovenia) and handed over half of Gorizia[3]. A new city, Nova Gorica, was built on the other side of the Slovenian border area, and the rest of the city of Gorizia remained in Italy. When Yugoslavia broke up in 1992, the physical border remained between the two cities, forming the dividing line between Italy and Slovenia.

These barriers lasted decades until New Member States (Czechia, Slovakia, Poland, Hungary, Slovenia, Latvia, Estonia) started stepwise lifting borders in 2004. Though the physical barriers still remained. The final step of pulling together the divided cities was in early 2008 after countries signed the Schengen Agreement[4]. Therefore, the historical cities physically returned to their pre-division conditions.

2.2.2 Historical City Centers (HCTRs)

In divided border cities, the historical significance and symbolism of the city center can play an important role in encouraging economic activity. The historical center may serve as a symbol of common identity & the city's historical roots, serve as a meeting place for residents on both sides of the border, and establish a sense of belonging and shared history. However, before European integration started, the presence of a physical border or barrier within the city was an obstacle to the historical center's operation. Newly emerged borders oftentimes cut through or were located near former city centers, which were typically the most economically active and lively portions of a city. Divided cities had checkpoints, security measures, and restricted access points that affected the movement of people and

[3]Gorizia and Nova Gorica were often compared to West and East Berlin before and after Iron Curtain.

[4]See Figure 2.C.1, for photo example illustration.

goods within the historical center.

In the post-war period, international borders and areas close to historical city centers were a serious barrier to economic activity for several reasons. First, zones close to borderlines were not fully protected while troops continued to fortify these territories until the end of the 20th century. Second, when barriers were raised, and people with hostile intentions took control of a territory, it could have various negative effects on economic activities. As a result, economic activities could move away from the newly emerged borders (away from the historical city center). Therefore businesses, industries, and investors may choose to relocate to safer and more stable areas. This could result in the displacement of jobs, reduced wages, and limited employment opportunities for the local population.

My hypothesis framework is based on three phases during 1900-2022. Phase I corresponds to the pre-war period of 1900-1939, Phase II refers to the post-war & prior to EU integration period of 1946-1989, and Phase III represents the period of EU integration, 1990-2022.

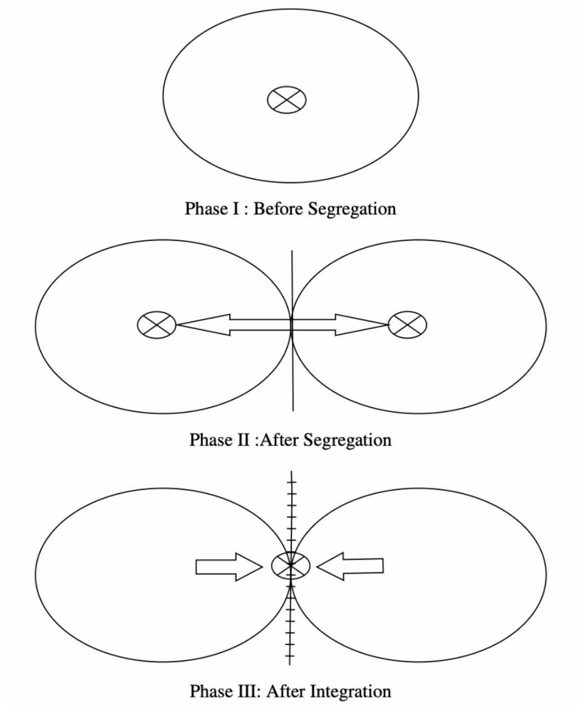
Phase I (before segregation): Early 20th century is the pre-war period prior to when cities became separated. In Figure 2.2 pre-war historical center *A* refers to the older part of a city that was established before the wars. These areas often contain historic buildings, landmarks, and cultural heritage that survived the conflict - serve as important cultural, tourist, and architectural attractions, reflecting the history and character of the city prior to the division.

Phase II (after segregation): The second half of the 20th century was marked by significant geopolitical changes. The aftermath of World War II led to the redrawing of boundaries and the fragmentation of cities. The establishment of new borders or the division of cities could affect transportation networks and connectivity. Economic activities may disperse to areas with improved transportation infrastructure, away from the borderline. I hypothesize that economic activities move from pre-war centers towards the centroid direction, as it is depicted in Figure 2.2. Also, impaired accessibility to local markets, suppliers, and customers could incentivize businesses to relocate to interior areas.

In early 1990, a process of reintegration and convergence began in Europe. The reintegration process gained significant momentum with the formation of the EU in 1993.

Phase III (after integration): The Eastern enlargement was a significant step toward promoting economic integration and cooperation within the EU in 2004. It aimed to ensure the free movement of goods, services, capital, people, and labor across the enlarged EU. However, it is important to note that even after joining the EU in 2004[5], certain barriers to full integration remained for the new member states. One key milestone in achieving full free movement was the abolition of internal border barriers.

Figure 2.2: Three Phases of Hypothesis Framework



Notes: Dashed circles in the circles represent 20th historical city centers. Arrays denote in which direction economic activities move. The solid line represents emerged border. The dashed line represents a lifted intra-city or state border.

In 2008, the Schengen Agreement was implemented, which allowed for the elimination of internal border controls. By removing internal border barriers, the Schengen Agreement

[5]It is worth noting that participation in the Schengen Area is not automatic upon joining the EU, and countries must meet certain criteria related to border control and security before gaining full membership.

enabled individuals to travel without passport checks between divided cities. This significantly impacted cross-border economic activities, as it streamlined trade, tourism, and labor mobility. The free movement of people facilitated by the Schengen agreements has fostered closer cooperation and integration between the newly joined countries and the existing EU member states, especially in the context of divided historical cities.

2.3 Data

I mainly utilize two datasets. First, I use NASA's satellite images of Earth at night to measure socio-economic activities at a granular level. Second, I use European business registers to deliver a rich dataset of different types of registered economic entities at a low spatial scale.

2.3.1 Satellite Nightlights

This paper uses nighttime light data measured by satellites - the only available data source that provides a proxy for the degree of socioeconomic activities since 1992 in Europe at sufficient granularity. In the context of Europe, where comprehensive and fine-grained data might be challenging to obtain, nighttime light data fill a critical data gap. The availability of consistent and reliable nighttime light data allows researchers to examine socioeconomic patterns, track changes, and explore relationships between human activity and various socioeconomic variables.

Researchers often encounter limitations when obtaining certain types of data, including official statistics such as gross domestic product (GDP), population numbers, and employment rates. These limitations often arise due to constraints related to spatial scale and temporal coverage. Eurostat, the statistical office of the European Union, provides administrative data on economic activities in Europe, but these data are typically aggregated at the NUTS2 and NUTS3 levels, which is unsuitable for fine-grained analysis within cities.

In my paper, I aim to overcome these limitations by utilizing satellite-detected nighttime light data. Nighttime light data have been extensively used in economics and are considered one of the most feasible data sources for observing changes in economic or human activities within cities over time. Several studies have measured economic and human activities using the stable nightlights of the Defense Meteorological Satellite Program (DMSP-OLS) in African cities (Michalopoulos and Papaioannou, 2014; Storeygard, 2016; Eberhard-Ruiz and Moradi, 2019; Dreher et al., 2019); in world cities (Hodler and Raschky, 2014; Düben and Krause, 2021; Kocornik-Mina et al., 2020; Mamo et al., 2019; Lessmann and Seidel, 2017); in Indian cities (Gibson et al., 2015; Castelló-Climent et al., 2018); in Indian constituencies (Baskaran et al., 2018; Prakash et al., 2019); in Barbados beaches (Corral and Schling, 2017); in Haiti communes (Mitnik et al., 2018); in OECD countries (Smith and Wills, 2018); in North Korea (Lee, 2018); and in Indonesian sub-districts (Heger and Neumayer, 2019). This dataset has been particularly useful for studying urbanization, economic development, energy consumption, environmental impacts, and other socioeconomic factors. Above mentioned studies have explored a wide range of socioeconomic variables, including GDP estimation, urbanization rates, economic inequality, population distribution, and even public health indicators. The stability and consistent coverage of DMSP-OLS nightlights make it a valuable resource for investigating long-term trends and patterns of economic and human activities at city, national, and global scales.

DMSP-OLS captured nighttime images of the Earth from 1993 to 2013. These images were obtained by satellites equipped with sensors that measure the intensity of lights emitted during the night. The resulting raster images have a resolution of 30 arc seconds, which is approximately equivalent to 1x1 km at the equator. This level of detail enables examining changes at a high-resolution spatial level.

In the DMSP-OLS raster images, each pixel is assigned a digital number (DN) that represents the intensity of lights in that area. The DN values range from 0 to 63, with 0 indicating no lights and 63 representing the highest concentration of lights. By analyzing these DN values, researchers can quantify the brightness or intensity of nighttime lights and use this information to study various socioeconomic phenomena. The detailed data are described in Table 2.A.1 and Figure 2.A.1. I built an app that displays dynamics of remotely sensed nightlights in historically divided border cities.

While other datasets, such as the Visible Infrared Imaging Radiometer Suite (VIIRS)

Day/Night Band, have been introduced since 2013 and offer improved capabilities, DMSP-OLS remains the most commonly used dataset for studying long-term trends and relationships between human activity and nighttime lights. Due to the consistent and long-term coverage provided by DMSP-OLS, as well as its relatively high spatial resolution, it has become the common data source for studying long-term changes in nighttime lights and their association with socioeconomic variables.

2.3.2 Registered Economic Entities

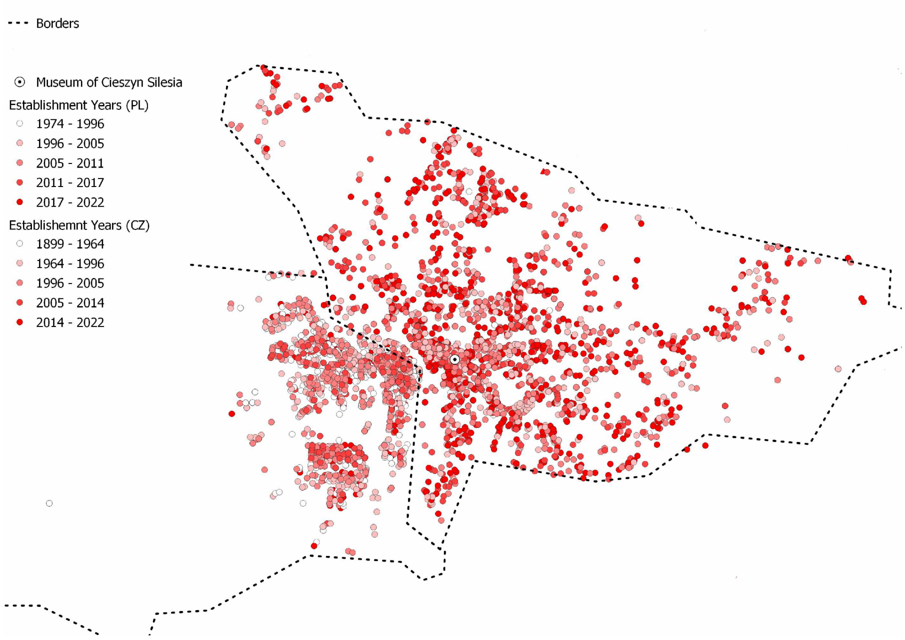
The concentration of economic activities near historical city centers can be attributed to several channels. These channels can reflect various factors and dynamics that contribute to the spatial organization of economic activities within cities.

Many historical city centers were established centuries ago, and over time, they became the central hubs of economic and social activities. As a result, businesses catering to consumer needs, such as retail stores, restaurants, cafes, entertainment venues, and tourism-related services, tend to cluster in these areas. This paper account for sectoral specialization, which has not yet been addressed in previous studies. I have collected firm-level data which allows me to understand the dynamics and patterns of economic activities near historical city centers - the specific characteristics and location choices of individual businesses within the city.

In order to uncover this channel, I use information from registers of economic entities. I constructed the database by bringing together several datasets containing information on about registration of economic entities. I define an economic entity as any legal entity that appears in a public register and is administered by the Ministry of Justice in Czechia, Slovakia, Slovenia, Germany, Poland, Hungary, Estonia, and Latvia. This definition encompasses a broad range of entities, including businesses, corporations, partnerships, and other legally recognized entities involved in economic activities within these countries.

My primary focus is on the establishment years of economic entities. The database I have compiled includes information on all legally recorded entities. By collecting data on entries, I can track changes in the economic landscape over time [6].

Figure 2.3: Economic Entities in Český Těšín (CZ) - Cieszyn (PL)



Source: Author's elaboration in QGIS based on geo-coded Registers Data

Notes: The map presents the locations and establishment years of economic entities in the divided cities of Cesky Tesin and Cieszyn. Dashed lines represent internal/state borders. Various points show the establishment years of economic entities during 1900-2022. The black-and-white dot denotes pre-war historical city center, identified by the Museum of Cieszyn in Silesia.

In Figure 2.3, I show an example of locations and establishment years of economic entities in Český Těšín on the Czech side and in its divided city of Cieszyn on the Polish side. I georeferenced each registered economic entity in the sample in QGIS and Google Earth Pro. The final georeferenced data has information on economic entities, including the establishment years, addresses (e.g., exact addresses with latitude and longitude coordinates), names, and NACE2. For details of data availability on entry dates, NACE2 codes, and coordinates, see Table 2.B.1.

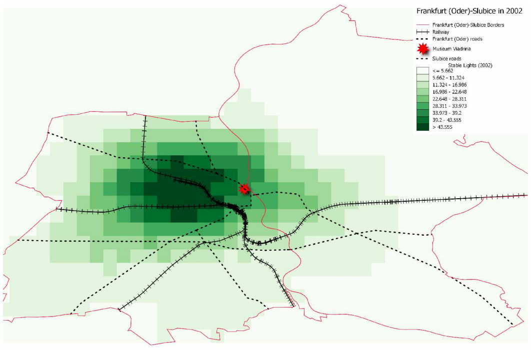
[6]National register databases suffer a survival bias, especially for data collected before 1990. Moreover, in some countries, data does not exist, i.e., due to the Soviet Union's planned market regulations, there were no registration records before 1990 in Estonia and Latvia.

2.4 Empirical Results

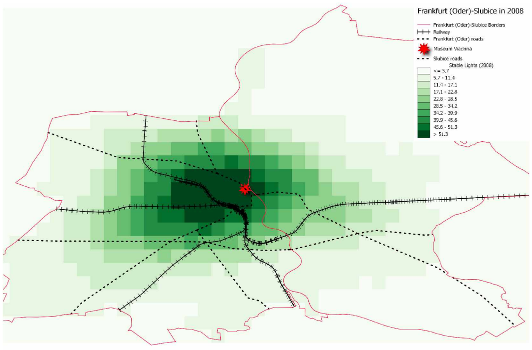
For the initial descriptive and motivational purpose, I illustrate the evolution of nighttime lights in one pair of divided cities: Frankfurt (Oder), Germany, and Slubice, Poland.

Figure 2.4: Nighttime Lights in Divided Cities: Frankfurt (Oder) & Slubice

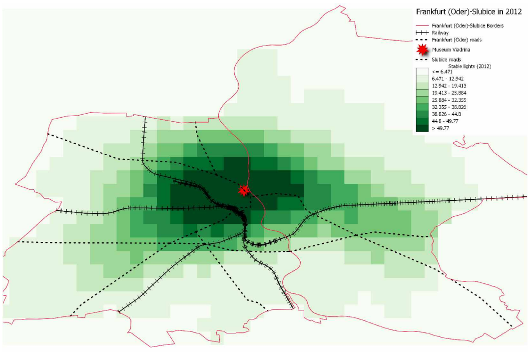
((a)) NTL in 2002



((b)) NTL in 2008



((c)) NTL in 2012



Source: Author's calculations based on DMSP-OLS satellite data.

Map (a) represents DMSP-OLS stable lights in 2002, map (b) represents stable lights in 2008, and map (c) represents stable lights in 2012. On the maps, the dashed lines represent German and Polish road connections. The red star is the historical city center, denoted by *the Museum of Viadrina*.

In Figure 2.4 map (a), during the pre-intervention period before the borders between Frankfurt (Oder) and Slubice were abolished, economic activities were not concentrated near the Museum Viadrina or the city center area. This suggests that economic activities were dispersed throughout the city.

In Figure 2.4 map (b), after the implementation of the Schengen agreement, which allowed for the free movement of people and goods within the Schengen Area, economic activities became more concentrated near the pre-war historical city center. This indicates that the removal of border restrictions and the increased mobility of people may have contributed to a clustering of economic activities in the pre-division city center.

Finally, in Figure 2.4 map (c), which represents the situation in 2012, after the free movement of Polish workers to Germany became allowed, economic activities grew even more and concentrated near the former historical city center. This suggests that the influx of Polish workers led to further economic concentrations near the historical city center.

Overall, these three maps demonstrate a shift in economic activities from a dispersed pattern to a more concentrated one near the historical city center over time. This transformation can be attributed to the abolition of borders, which facilitated increased mobility and economic integration between the divided cities.

Since Figure 2.4 hints to the concentration of economic activities near the city center, I empirically test the following baseline model:

$$Log(DN)_{it} = \beta_1 + \beta_2 Integration_t + \beta_3 HCTR_i + \beta_4 Integration_t \times HCTR_i + \epsilon_{it} \quad (2.1)$$

where i denotes a unit of analysis at 1x1 km grid cell; $Log(DN_{it})$ represents the digital number of stable lights (DN) - a proxy of local socioeconomic outcomes in grid cell i at time t; $HCTR_i$ measures the proximity to a historical city center, from grid cell i to historical center and is standardized based on the geographical size of the city; $Integration_{i,t}$ is a indicator variable which represents stepwise abolishing of borders: is a dummy variable taking a value of one after 2004 (EU Enlargement), and zero otherwise and is a dummy variable taking a value of one after 2008 (Schengen), and zero otherwise; the key interaction coefficient explains how NTL grew in areas close to historical centers after border barriers were removed; ϵ_{it} is an error term. Standard errors are heteroskedasticity-autocorrelation (HAC) robust in all specifications.

I standardize historical centers based on the geographical size of each city at LAU-2 level:

$$StandardizedDistance_i = \frac{Distance_{ij}}{CitySize_i}$$

Here, $Distance_{ij}$ denotes the distance from pixel i to historical center j, while $CitySize_i$ represents the size of the city where pixel i is situated. The term $StandardizedDistance$ refers to the distance of each pixel i to historical centers, which has been standardized. This standardization enables the creation of comparable distances to historical centers irrespective of the city's size. For instance, the distance to the historical center in Cesky Tesin can be reasonably compared to the distance to the historical center in Frankfurt (Oder).

Upon computing the standardized distance for each pixel within the dataset, I proceeded to determine the proximity to historical centers using the subsequent formula:

$$ProximityToHCTR_i = -StandardizedDistance_i$$

Where $ProximityToHCTR_i$ indicates the distance measured in kilometers to historical city centers.

The European integration facilitated greater access to non-tradable goods and services on the other side of the border. The increased ease of movement across borders allowed people to take advantage of the proximity of pre-division historical centers and consume goods and services available in those areas.

By reducing and removing barriers to cross-border movement, people living near the border could easily access nearby zones with pre-division historical centers and consume goods and services that were locally available but might have been more convenient or attractive in terms of price, quality, or variety. Such cross-border consumption could influence location decisions and economic activity patterns within divided historical cities. Firms might have been attracted to areas near pre-division historical centers due to the increased demand generated by the movement of people seeking local non-tradable goods and services.

Table 2.2: The Effect of Stepwise Integration on Nightlights in Divided Cities

	(1) Log(NTL)	(2) Log(NTL)	(3) Log(NTL)
European Union	0.188***	0.216***	
	(0.016)	(0.016)	
European Union × HCTR	-0.226*	-0.060*	
	(0.024)	(0.026)	
Schengen	0.199***		0.171***
	(0.016)		(0.016)
Schengen × HCTR	0.277***		0.108***
	(0.027)		(0.029)
N	74729	74729	74729
R^2	0.233	0.231	0.232
Time Span	1992-2013	1992-2008	1992-2013
Treatment Years		2004-2008	2008-2013
Year FE (1992-2013)	✓	✓	✓
Satellite FE (5 years interval)	✓	✓	✓
Pixel FE (1x1 km)	✓	✓	✓

Notes: *Estimation method:* panel fixed effects. *Dependent variable:* Log(NTL) is log transformed NTL luminosity. Robust standard errors in parentheses. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. Robust standard errors in parentheses. HCTR is in proximity to historical centers and is standardized based on the geographical size of the city. *Source:* Author's calculations.

However, on the other hand, in the presence of low trade costs within a city, changes only in goods mobility may have a limited impact on firm location decisions within the city. When trade costs are already low, changes in goods mobility are unlikely to have a significant influence on firm location decisions within a city. Table 2.2 in column (2) shows that economic activities are not concentrated in a close radius to historical centers, indicating that other factors play a more prominent role in determining firm location towards historical city centers.

Table 2.3: The Effect of European Segregation and Integration on Establishments

	(1)	(2)	(3)	(4)
	# firms	# firms	# firms	# firms
Segregation	-9.437*	-23.103**		
	(4.968)	(9.405)		
Segregation × HCTR	-2.252	-3.351**		
	(1.827)	(1.662)		
European Union	32.911***		28.321***	
	(2.892)		(3.521)	
European Union × HCTR	-0.023		0.037	
	(0.245)		(0.270)	
Schengen	-5.077			27.362***
	(3.380)			(1.872)
Schengen × HCTR	1.531***			1.648***
	(0.414)			(0.490)
N	3101	2952	1731	3101
R^2	0.240	0.143	0.243	0.239
Time Span	1945-2020	1945-2020	1945-2008	1945-2020
Treatment Years		1945-1990	2004-2008	2008-2020
Year FE (1900-2020)	✓	✓	✓	✓
Block FE (500x500meters)	✓	✓	✓	✓

Notes: *Estimation method:* panel fixed effects. *Dependent variable:* is #firms (number of firms) - total number of firms based on establishment years in 500x500m grid/block. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. Robust standard errors in parentheses. HCTR is proximity to historical centeres and is standardized based on the geographical size of the city. *Source:* Author's calculations.

After discussing the results of the EU analysis, it is worthwhile to shift the focus to the

2008 Schengen enlargement. In Table 2.2 in columns (1) and (3), the results indicate that in areas near the former historical city centers, there is an approximate increase of 10 percentage points in annual NTL radiance at the 1x1km grid cell level. This finding suggests that these areas experienced a relative increase in economic activities, as represented by the increase in nighttime light intensity, compared to other zones. The analysis demonstrates that the areas in proximity to historical city centers exhibited a stronger economic performance relative to their respective pre-Schengen (*borderless* travel area) levels. This finding suggests that the removal of border restrictions within the Schengen area has contributed to increased economic activity and development in these areas. These results provide evidence of the economic impact of the Schengen agreement inside the divided city and highlight the significance of proximity to historical city centers.

The increased economic activity near historical city centers can have positive spillover effects on the surrounding zones as well. The concentration of economic activities in these areas can lead to job creation and investment opportunities, further stimulating the labor and employment economy.

To further enhance my analysis, I geocoded economic entities registered in divided historical cities. I have created a three-way panel dataset that captures the establishment of firms within 500m x 500m blocks over a span of the century 1900-2020. This dataset includes information on the firms, the blocks in which they are located, and the corresponding year of establishment. So I can identify clusters of firm establishments within certain blocks and identify periods of rapid growth or decline in firm formation within specific blocks. I run the fixed effects models on my three-way panel dataset:

$$\#firms_{i,b,t} = \beta_1 + \beta_2 Segregation_{i,b,t} + \beta_3 HCTR_{i,b} + \beta_4 Segregation_{i,b,t} \times HCTR_{i,b} + \epsilon_{i,b,t} \tag{2.2}$$

$$\#firms_{i,b,t} = \beta_1 + \beta_2 Integration_{i,b,t} + \beta_3 HCTR_{i,b} + \beta_4 Integration_{i,b,t} \times HCTR_{i,b} + \epsilon_{i,b,t} \tag{2.3}$$

Where subscript i denotes a registered economic entity; subscript b denotes a 500x500m block; and subscript t denotes time; variable $\#firms_{i,b,t}$ is constructed from the total number of firms in block b established at time t; $HCTR_i$ measures the proximity to a historical city center, from grid cell i to the historical center and is standardized based on the geographical size of the city;

$Segregation_{i,b,t}$ represents the time period of interest when segregation was prevalent and is a dummy variable that takes a value of 1 for the time period from 1945 to 1990 when cities were segregated politically, institutionally, and economically; $Integration_{i,b,t}$ represents the stepwise removal of a border and is a dummy variable that takes a value of 1 during the period of 2004-2008 when countries became members of the European Union (EU); $Integration_{i,b,t}$ is a dummy variable that takes a value of 1 during the period of 2008-2020 when countries became members of the Schengen Agreement; interactions express the difference in the number of economic entities established in blocks close to pre-war centers compared to remote blocks during the segregation and after integration, respectively; $\epsilon_{i,b,t}$ is an error term.

Overall, the consistency between the regression results in Table 2.3 using registered economic entities and Table 2.2 using remotely sensed nightlight data strengthens my findings.

The results of the estimated models indicate that there was a concentration of newly established economic entities away from the pre-war historical centers following the segregation of historical border cities between 1945 and 1990. The concentration of newly established economic entities away from the pre-war historical centers suggests that other areas or regions experienced increased economic activities following the segregation. Furthermore, establishing new borders and the physical separation of historical border cities have disrupted the flow of goods, services, and people between the pre-war historical centers and the newly formed cities. This disruption created barriers for businesses operating in the pre-war historical centers. In Table 2.3, in columns (1) and (2), I show that disruptions led to the establishment of economic entities in areas outside the historical centers.

Furthermore, in Table 2.3, column (1) and (3) demonstrates that there was no significant change in the concentration of newly established entities after the political and economic union, specifically after the 2004 Eastern enlargement. This finding suggests that the expansion of the union did not lead to a notable shift in the spatial concentration of economic entities near the historical city center.

However, in Table 2.3 columns (1) and (4) show that it appears that, on average, for every block (500x500m) closer to the historical city center, there is an average increase of 2 firms in the area. This suggests that the ability for individuals to freely move and interact across formerly divided cities plays a crucial role in shaping the spatial distribution of economic entities.

Table 2.4: Language and Cultural Similarities

	(1)	(2)	(3)	(4)	(5)
	Lexical Similarity	No Lang. Barrier	Lang. Barrier	Cesky Tesin	Ciezsyn
Schengen	22.925	30.734***	23.690***	55.305**	34.307***
	(5.575)	(3.724)	(5.946)	(19.561)	(2.538)
Schengen × HCTR	0.545	2.001***	1.403	8.251*	3.643***
	(0.872)	(0.660)	(0.850)	(4.526)	(1.105)
Schengen × Lexical	13.657				
	(14.410)				
Schengen× Lexical × HTCR	4.646**				
	(2.589)				
Observations	3101	1329	1772	188	434
R^2	0.240	0.358	0.209	0.620	0.663
Year FE (1900-2020)	✓	✓	✓	✓	✓
Block FE (500x500meters)	✓	✓	✓	✓	✓

Notes: *Estimation method:* panel fixed effects. *Dependent variable:* is #firms (number of firms) - total number of firms based on establishment years in 500x500m grid/block. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. Robust standard errors in parentheses. HCTR is proximity to historical centeres and is standardized based on the geographical size of the city. *Source:* Author's calculations.

2.5 Main Channels and Disscusions

In addition to the free movement of people, cultural and linguistic factors can contribute significant roles in shaping economic activities and concentration in divided cities.

Language is deeply tied to culture and plays a crucial role in shaping economic dynamics. Also, language serves as an important tool for cultural understanding and market adaptation, especially in cross-border areas (Commission, 2015).

Firms can connect with more customers and take advantage of potential opportunities in cross-border regions if residents speak similar languages on both sides of the border. It is important to note that if such companies are located near historical centers in divided cities, they may have a unique opportunity to access and cater to both local and foreign markets, markets of similar language, on each side of the border. A market of similar language refers to a market where the majority of the population shares a common language or where linguistic similarities exist among the population.

I investigate the linguistic proximity between divided cities and show whether cities sharing a common or similar language with their neighbors experience stronger economic concentrations near historical city centers.

To proxy language and culture similarities, I use the lexical similarity coefficients from Ethnologue website. These estimates indicate that approximate percentages of what extent the vocabulary items in language A and language B may have similarities or shared roots. The Czech-Austrian similarity estimate is 0.1; Czech-Polish is 0.6; German-Polish is 0.2; Italian-Slovenian is 0.2; Hungarian-Slovakian is 0.1; Estonian-Latvian is 0.5. Low and high coefficient implies that there is limited shared vocabulary and a significant overlap in vocabulary between the two languages, respectively.

In addition to lexical similarity coefficients, I use cross-border cooperation (CBC) survey, which represents respondents' perceptions of what extent the language and cultural differences pose major problems in the cooperation between Country A (domestic) and the cross-border Country B (foreign). The wording of the question I focus on in the survey is: Thinking about the cooperation between (Country A) and [Cross-Border Country B], to what extent are language differences & cultural differences a major problem? I have calculated the share of respondents who responded that language, and cultural differences are major problems with foreign cross-border areas (see Table 2.C.1).

Based on Table 2.4 column 1, it appears that cities with higher lexical similarity coefficients tend to experience a concentration of firms near historical city centers after the abolition of all types of borders in 2008. Specifically, I show that the number of newly created firms is growing by five within a 500x500-meter radius close to the pre-division center after implementing Schengen policies.

Moreover, in Table 2.4, in columns 2 and 3, I show that proximity to a former historical city center matters more in cities where citizens think that language and cultural differences are not a major barrier to cooperation with their cross-border area. For example, Czech and Polish both languages belong to the West Slavic branch of the Slavic language family, which means they have a common linguistic heritage. In Table 2.4 columns 4 and 5, I show that the average number of firms established based on their proximity to a historical center (within 500m x 500m blocks) is growing roughly by 8 in Cesky Tesin and by 4 in Ciezsyn after 2008.

Table 2.5: Firms Creation by Sector in Divided Cities, 1900-2022

Sectors	Agriculture	Manufacturing	Food Services	Cultural and Entertainment
Schengen	-0.683	-9.050	2.311	1.784
	(0.678)	(9.052)	(4.815)	(5.236)
Schengen × HCTR	0.027	-2.559	5.035**	1.437*
	(0.196)	(1.968)	(2.040)	(0.839)
N	1693	1693	1422	1328
R^2	0.076	0.190	0.150	0.234
Year FE (1900-2020)	✓	✓	✓	✓
Block FE (500x500meters)	✓	✓	✓	✓

Notes: *Estimation method:* panel fixed effects. *Dependent variable:* is #firms (number of firms) - total number of firms based on establishment years in 500x500m grid/block. (*) (**) (***) denotes statistical significance at the (10) (5) (1) percent level. Robust standard errors are in parentheses. HCTR is in proximity to historical centers and is standardized based on the geographical size of the city. *Source:* Author's calculations.

Alongside the free movement of people, historical, cultural, and linguistic factors, I show that the sectoral specialization or concentration of newly established firms within specific industries significantly shapes economic activities and concentration in divided cities. For example, consumer-oriented industries may thrive more than production-oriented industries due to the increased flow of people after removing border barriers. Moreover, certain industries have historical ties to the pre-division centers and benefit from cross-border integration.

I show in Table 2.5 that firms in the consumption sector, such as restaurants, cafes, and cultural and entertainment venues, often seek locations near former historical centers. These areas typically have a higher concentration of potential customers, both residents and visitors, due to their historical and cultural significance. Therefore, the proximity to former historical centers makes these locations attractive for setting up businesses in the consumption sector.

On the other hand, there is no significant change in production-oriented industries, i.e., agriculture and manufacturing activities which involve in the production of foods and goods for people, as well as the production of various intermediate products. Production-intensive sectors may not necessarily concentrate in close proximity to historical centers after removing borders. The concentration of production-intensive sectors often depends on different factors than those driving the concentration of consumer-oriented.

Manufacturing and agriculture sectors typically focus on supplying goods to local markets rather than international markets. The target consumers/buyers are often within close proximity to the production facilities. As a result, the need for cross-border communication may be less significant compared to service and consumer-oriented sectors.

2.6 Conclusion

I examine the quasi-natural experimental setting of stepwise lifting borders across divided European cities. I find that, in divided cities that were united in the past, internal city structures changed after all types of border barriers were lifted upon the Schengen agreements.

This paper provides important insights into the factors influencing economic concentrations in historically divided border cities, specifically highlighting the importance of the free movement of people, historical, language, cultural, and sectoral factors. I find that the ability of people to move freely across borders plays a crucial role in the concentration of economic activities. This suggests that removing barriers to human mobility allows divided cities to return to their older forms and facilitate the shift of economic activities, measured by nightlights and registered firms, back towards former historical city centers.

Furthermore, I study sectoral specialization as an additional channel through which agglomeration effects occur. The presence of firms in the consumption sector, which directly cater to people, leads to a clustering of economic activities close to former historical centers. This physical proximity fosters greater interaction and collaboration among individuals and contributes to concentration.

Importantly, I find that historical factors, such as proximity to former historical centers, are more significant for cities that share language and cultural similarities with their cross-border neighbors. This emphasizes the role of history and cultural affinity in shaping economic concentrations within cities.

Overall, my analysis highlights the significance of the free movement of *people* over the free movement of *goods* in driving economic activities near historical city centers. Policymakers should facilitate the movement of individuals across borders and work towards promoting and preserving the principles of *borderless Europe*. Moreover, my research highlights the importance of linguistic similarities in shaping the economic landscape. Policymakers should consider these factors when designing policies and strategies for economic development in divided cities. For example, promoting language learning programs, cultural exchange initiatives, and cross-border collaborations can help capitalize on language and cultural affinity to *bring together what historically belongs together*.

2.7 Appendix A: Satellite Nightlight Data

DMSP-OLS NTL: I use stable nighttime light images; all light sources that can cause measurement errors, such as forest fires, lunar lights, and other unstable human-made luminosity sources are filtered from the raster images. The raw data of stable lights is presented here. As Figure (a) shows, the raw data is not normally distributed and requires transformations. Before log transformation, I add a small constant one to every grid cell in the row data - the minimum non-zero digital number in the data is ≈ 1. Approximately 10 thousand pixels have zero values in the sample, which is highlighted in blue in Figure (a). Next, I transform the data into log values so that in Figure (b), log-transformed data contains zeroes and is not normally distributed. I do not drop zeroes in either row or in log-transformed data. I assume that zeroes indicate no human economic activities, which is necessary information when tracking changes within cities.

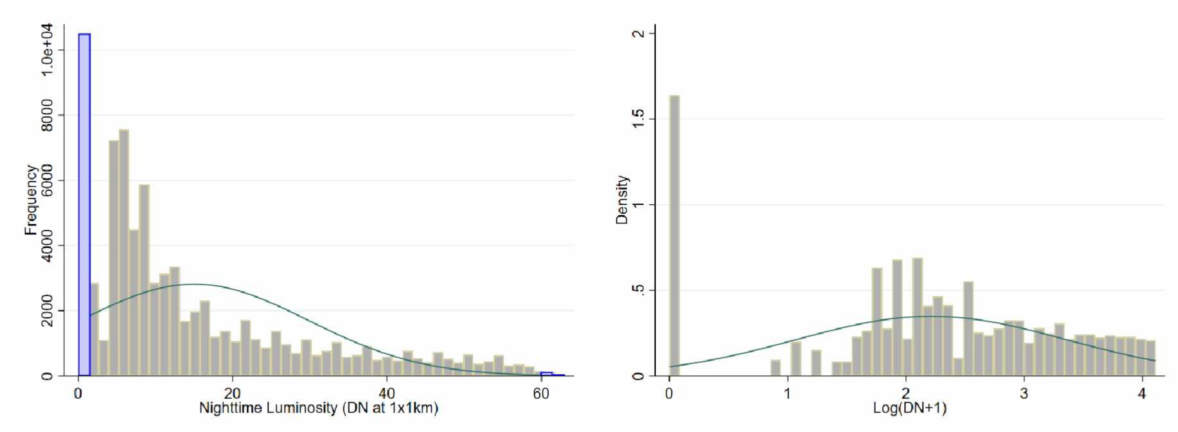
Here, I describe a process for handling and transforming nighttime light data in my research. Let me summarize the steps :

- Filtering: I filter out any light sources that can cause measurement errors, such as forest fires, lunar lights, and other unstable human-made luminosity sources, from the raw nighttime light images.
- Raw Data: The raw data of stable lights is presented.
- Non-Normal Distribution: I observe that the raw data is not normally distributed and requires transformations.
- Adding a Small Constant: Before applying the log transformation, I add a small constant value of one to every grid cell in the raw data.
- Zero Values: In the raw data, around ten thousand pixels have zero values in the sample, which are highlighted in blue in Figure (a).
- Log Transformation: I then perform a log transformation on the data. The resulting log-transformed data in Figure (b) contains zeros and is relatively normally distributed.

- Zeroes as Information: I do not drop the zero values in either the raw. Instead, I interpret these zero values as indicating no human economic activities. This information is essential for tracking changes within cities.

Transformation of the raw data lessens the measurement error of the data in lower bounds. Regarding top coding, only four grid cells reach 63 - the maximum digital value in the data, and 181 pixels have DN above 60 – I drop these outliers from the sample (frequencies in the top threshold are highlighted in blue; see Figure (a)).

Figure 2.A.1: Transforming Nighttime Luminosity



(a) Nighttime Luminosity (Raw data)

(b) Log Transformed NTL

Source: Author's elaboration based on DMSP-OLS satellite nighttime lights.

I discuss several strategies to address limitations in my analysis. Let's summarize these strategies:

- Averaging Data across Satellites: When two satellites were available in a given year, such as in 1994 with the F10 and F12 satellites, I chose to average the data from both satellite sources. This approach helps to reduce measurement errors if they are random in nature.

- Including Satellite Fixed Effects: If the measurement errors are not random and there are variations in how different satellites capture lights, I account for this potential bias by including satellite-fixed effects in my model. By doing so, I control for within-satellite correlation across years. For example, during 1997-1999, the F12 and F14 satellites were launched; during 2000-2003, it was F14 and F15, and during 2004-2007 it was F15 and F16.

- Dropping Pixels with High Digital Numbers: To minimize concerns related to top coding or extreme values, I choose to drop all pixels from the sample with digital numbers higher than 60. By excluding these high-value pixels, I aim to mitigate any potential issues associated with outliers in my analysis.

By employing these strategies, I aim to enhance the accuracy and reliability of my analysis while addressing the limitations associated with satellite data availability, potential biases in satellite-specific measurements, and extreme values in the dataset.

Table 2.A.1: Summary Statistics after Data Cleansing

Variable	N	Mean	Std. Dev.	Min.	Max.
Nighttime Luminosity	74,729	14.33537	14.42692	0	60
Log(NTL)	74,729	2.212735	1.145026	0	4.110874
Distance to Historical Center	74,729	7.563277	4.337439	.1507614	22.15463
Satellite F10	74,729	.1365333	.3433563	0	1
Satellite F12	74,729	.2730667	.4455378	0	1
Satellite F14	74,729	.3187384	.4659905	0	1
Satellite F15	74,729	.3643298	.4812449	0	1
Satellite F16	74,729	.2733878	.4457012	0	1
Satellite F18	74,729	.1805056	.3846106	0	1
Years	74,729	2002.489	6.339127	1992	2013
Schengen Entry	74,729	.2716348	.4448056	0	1
Longitude of Pixels	74,729	15.80379	2.709864	13.55833	26.11667
Latitude of Pixels	74,729	50.24682	2.824156	45.84167	57.81667
Longitude of HC	74,729	15.76925	2.732708	13.6269	26.0376
Latitude of HC	74,729	50.24786	2.83374	45.9413	57.7773
Pixel ID	74,729	-	-	1	3405
Country ID	74,729	-	-	1	10
City ID	74,729	-	-	1	22
Historical Center ID	74,729	-	-	1	11
Divided city pairs ID	74,729	-	-	1	11

2.8 Appendix B: Firm Register Data

Registers: I have gathered data on economic entities, including their establishment dates, sectors, and locations, for various cities in different countries. Here is a summary of the data sources I used for each city:

- German Cities (Frankfurt (Oder), Görlitz, Gubin): The data for these cities is obtained from the Common Register Portal of the German Federal States.
- Polish Cities (Cieszyn, Słubice, Zhořelec, Guben): The data for these cities is collected from the national official business registers in Poland. An alternative data source is the Central Register and Information on Business Activity.
- Slovak City (Komárno): The data for this city is obtained from the National Statistical Office of Slovakia.
- Hungarian City (Komarom): For this city, I initially obtained the names of registered economic entities from the Hungarian Central Statistical Office (HCSO). Then, using the names, I searched and collected information on the establishment years of these entities from the Ministry of Justice's Company Information and Electronic Business Procedure Service.
- Estonian City (Valga): The data for this city is sourced from the Center of Registers and Information Systems in Estonia.
- Latvian City (Valka): The data for this city is obtained from the register of enterprises of the Latvian Republic.
- Slovenian City (Nova Gorica): The data for this city is sourced from the Agency of the Republic of Slovenia for Public Legal Record.
- Italian City (Gorizia): For this city, I used the Italian Digital Database of Companies (AIDA) to gather the required information.

Once I have collected the data from these various sources, I merge the datasets to create a comprehensive dataset covering 54,669 economic entities in the divided cities.

Table 2.B.1: Registered Economic Entities in Cities - Availability

City	**Country**	**Entry Date**	**NACE**	**Lat-Long**	**N**
Cieszyn	Poland	Y	Y	Y	6710
Cesky Tesin	Czechia	Y	Y	Y	4387
Komarom	Hungary	Y	Y	Y	998
Komarno	Slovakia	Y	Y	Y	19354
Nova Gorica	Slovenia	Y	Y	Y	7903
Goriza	Italy	Y	Y	Y	1002
Valga	Estonia	Y	Y	Y	650
Valka	Latvia	Y	N	Y	540
Slubice	Poland	Y	Y	Y	5554
Frankfurt	Germany	Y	N	Y	2035
Gubin	Poland	Y	Y	Y	458
Guben	Germany	Y	N	Y	640
Zhorlec	Poland	Y	Y	Y	2695
Gorlitz	Germany	Y	N	Y	1743
Ceske Velenice	Czechia	Y	Y	Y	738
Gmund	Austria	N	N	N	-
Total					54,669

2.9 Appendix C: Supplementary

Figure 2.C.1: Border Crossing between Komarom & Komarno: in 20th vs. 21st centuries

((a)) Border Crossing in 1925

((b)) Border Crossing in 2006

Source: Photo (a) is taken from a Hungarian silent film from 1925, “The Trianon frontier on the Komárom Bridge” (1925) (available on the following link). Photo (a) shows border guards policing the bridge linking Komárom in Hungary with Komárno in Czechoslovakia (today in Slovakia). People pass between the two countries through gates. Photo (b) displays the same area in 2006 where police(wo)man controls on passport checks and border crossing before Schengen came into force in 2008.

Table 2.C.1: Language and Cultural Differences between Border Cities

Cities	**Language difference %**	**Cultural difference %**	D(No=1)	Respodents
Gorizia	0.37	0.14	0	54
Nova Gorica	0.20	0.03	0	105
Cesky Tesin	0.04	0.001	1	46
Ciezsyn	0.08	0.03	1	114
Frankfurt (Oder)	0.33	0.11	0	27
Slubice	0.35	0.11	0	114
Guben	0.41	0.40	0	54
Gubin	0.34	0.08	0	342
Gorlitz	0.44	0.10	0	165
Zgorlec	0.26	0.09	0	192
Valga	0.24	0.23	0	301
Valka	0.33	0.05	0	83
Komarom	0.02	0.03	1	15
Komarno	0.04	0.06	1	64
Gmund	0.32	0.001	0	37
Ceske Velenice	0.31	0.09	0	208
N				1921

Notes: Auhtor's calculations based on Interreg A survey, 2022. Column 1 represents divided cities; Columns 2 & 3 show the shares of respondents who think that language and cultural differences with the neighboring country are very problematic. Column 4 displays the dummy variable constructed based on how many people responded that differences matter - a dummy equals one in cities where a majority of residents do not see these differences as a major problem, and zero otherwise. Column 5 represents the number of respondents in NUTS3 regions where divided cities are located.

CHAPTER 3

3 Europe, we have a problem! The Economic Effects of Border Closures during COVID-19

3.1 Introduction

"This virus has no passport. We must unify our forces, coordinate responses and cooperate. I sincerely believe that closing borders are bad decisions within Europe..."

-Emmanuel Macron, May 2020

It has been almost a quarter century since the *borderless* Europe, known as the Schengen Area, was established in 1995. Since then, there has been no tighter restriction on internal borders as during the COVID-19 pandemic. As governments were unprepared for the unexpected shock, it was difficult to set effective policies that could minimize the economic costs of the global pandemic and, at the same time, maximize the benefits of stopping the spread of the virus. One of the first implemented policies was the re-introduction of border control, which was seen as a necessary measure to combat the spread of the virus. Border control policies aimed at protecting public health, though they could adversely affect the economy overall. My paper evaluates the economic impact of border control policies in Europe. It provides potential insights for policymakers facing the challenge of balancing public health protection and minimizing economic consequences.

Several politicians have criticized the decision to introduce border controls because such restrictions could spillover negative effects on the local economies, e.g., the decline in tourism revenue, especially in border cities. While there is substantial research on the overall (at the country level) economic impact of border controls and travel restrictions during the COVID-19 pandemic, the regional dimension has not been extensively explored in the literature (Eckardt et al., 2020, Gros, 2020; Broughel and Kotrous, 2021). Economic costs can vary across different regions depending on factors such as the level of integration into international markets, the importance of cross-border trade, and the reliance on tourism. The motivation for this paper is that nearly 30 years after the creation of the Schengen area, it is now time to assess the recent resurgence of *fences* along internal borders, which represents a significant departure from the principles of free movement established by the Schengen area. The main research questions this paper answers are (1) To what extent did the border control policies affect human and economic activities in border municipalities relative to areas far away from the international border? (2) Were there any differences between different types of borders, and (3) what were the main channels of such effects? The motivational illustration is depicted in Figure 3.1[1], which highlights a notable decrease in nighttime lights intensity across central Western and Eastern Europe. This decline clearly indicates a significant shortage experienced by the border regions.

Studying the economic impact of border policies is challenging due to the unavailability of granular data (at the municipality level) that varies over time (monthly). However, remotely sensed night-time lights (NTL) data allows the capture of large-scale changes in economic activities at the desired time and at a desired spatial level. Using NASA's Black Marble products and remotely sensed NTL data, I show how the national border controls changed economic activities in municipalities - at the finest territorial typologies, i.e., at Local Administrative Units (LAU-2) level. I find that municipalities (hereafter, I use municipalities and cities interchangeably) close to the border experienced a significant decline in NTL after imposing border controls relative to central cities. Moreover, I show that the decrease in NTL radiance in border municipalities is larger in New Member States (NMS) than in Old Member States (OMS). The Old Member States have established stronger economic ties and

[1]For the detailed illustration of changes after the border controls, see Figure 3.A.2 - Figure 3.A.5

integration with neighboring countries, which could provide a buffer against the negative impacts of border controls. In contrast, New Member States may still seek to deepen their economic integration, making them more vulnerable to disruptions.

The European integration literature emphasizes how the creation of a *borderless Europe* entails the abolition of economic, institutional, and political barriers through four main pillars, e.g., by eliminating the free movement of goods, services, capital, and people across internal borders. Several studies have shown that these effects can be positive or negative, depending on the specific context and the policies implemented during the integration process (Niebuhr, 2008; Braakmann and Vogel, 2011; Brakman et al., 2012; Mitze and Breidenbach, 2018; Heider, 2019; Brülhart et al., 2018; Kapanadze, 2021). The natural question stemming from the integration literature would be: what kind of effect should we expect as a consequence of violating the basis of the EU treaties, e.g., as a result of the re-introduction of border controls and the temporary segregation process? Similarly to how the creation of the single market generated spatially conflicted diverse results, the temporary border restrictions slowed down the economies, and the losses were unevenly distributed across different regions.

This study makes several contributions to the literature. First, the paper overcomes the challenge of correctly identifying spatial units of analysis. I study the effect of border controls at the finest possible geographical level (LAU2) comparable across Schengen countries. It is a preferable spatial unit of analysis, especially in border studies where measuring economic activities very close to the borderline is extremely important. Other spatial units, such as NUT3 or NUTS2, frequently used in regional economics, might bias the results due to the relatively large spatial aggregation compared to LAU-2 areas.

Second, the paper utilizes the potential channels through which agglomeration size and sectoral specialization can influence the economic consequences of border controls. I show that the economic effect of border restrictions varies across city sizes; small border cities experience more negative effect than larger cities. Furthermore, the negative economic effect of border restrictions is larger in border cities specializing in manufacturing, consumer, and service industries than in agricultural towns.

Third, using the cross-border cooperation (CBC) survey, the paper introduces municipality-type sub-groups and shows that the decline in NTL is larger in municipalities where the majority of residents are employed, have a high awareness of EU-funded cross-border cooperation activities and perceive living near the internal border as a good opportunity; and commute to foreign cross-border regions for purposes such as leisure, work, or shopping. Overall, I show that recognizing cities' vulnerabilities based on their industry specialization, size, and needs for cross-border mobility is crucial for effective policy-making. It allows policymakers to develop tailored strategies and interventions that address the specific challenges and promote economic resilience and growth in cities after the pandemic.

The study also contributes to the growing body of literature on the effects of preventive measures for COVID-19 on human and economic activities, measured by NTL radiance. Previous papers have studied the impact of national lockdowns on the NTL in India (Ghosh, 2020); in global megacities (Xu et al., 2021); in USA and China (Small and Sousa, 2021; Elvidge et al., 2020); in Africa (Anand and Kim, 2021); in Japan (Hayakawa et al., 2022). This paper adds to this strand of literature in three ways. First, the paper uses NTL data in the European context, which has not been done before. Second, whereas the previous papers are based on a single-country setup, this paper provides a cross-country comparison. Since the NTL data is highly standardized, it can easily be used in multiple countries and allows for comparative analysis. Third, most pandemic-related research that uses unconventional data sources focuses mainly on the country or city level. Little research has been done on border areas between two foreign countries (Zhao et al., 2022). The paper is also policy-relevant. Understanding the specific economic impact of border policies can support decision-making processes in the Schengen area and help policymakers develop effective policies in the future.

The rest of the paper is organized as follows: Section 2 introduces materials, methods, and data; Section 3 presents the empirical analysis and main results; Section 4 shows the additional analysis and discussion; and Section 5 concludes the paper.

3.2 Data and Methods

3.2.1 NASA's Black Marble Nighttime Lights

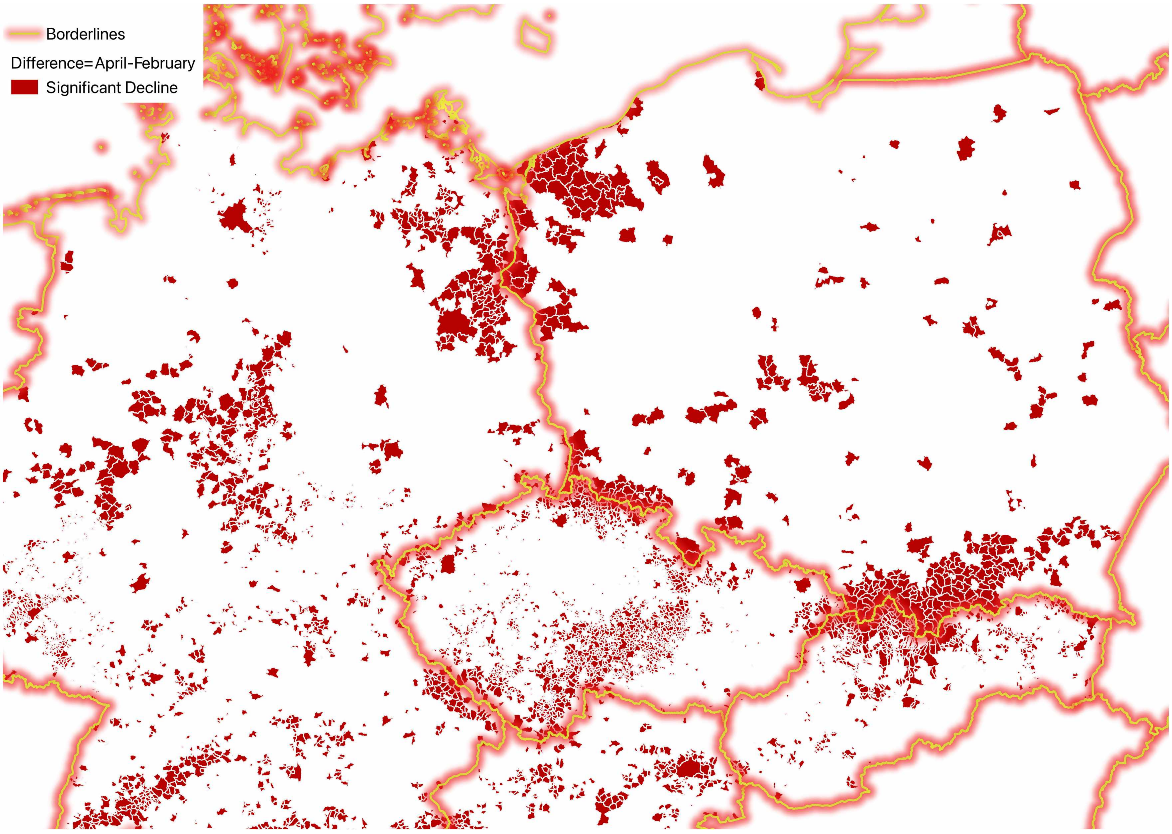
Remotely sensed nighttime lights are increasingly used in economics as a typical proxy, a typical proxy for human and economic activity (Gibson et al., 2021). The vast majority of studies have used the Defense Meteorological Satellite Program (DMSP-OLS) to monitor lights from space and study long-term relationships between human activity and socioeconomic variables since 1992[2]. However, the spatial and radiometric resolution is a course of the DMSP-OLS, which makes the sensor saturate, bloom, and over-glow. In addition, it has the disadvantage of having no onboard calibration, which is the basis for deriving a reliable remote sensing record over time. Generally speaking, DMSP-OLS is an ideal and without an alternative when looking at long-term, large-scale changes in human and economic activities - the data from this source has been beneficial in understanding long-term historical trends. However, it is less used in remote sensing literature when examining more recent nighttime dynamics.

The satellite generation Visible Infrared Imaging Radiometer Suite (VIIRS) is the latest and the best version of nighttime light sensors. The day-night band on the VIIRS is ultra-sensitive even in low-light conditions. It allows researchers to observe the dynamics of the nighttime lights with better spatial and temporal resolutions than DMSP-OLS. The VIIRS day-night band presents a significant improvement over the DMSP-OLS sensor for several reasons. First, it has a higher spatial resolution of $\approx$ 750 meters instead of $\approx$ 2.7 km for the DMSP-OLS. The VIIRS day-night band is sensitive to lower light levels than the DMSP-OLS. It has a 14-bit radiometric quantization, which means it is 256 times more sensitive to radiometric differences in nighttime lights than DMSP-OLS. Second, VIIRS

[2]in African cities (Michalopoulos and Papaioannou, 2014; Storeygard, 2016; Eberhard-Ruiz and Moradi, 2019; Dreher et al., 2019); in world cities (Hodler and Raschky, 2014; Düben and Krause, 2021; Kocornik-Mina et al., 2020; Mamo et al., 2019; Lessmann and Seidel, 2017); in Indian cities (Gibson et al., 2015; Castelló-Climent et al., 2018); Prakash et al., 2019); in Barbados beaches (Corral and Schling, 2017); in OECD countries (Smith and Wills, 2018); in North Korea (Lee, 2018); in Indonesian sub-districts (Heger and Neumayer, 2019); in European twin cities (Kapanadze, 2023).

sensors do not saturate and have little blooming and over-glow effect. Third, VIIRS has onboard radiometric calibration, which allows the time series data to be corrected and stable over time. Surprisingly, even though the quality of VIIRS is way better than DMSP-OLS, VIIRS is rarely used in economics (Gibson et al., 2021). The use of VIIRS in economics research might be limited due to economists' and social scientists' lack of awareness[3].

Figure 3.1: Change in NTL: where West meets East



Notes: Author's own elaboration in QGIS based on NASA's Black Marble Nightlights in Germany, Poland, Czechia.

NASA developed the Black Marble products, the first daily calibrated and corrected product suite of VIIRS nighttime lights in 2020. The data was significantly improved and can be used effectively in all scientific areas. NASA released Black Marble's VNP46A2

[3]The interdisciplinary nature of using remote sensing data in economic analysis requires researchers to understand satellite imagery, data processing techniques, and relevant statistical methodologies.

- VIIRS/NPP Lunar BRDF-Adjusted Daily Nighttime Lights in July 2020. It is the first database of improved remotely-sensed lights at night, available daily. In April 2021, NASA released VNP46A3 Lunar BRDF-Adjusted Monthly Nighttime Lights and VNP46A4 Lunar BRDF-Adjusted Yearly Nighttime Lights. The Black Marble has low resolution and allows me to build a dataset of economic and human activities at the finest spatial level.

To obtain administrative data at the city level in Europe is challenging due to variations in requirements and bureaucratic systems across countries. Data unavailability is always a barrier for researchers studying economic dynamics in European cities. The statistical office of the EU (Eurostat) maintains a territorial disaggregation at the LAU-2 or city level. This stands for local administrative units and is part of the nomenclature of territorial units for statistics (NUTS) classification system, i.e., $LAU2 \approx NUTS5$. Each EU member state divides its territory into LAU-2 units, corresponding to municipalities, cities, or towns.

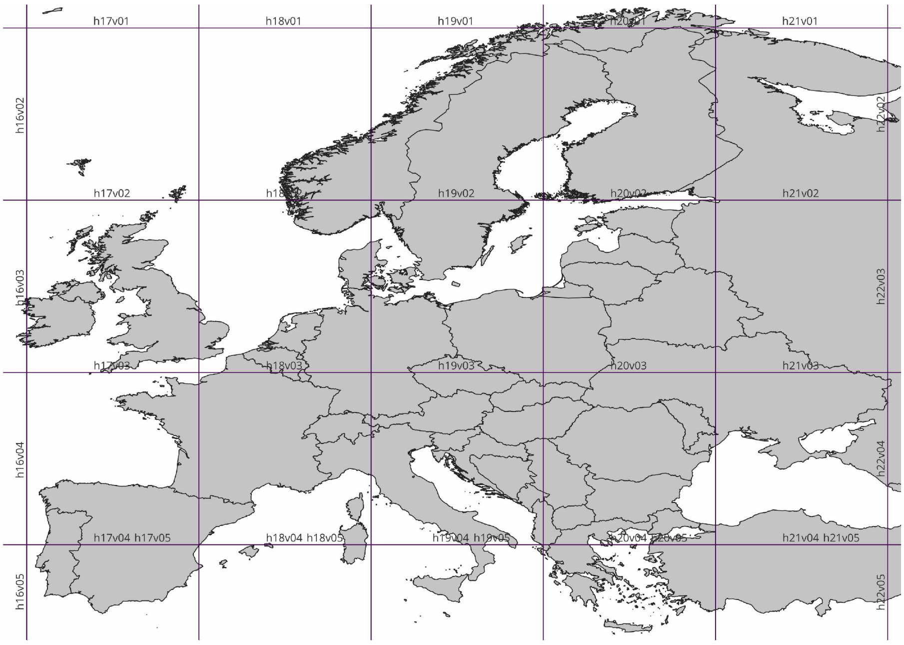
The availability and accessibility of data at the LAU2 level can vary depending on the country and the specific datasets. However, obtaining comprehensive information at such a granular spatial level is challenging. Statistical agencies often prioritize collecting data periodically, such as once every few years or less frequently, depending on the country and the specific data set. This gives another argument why it is timely and necessary to use non-traditional data in this study. Unconventional data sources can address the main limitations and provide a dynamic and comprehensive understanding of the characteristics and changes across LAU2 areas. Figure 3.A.6 shows the spatial distribution of LAU2 entity area (km2). Having identical-sized spatial units makes it easier to ensure comparability across/within countries and draw valid statistical inferences. However, it is important to note that there can still be some variation in the size of LAU-2 units due to historical boundaries and population distribution.

Black Marble products consist of 460 non-overlapping worldwide land tiles, which measure the whole world approximately into a 10 degrees by 10 degrees grid[4]. Continental

[4]To calculate the area of a grid cell, I use the following formula: Area of a grid cell = (latitude) * (longitude) * (cosine of the average latitude). Then the formula becomes the approximate area of 10 degrees by 10 degrees grid cell = (10 degrees) * (10 degrees) * 1 = 100 square degrees

Europe covers 16 land tiles. I retrieved the spatial layers of the 16 tiles in shape-file format from the Black Marble server to create the raster map of the Schengen area. In Figure 3.2 , tiles corresponding to Europe are h17v02, h18v02, h19v02, h20v02, h17v03, h18v03, h19v03, h20v03, h17v04, h18v04, h19v04, h20v04, h17v05, h18v05, h19v05, h20v05 and they were extracted from the archives.

Figure 3.2: Black Marble Tiles in the Schengen Area



Source: Author's own elaboration in QGIS based on Black Marble tiles.

Notes: Selected Schengen countries are - Austria (AT), Belgium (BE), Czechia (CZ), Estonia (EE), France (FR), Germany (DE), Hungary (HU), Italy (IT), Latvia (LV), Lithuania (LT), Netherlands (NL), Poland (PL), Portugal (PT), Slovakia (SK), Slovenia (SI), Switzerland (CHE) and Spain (ES).

The initial Black Marble products are in Hierarchical Data Format (HDF5) version. This provides a flexible and efficient way to manage and access data, particularly in numerical applications. To work with the data in geographical statistical software such as ArcGIS & QGIS, I converted all data into TIFF file format through the Black Marble server tools. Converting the data to TIFF format ensures compatibility with the Geographic Information System (GIS) and enables me to leverage the rich set of geospatial analysis tools available in the GIS software applications[5]. Then finally, I retrieved the VNP46A3 database. The data provides moonlight and atmosphere-corrected composites of nighttime lights captured by the VIIRS satellite. The VNP46A3 dataset is specifically designed to address the challenges of observing nighttime lights in the presence of moonlight and atmospheric effects. It applies a lunar bidirectional reflectance distribution function (BRDF) correction to account for the variations in lunar illumination and incorporates atmospheric correction algorithms to remove atmospheric interferences. Thus the final data, the moonlight and atmosphere-corrected NTL composites from the VNP46A3 dataset, can be used for socioeconomic studies. The corrected composites provide a much more accurate representation of the distribution and intensity of artificial lights on the Earth's surface.

The final composites consist of 28 layers containing information on the radiance, the quality, categories of the different angles (i.e., near-nadir, off-nadir, and all angles), and snow status (snow-covered and snow-free). I retrieved and worked on two layers from the VNP46A3 composite product. The first layer is All Angle Composite Snow Free, which represents the temporal radiance composite using all observations during the snow-free period. The second layer corresponds to quality flags. The quality flags are associated with each pixel in a raster graphic image and provide information about the quality or reliability of the data captured by the sensor. These flags indicate certain characteristics that may affect the pixel's accuracy for further analysis. A quality indicator is a dummy variable that takes the value of one if pixels are good quality and zero if pixels suffer cloud contamination, sensor saturation, or missing data. After examining the aggregated quality flags, I found no significant pattern where certain quality flags are abnormal. This suggests that the pixels captured by the sensor are, on average, of good quality and do not exhibit consistent issues[6]. All data work is outlined in the Figure 3.A.1; the process has a graphical and textual representation.

And finally, I calculated NTL radiance in 89,849 municipalities in 17 Schengen countries.

[5]The total size of TIFF files during the Q1 of 2020 is $\approx 64GB$.

[6]However, it is important to note that the absence of significant patterns could also be influenced by factors such as the sensor's calibration and data processing techniques. These factors ensure high-quality data and minimize systematic errors.

Raw (text) data of the NTL radiance at LAU-2 level is available upon request. I included in the sample countries that implemented the Schengen treaty in 1995: Austria, Belgium, France, Germany, Italy, Netherlands, Portugal, and Spain - Old Member States. Countries that became members of the free zone in 2008 are Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, and Switzerland - New Member States. I excluded from the analysis small-sized Schengen member states, i.e., European microstates (less than a million population) - Liechtenstein, Luxembourg, Malta; Island countries (no land borders) - Iceland, Greece; Scandinavian countries (half-island states) - Finland, Sweden, Norway, Denmark. Considering the highly distinctive Covid management approaches undertaken by the latter countries, I exclude them from the dataset.

3.2.2 Interreg-A Cross Border Cooperation (CBC) Programs

After reviewing the initial analysis, I used additional data sources to examine mechanisms and channels. European Cross-Border Cooperation (CBC) programs, known as Interreg A, support cross-border initiatives such as sharing resources, developing infrastructure, and increasing collaboration across internal borders. The first ever CBC survey was conducted in 2015 among residents of border regions to gain insights into their lives and to understand the local community better. Approximately 40,000 respondents were classified into 56 CBC program units. By categorizing the respondents into CBC program units at the NUTS3 level, the survey aimed to identify regional variations in socioeconomic conditions, infrastructure development, resource sharing, and collaboration opportunities. The survey revealed interesting results, and in 2020, the second survey was conducted to get even more accurate information on cross-border areas [7].

[7]The survey was conducted between February and April 2020. The interviewers in the survey were highly trained so that all of the respondents' answers applied to a *COVID-free* situation, thus minimizing the measurements errors due to the pandemic.

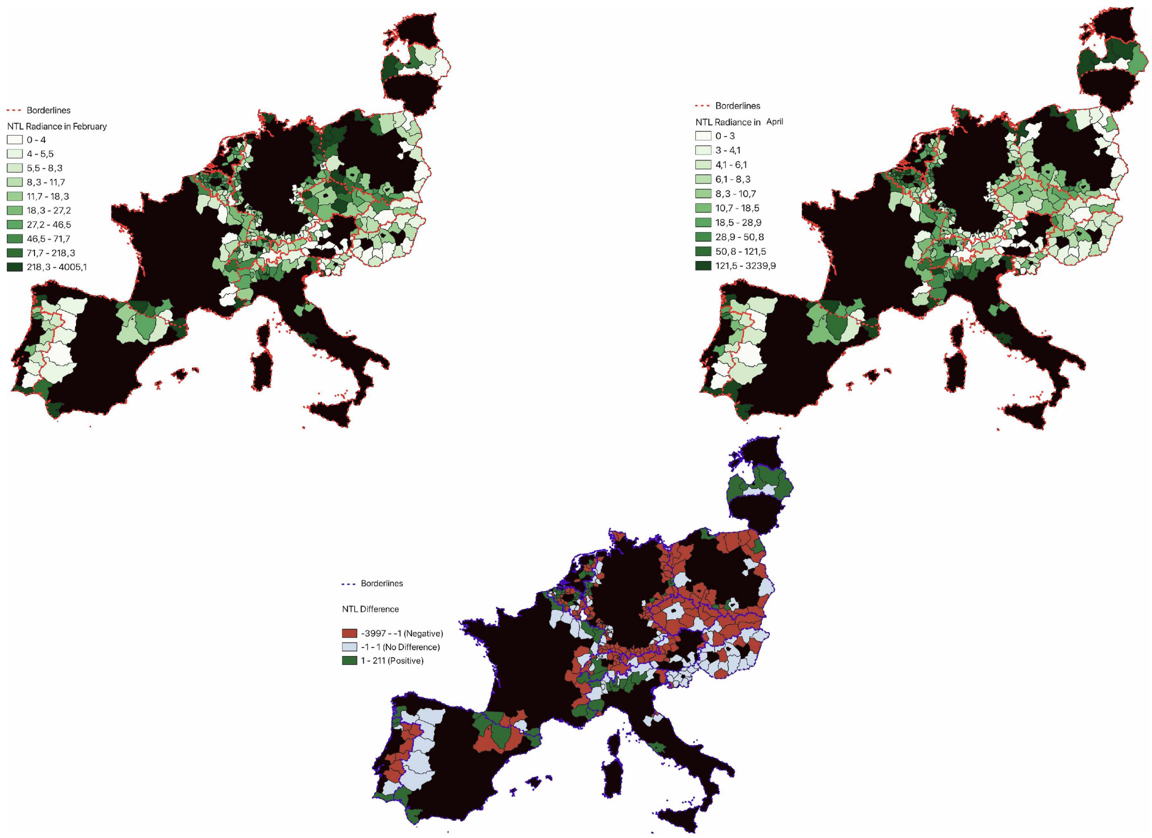
Table 3.1: The Interreg-A CBC Programs and Neighbouring Country Pairs

Interreg CBC Program/Country Pair	Border Enactment	Interreg CBC Program/Country Pair	Border Enactment
CB001 BE-DE-NL	March 14	CB029 Slovenia-Croatia	March 14
CB002 Austria-Czech Republic	March 12	**CB030 Slovakia-Czech Republic**	March 14
CB003 Slovakia-Austria	March 14	**CB031 Lithuania-Poland**	March 14
CB004 Austria-DE/Bavaria	March 11	CB032 SE-FI-NO	March 16
CB005 Spain-Portugal	March 16	**CB033 Italy-France**	March 14
CB006 ES-FR-AND	external border	**CB034 France-Italy**	March 14
CB008 Hungary-Croatia	March 12	**CB035 Italy-Switzerland**	March 13
CB009 DE/Bavaria-Czech Republic	March 14	**CB036 Italy-Slovenia**	March 14
CB010 Austria-Hungary	March 12	CB037 Italy-Malta	March 14
CB011 DE/Brandenburg-Poland	March 15	CB038 FR-BE-NL-UK	external border
CB012 Poland-Slovakia	March 16	**CB039 FR-DE-CHE**	March 14
CB013 PL-DN-DE-LI-SE	March 16	CB040 France-United Kingdom	external border
CB014 FI-EST-LV-SE	Marrch 16	**CB041 France-Switzerland**	March 13
CB015 Slovakia-Hungary	March 12	CB042 Italy-Croatia	March 12
CB016 Sweden-Norway	March 16	**CB044 Belgium-France**	March 20
CB017 DE/Saxony-Czech Republic	March 14	CB045 FR-BE-DE-LUX	March 16
CB018 Poland-DE/Saxony	March 15	**CB046 Belgium-The Netherlands**	March 20
CB019 Germany-Poland	March 15	CB047 United Kingdom-Ireland	external border
CB020 Greece-Italy	March 12	CB048 United Kingdom-Ireland	external border
CB021 Romania-Bulgaria	external border	CB049 Hungary-Romania	external border
CB022 Greece-Bulgaria	external border	**CB050 Estonia-Latvia**	March 14
CB023 Germany-The Netherlands	March 14	**CB052 Italy-Austria**	March 11
CB024 DE-AT-CHE-LI	March 14	**CB053 Slovenia-Hungary**	March 12
CB025 Czech Republic-Poland	March 16	**CB054 Slovenia-Austria**	March 11
CB026 SE-DE-NO	March 16	CB055 Greece-Cyprus	external border
CB027 Latvia-Lithuania	March 16	CB056 Germany-Denmark	March 12
CB028 SE-FI-NO	March 16	PC001 Ireland-United Kingdom	external border

Notes: Author's own elaboration based on cross-border cooperation programs and information about member states' notifications of the temporary reintroduction of border control at internal borders pursuant to Article 25 and 28 et seq. of the Schengen Borders Code (Europeia, 2022). This study covers internal border areas along Schengen countries: Austria, Belgium, Czechia, Estonia, France, Germany, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovakia, Slovenia, Switzerland, and Spain.

Although the 2015 CBC survey has a mass of information, it has a salient drawback that can hamper researchers from analyzing respondents' answers deeply (Decoville and Durand, 2019). The first is the need for granularity. While respondents were classified into CBC program units, the program-level classification does not provide enough spatial granularity. Researchers could not examine localized variations and characteristics (e.g. it was possible only at the program level).

Figure 3.3: Spatial Distributions of Monthly Averaged NTL Luminosity



Notes: Author's own elaboration based on remotely sensed VIIRS nightlights data and GISCO shapefiles.

Map (a) shows NTL radiance in cross-border NUTS3 regions before the border control.

Map (b) depicts the NTL after the border controls.

Map (c) illustrates the monthly difference (i.e., $\triangle NTL_i = NTL_{i,after} - NTL_{i,before}$) in the luminosity.

The second limitation was the limited scope of questions available in the survey. The survey had two ways in which questionnaires had improved: enhanced granularity and expanded scope of questions. In the 2020 survey, information on the respondents' regional identifiers at the NUTS3 level became available. This allows me to have information on respondents' attitudes and activities in cross-border sub-regions. The second extension was to have information on territorial typologies, i.e., if respondents lived in villages, small cities, or large cities. By incorporating information about respondents' settlement types, the CBC survey gained an additional layer of analysis about cross-border dynamics.

During the first wave of the pandemic in 2020, one country's border controls were followed by border restrictions in another country. Table 3.1 gives detailed information about the dates of border controls along 56 CBC areas, including the internal and external European borders. For example, if country A's border had been closed and A's neighboring country B had not enacted border restrictions yet, I still count this as a border enactment. For example, Austria closed the border officially on March 12th and then Slovakia on March 14th, so I count that on March 12th, the border between the two countries had been closed in response to the pandemic. As the virus spread around Europe, countries introduced border controls in a domino effect mode.

For the initial descriptive and motivational purpose, I merged the CBC survey to the NTL dataset and calculated the spatial distribution of monthly averaged NTL radiance before and after the enactment of border controls across CBC cooperation areas. I conducted the raster calculation to generate monthly differences, which are defined as follows:

$$\triangle NTL_i = NTL_{i,after} - NTL_{i,before}$$

Where $\triangle NTL_i$ is the monthly difference in luminosity in the cross-border region i, $NTL_{i,after}$ is the monthly averaged luminosity after the border controls in area i, and $NTL_{i,before}$ is the monthly averaged luminosity before the border controls in region i.

Graphical inspection in Figure 3.3 clearly shows that NTL luminosity decreased in cross-border areas after the border controls came into force in March. The sole plausible justification for such outcomes is decreased economic activities. An explanation based on people's movement is invalid due to data-related constraints. First, the approximate time Suomi NPP VIIRS satellite nightly overpass is ca. 1:30 am local time. The Suomi NPP VIIRS sensor can capture stable lights, such as those produced by cities, towns, and other permanent artificial lighting sources. It can detect the intensity of light emitted by streetlights, buildings, industrial regions, and other infrastructure that contribute to the consistent illumination of the nighttime. However, if a movement of people does not result in significant changes in the intensity of artificial lighting in an area, it may not be captured by satellite sensors.

These sensors are suited to capturing and monitoring stable sources of artificial lighting[8]. Second, it is true that car lights, including headlights and taillights, can be captured by VIIRS, but only if they are bright enough to be detected from space and *not in motion*. Third, displacement is more likely to occur during the day or earlier in the evening than 1:30 am. And fourth, during the late-night hours, most people are typically asleep, and the presence of lights captured in satellite imagery can only indicate ongoing economic activity; if lights are still visible at that time, it suggests that there is likely an active and operating economy.

3.3 Empirical Results

I empirically investigate the effects of border controls on NTL radiance by comparing municipalities near the international border (treatment group) with those located further inland (control group)[9]. The regression model I have specified includes an interaction term between a border dummy and a border control dummy. I adopt a difference-in-difference approach, and the benchmark model is as follows:

$$Log(NTL)_{i,t} = \beta_1 + \beta_2 Closure_t + \beta_3 Border_i + \beta_4 Border_i \times Closure_t + \epsilon_{i,t} \tag{3.1}$$

In Equation 3.1 where $Border_i$ is a binary variable that equals one for municipality i near the international border (within a 25km radius) and zero for interior municipality i. The 25 km distance is used by Eurostat, the statistical office of the European Union, as a threshold to define cross-border regions. These are regions that are located within 25 kilometers of an international border. This definition is often used in the literature to analyze cross-border

[8]Otherwise, the monitoring of human movements and displacements is complex and often requires multiple sources of data, such as surveys, census data, mobile data, and other types of data collection and analysis.

[9]Oftentimes, border regions are defined as treated and interiors as a control group in the European integration and border studies - primarily at NUTS3 level (Mitze and Breidenbach, 2018; Niebuhr, 2008; Braakmann and Vogel, 2011) and at NUTS2 level (Wassmann, 2016), and hardly ever at the cities' level (Brakman et al., 2012; Heider, 2019; Brülhart et al., 2018). However, the border control treatment policy was intensely and immediately directed to peripheral border cities rather than targeted to the whole country, so using interior cities should not contaminate the donor pool substantially.

interactions, economic activities, and other phenomena that may be influenced by proximity to a border. $Closure_{i,t}$ is a binary variable that equals one for the post-border control period and zero for the pre-border control period. The interaction term $Border_i \times Closure_{i,t}$ captures the differential effect of border control on municipalities near the border compared to those further inland - interaction is a key coefficient. A significant negative coefficient for the interaction term indicates that border control has a differential impact on NTL radiance in the treatment group compared to the control group, particularly relative adverse effects.

It is important to note that the Schengen Area went through a resembling situation, as the European countries involved in the refugee crisis in late 2015 had to implement border restrictions to combat illegal migration. Some countries introduced identity checks at internal borders in response as hundreds of thousands of people moved to Europe seeking asylum. Though the scale and intensity of border controls were the greatest during the COVID pandemic, borders have not been so widely and tightly restricted for nearly three decades [10]. Many Europeans believe that the main advantage of European integration is the abolition of internal border controls, which allowed the free movement of people, goods, services, and capital (Commission, 2015). Despite such public attitudes toward "borderless Europe", temporary segregation was re-introduced in some countries to slow down the spread of coronavirus during the first unexpected wave in March 2020. In July 2020, the second wave of the virus started worldwide and lasted until December 2020. In response to the second wave of the pandemic, governments were much more prepared and introduced more selective policy measures that were expected to be more effective than those of the first wave. Governments learned from the experiences of the first wave and utilized the knowledge gained to refine their strategies. They better understood the virus and its transmission dynamics, which allowed them to implement measures targeting high-risk areas or population groups while minimizing disruptions to the overall economy and society. The impact of the second

[10] In France and other parts of Europe, there has been a noticeable trend of once closely integrated communities being separated by makeshift border walls and barriers that now divide towns and villages. This change comes after decades of primarily open borders in the region, and it has become a common sight across various European towns, see Figure 3.C.1.

wave cannot be considered a quasi-experimental shock as interventions were deliberately put in place to mitigate its adverse effects.

This paper examines the domino effects of border controls and their impact on European socio-economic activities during the quasi-experimental scenario of the first unexpected outbreak as it involved sudden and unforeseen border restrictions. From this study, we can learn that there are short-run border restrictions-induced effects (e.g., an immediate reduction in cross-border people, goods, services, and capital flows). As the COVID-19 pandemic continued to evolve, the initial and unforeseen impact of restrictions imposed by the pandemic gradually slowly faded away. Consequently, this study is limited in providing insights into the potential consequences of these restrictions in the long run.

In Table 3.2, my results show that nightlight luminosity declined by approximately 12% in border cities relative to interior cities during the initial COVID-19 border restrictions. I conduct a comparative analysis to gain a deeper understanding of the differences between Eastern and Western border regions after implementing border restrictions. The results in Table 3.3 show that there is a substantial decline in NTL in Eastern border cities relative to interiors, and it is roughly 30% (for more detailed descriptive statistics, see Table 3.A.1 and

This paper proposes several factors that could contribute to a more significant relative decline in nighttime luminosity in Eastern border regions compared to Western border regions. First, Eastern European countries have a higher share of industrial and manufacturing industries than Western European countries in border regions. During the pandemic, industrial activities experienced significant disruptions due to supply chain interruptions and reduced demand. The decline in industrial production and related energy consumption in Eastern border regions could have contributed to a more considerable decrease in nighttime luminosity than in Western border regions. Second, socioeconomic disparities between Eastern and Western border regions could have also played a role. Eastern border regions, on average, have lower incomes, are less integrated into the EU, and have a higher proportion of jobs severely affected by the pandemic.

Table 3.2: The effects of border controls on VIIRS NTL luminosity: border vs. interior cities

	(1)
	Log(NTL)
Border Closures	-0.155***
	(.002)
Border × Closures	-0.121***
	(.0029)
Month Fixed Effects (Q1)	✓
Municipality Fixed Effects	✓
Constant	✓
N	338,404
$Adjusted\ R^2{}_{within}$	0.116

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

I introduce two key potential channels through which adverse effects in border cities can manifest: agglomeration size and sectoral specialization. The impacts of border controls on the different subgroups of border towns were estimated separately using triple differences (DDD) models of the following form:

$$Log(NTL)_{i,t} = \beta_1 + \beta_2 Closure_t + \beta_3 Border_i + \beta_4 SpecializedSector_i^r + \beta_5 Border_i \times Closure_t + \beta_6 SpecializedSector_i^r \times Closure_t + \beta_7 Border_i \times SpecializedCity_i^r + \beta_8 SpecializedCity_i^r \times Closure_t \times Border_t + \epsilon_{i,t} \tag{3.2}$$

$$Log(NTL)_{i,t} = \beta_1 + \beta_2 Closure_t + \beta_3 Border_i + \beta_4 CitySize_i + \beta_5 Border_i \times Closure_t + \beta_6 CitySize_i \times Closure_t + \beta_7 Border_i \times CitySize_i + \beta_8 CitySize_i \times Closure_t \times Border_i + \epsilon_{i,t} \tag{3.3}$$

In Equation 3.2 and Equation 3.3 where $Border_i$ is a binary variable that equals one for municipality i near the international border (within a 25km radius) and zero for interior municipality i, $Closure_t$ is a binary variable that equals one for the post-border control period and zero for the pre-border control period. $CitySize_i$ is a binary variable that equals one for small cities and zero for big cities[11]. $SpecializedCity_i^r$ is a sub-group category based on NUTS3 level (*identified as r*). Sectoral specialization is a categorical variable[12] - industrial city, financial city, and service city. I benchmarked agricultural-oriented cities against a comparison group to analyze the differences. A significant coefficient for the triple interaction term indicates that border controls have a differential impact on NTL radiance in small border cities vs. large cities (in Equation 3.2) and industrial, consumer, service, finance-oriented vs. agriculturally oriented border cities (in Equation 3.3), respectively.

Both channels are addressed by dummies for different municipality-type subgroups. Consequently, two subgroups are defined: (i) *Small cities vs. Large cities.* All cities within the lower quantile of the population density distribution are considered small cities. I calculate the mean population density $\sum_{i=1}^{i} \frac{\frac{population}{area(km^2)}}{i}$ for each country by averaging the population density values within each country. I compare the population density value for each country with its corresponding mean. Then I identify values below the mean population for that specific country and arrange the cities in the dataset in ascending order based on their population density. The lower quantile includes cities with populations ranging from the minimum value to the mean population density size. These cities are considered small based on the given definition. *(ii) Industrial cities & consumer cities & financial cities & service cities vs. agricultural cities.* The selection into this subgroup is based on employment data (share of employed people) at the NUTS3 level from the 2018 statistics. If a NUTS3 region is specialized in a particular sector, I assume that the cities within that region also have specialization in the same sector. If a specific sector dominates the regional economy and is concentrated within Region A, in that case, the cities within Region A most likely also have a certain level of specialization in a similar sector. Therefore, it is common to use the specialization of NUTS3 regions as an indicator of the specialization of cities within those regions[13].

[11] I define city size based on population density and the mean value for each country independently.

[12] I define the city as industrially oriented if the highest share of people is employed in the manufacturing sector (at NUTS3 level).

[13] While there may be some variation and diversity in economic activities within individual cities, the overall

Table 3.3: The effects of border controls on VIIRS/NTL luminosity: OMS vs. NMS

	(1)	(2)
	OMS	NMS
Border Closures	-0.161***	-0.0597***
	(0.002)	(0.011)
Border × Closures	-0.066***	-0.287***
	(0.003)	(0.011)
Month Fixed Effects (Q1)	✓	✓
Municipality Fixed Effects	✓	✓
Constant	✓	✓
N	274,852	63,552
Adjusted $R^2{}_{within}$	0.125	0.117

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The first channel, agglomeration size, has been previously examined in border studies focusing on border easing, though it has not been adequately addressed yet in the context of border restrictions. Redding and Sturm (2008), and Brülhart et al. (2018) found that small towns exhibit a higher degree of responsiveness to the integration (fall of the Iron Curtain) compared to larger towns; however, on the other hand, Brakman et al. (2012) suggest that larger European cities play a more significant role in the process of integration compared to smaller towns or rural areas. If the size of a city can have a salient role in the course of integration, it is expected that city size will be important in the case of temporary segregation. While larger cities may face significant disruptions due to their high population density, in Table 3.4, surprisingly, I find that small towns experienced more substantial effects due to border restrictions during the pandemic (approx. 7% decline in small border cities relative to large non-border cities). We can note a few factors why

specialization of the region can still influence the specialization of its constituent cities.

small towns were so differently and adversely affected by border restrictions. First, small cities heavily reliant on tourism and cross-border trade experienced a significant economic downturn when border restrictions limited visitor inflows and disrupted supply chains. These cities have limited economic diversification compared to larger cities, making them more vulnerable to disruptions. Second, small towns have limited transportation options, with fewer international flights and direct routes. When borders closed, and travel restrictions were imposed, it was more challenging for people in small cities to travel internationally and for international visitors to reach these destinations. Third, small cities near international borders often have closer ties and dependencies on neighboring countries, e.g., formerly historically united cities or so-called twin cities Gubin (PL) & Guben (DE).

Table 3.4: The effects of border controls on VIIRS NTL: city size

	(1) Log(NTL)
Border Closure	-0.0126***
	(0.00310)
Closure × Border × Small City	-0.0755***
	(0.00634)
Month Fixed Effects (Q1)	✓
Municipality Fixed Effects	✓
Constant	✓
N	338404
Adjusted R^2_{within}	0.133

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.5: The effects of border controls on VIIRS NTL: sectors

	(1)
	Log(NTL
Border Closure	-0.138***
	(.003)
Closure × Border	-0.075***
	(.0067)
Closure × Border × Industrial	-0.0508***
	(.007)
Closure × Border × Wholesale & Food Service	-0.0276**
	(.0125)
Closure × Border × Financial	-0.202
	(.127)
Closure × Border × Service	-0.043***
	(.009)
Border Closure × Industrial	✓
Border Closure × Wholesale & Food Service	✓
Border Closure × Financial	✓
Border Closure × Service	✓
Month Fixed Effects (Q1)	✓
Municipality Fixed Effects	✓
Constant	✓
N	338,404
Adjusted $R^2{}_{within}$	0.117

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis
I benchmarked the agriculture sector against a comparison group (4 main sector) to analyze the differences.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The second potential channel is sectoral specialization. I show that border cities specializing[14] in manufacturing, retail & consumer industries, and services are more negatively

[14] I call this "sector specialized" as it signifies that the sector has a particular focus, expertise, and workforce concentration compared to other industries. It suggests that the sector significantly impacts the overall employment landscape and potentially plays a crucial role in the economy.

affected by border regulations than other cities because economic entities in these sectors are embedded in transnational networks. These networks involve the movement of goods, services, and capital across national borders to meet the demands of a local market. Table 3.5 suggest a decline in NTL by approximately 5% in industrial, 4% in service, and 3% in consumer border cities relative to agriculture-oriented non-border cities - and no significant effects in financial cities.

First, I show that cross-border mobility limitations can significantly impact manufacturing companies as disruptions in cross-border mobility lead to supply chain disruptions, production delays, and increased costs, which can have a larger effect on the local economy in these areas. Second, retailers and consumer-oriented economic entities often rely on cross-border mobilities, especially on tourism-related activities, which were significantly impacted by the policy restrictions. Third, border cities specializing in the financial sector may be less exposed to the effects of temporary border restrictions. These cities have less dependence on the foreign market. Moreover, the financial sector maintained operations and served clients even during periods of restricted mobility. Recognizing these distinctions is crucial for policymakers to develop targeted strategies to promote resilience in different types of border cities.

3.4 Additional Analysis and Discussion

The above-described estimation results hint at an adverse effect of the border restrictions on the NTL of border municipalities, particularly in small border cities. I showed that when examining the effects of border restriction orders on cities, it is possible to observe heterogeneous impacts within the treated group. The results can differ based on several factors, including the city's characteristics (city size), industry composition or pre-existing economic conditions (specialized cities), and geographic location (proximity to the border). In this section, I zoom in and analyze the border areas more deeply to provide a more granular understanding of the impacts of border restriction and show a few other reasons why the effects can be even more heterogeneous[15]. This section is entirely devoted to an analysis of small border cities. Figure 3.B.1 displays that roughly 80% of the respondents in the CBC survey 2020 reside in rural or small cities and just 20% in urban or large cities.

Using the CBC survey, I study cross-border experiences and obstacles in border regions and understand the factors contributing to differences in these areas. I focus on three key dimensions/subgroups: cross-border mobility, cross-border experiences, and the composition of border cities. The selection into subgroups is based on 2020 cross-border cooperation survey data. The effects of the border restrictions on the different subgroups of border towns are defined in the following model:

$$Log(NTL)_{i,t} = \beta_1 + \beta_2 Closure_t + \beta_3 Groups_i + \beta_4 Groups_i \times Closure_t + \epsilon_{i,t} \tag{3.4}$$

in Equation 3.4 where $Groups_i$ is defined in three dimensions[16]. The first group is related to the reasoning for cross-border mobility. The decline in NTL could be a major if (i) respondents residing in border region A commute to border region B because of *buying goods & services, leisure, and business purposes*. However, in border regions where the largest share of respondents answered that the main reasons for cross-border mobility are *friend/family visits or using public service*, the decline in NTL was not detected. The second group is the composition of border areas. If respondents are *highly educated and employed*, then regions where they reside are negatively affected by border restrictions because cross-border mobility is high in such areas. The third group is cross-border experience; if respondents live in regions *where there is a heightened awareness of EU-funded cross-border cooperation and no obstacles to border crossings*, then the imposed border controls should be negatively influential as cross-border mobility is exceptionally high in those border regions.

[15]By zooming in on the border areas, I capture unique challenges faced by these regions due to border restrictions. This localized analysis contributes to a more comprehensive understanding of the impacts and allows for targeted interventions to address the specific needs of the border communities during the pandemic.

[16]The questionnaire is provided in Table 3.B.1 - Table 3.B.4

Table 3.6: The effects of border controls on VIIRS NTL: cross-border mobility

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Border Closure	-0.498***	-0.332***	-0.351***	-0.319***	-0.241***	-0.281***	-0.538***
	(0.0132)	(0.00600)	(0.00693)	(0.00429)	(0.00724)	(0.00551)	(0.0123)
Closure × Visit Family	-0.00319	0.241***					
	(0.0374)	(0.0316)					
Closure × Visit Friends	0.151***		0.266***				
	(0.0338)		(0.0272)				
Closure × Use Public Service	0.0318			0.237***			
	(0.0374)			(0.0320)			
Closure × Shopping	-0.286***				-0.128***		
	(0.0194)				(0.0165)		
Closure × Business Purposes	-0.0729*					-0.0692*	
	(0.0309)					(0.0305)	
Closure × Leisure Activities	-0.486						-0.406***
	(0.0222)						(0.0196)
Month Fixed Effects (Q1)	✓	✓	✓	✓	✓	✓	✓
Municipality Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Constant	✓	✓	✓	✓	✓	✓	✓
N	128872	128872	128872	128872	128872	128872	128872
Adjusted R^2_{within}	0.131	0.125	0.125	0.124	0.124	0.124	0.128

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Studying the factors behind the cross-border movement of people from border regions to foreign countries is crucial for understanding why one particular border city may be affected less than another. Therefore I construct and define variables to reflect why people travel to border regions. The CBC survey question is worded as follows: How often do you go to a foreign area (sharing the same borderline) for each of the following reasons? (i) To visit family (ii) To visit friends (iii) To use public services (e.g., health or education services) (iv) To shop for goods or services (e.g., buying clothes or visiting a hairdresser) (v) For work or business purposes (vi) For leisure activities including tourist visits[17].

[17]CBC survey is conducted at the NUTS3 level, and I have constructed sub-groups based on respondents'

In Table 3.6, my findings indicate that where the primary reasons for cross-border mobility are family and friend visits or public services, border restrictions imposed on cross-border mobility had no effect or did not result in negative consequences. There are some potential reasons why restrictions on cross-border mobility may not have had a negative economic impact. Cross-border mobility for family and friend visits or public services does not involve significant economic spending. For example, visiting family and friends may primarily involve personal expenses rather than a substantial economic activity that could be detected in the NTL luminosity or other economic indicators. Also, in regions where there are accessible alternatives for public services locally, such as healthcare, education, or government facilities, the impact of cross-border mobility restrictions may be minimal. So if people can access similar services within their own region locally, there should not be an economic loss due to border restrictions.

I show that the restrictions imposed on cross-border mobility adversely influenced economic indicators such as NTL luminosity - namely, where the reason for cross-border mobility is leisure and tourist activities, buying goods and services, and work or business purposes. First, restrictions on cross-border mobility can significantly affect the tourism and leisure industry, which often relies on visitors from other countries. Tourism contributes to local economies through spending on accommodations, restaurants, transportation, attractions, and other related services. Border restrictions led to a decline in tourist arrivals and decreased economic activity and NTL luminosity in tourist-dependent areas. Second, some regions experience significant cross-border shopping activities, where people from one country travel to another for better deals, tax advantages, or product availability. Restrictions on cross-border mobility can impact this consumer behavior, leading to decreased retail spending and potentially affecting local businesses. This reduction in economic activity could result in lower NTL luminosity in areas where cross-border shopping is common.

responses. It is reasonable to assume that these sub-categories can also correspond to the municipality level within the NUTS3 regions. This assumption allows for a more granular analysis and understanding of the factors influencing migration within specific municipalities. Each sub-group was constructed independently based on respondents' responses. I have calculated the share in each group at the NUTS3 level.

Third, cross-border mobility is crucial for work and business purposes, such as commuting, employment, and business transactions. Restrictions on mobility can disrupt these activities, impacting both individuals and businesses. Reduced cross-border movement for work and business reasons may result in decreased economic productivity and lower NTL luminosity in regions relying heavily on cross-border economic interactions.

Table 3.7: The effects of border controls on VIIRS NTL: education & employment level

	(1) Education	(2) Employment
Border Closure	-0.292***	-0.264***
	(0.00907)	(0.00414)
Closure × Highly Educated	-0.000326	
	(0.0177)	
Closure × Employed		-0.0475***
		(0.00558)
Month Fixed Effects (Q1)	✓	✓
Municipality Fixed Effects	✓	✓
Constant	✓	✓
N	128932	128932
Adjusted R^2_{within}	0.124	0.125

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Aside from the importance of reasons for cross-border mobility, the characteristics such as the educational and employment backgrounds of the people who move across borders are crucial. Border controls can significantly affect cities with many educated and employed individuals. In Table 3.7, I show that border controls had negative implications for towns with many employed individuals, regardless of their educational background. Educated people can have more opportunities and resources to navigate the challenges posed by border controls.

In addition to the reasoning for cross-border mobility and characteristics of cross-border movers, I study cross-border experiences. Mainly I focus on the awareness of EU-funded cross-border cooperation activities in border areas and whether living near the border represents an opportunity. A heightened awareness of EU-funded cross-border cooperation activities indicates that individuals in border regions have actively engaged with and benefited from these initiatives.

Table 3.8: The effects of border controls on VIIRS NTL: cross-border experience

	(1)	(2)
	EU Fund	More Opportunity
Border Closure	-0.225***	-0.232***
	(0.00751)	(0.0113)
Closure × Awareness on EU fund	-0.264***	
	(0.0272)	
Closure × More Opportunity		-0.109***
		(0.0200))
Month Fixed Effects (Q1)	✓	✓
Municipality Fixed Effects	✓	✓
Constant	✓	✓
N	128932	128932
Adjusted R^2_{within}	0.125	0.124

Notes: Fixed-Effects model. Robust standard errors are presented in parenthesis
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 3.8, my results suggest that as more individuals become aware of activities funded by the EU-funded CBC activities and view living near the border as an opportunity rather than an obstacle, the economic consequences of border restrictions in border regions become relatively negative. Increased awareness about EU-funded projects can lead to greater participation, collaboration, and utilization of funded projects, contributing to the region's economic growth and job creation. In line with this, if more people start perceiving border regions as areas with economic potential rather than barriers, it can increase investment, trade, and tourism activities. However, as restrictions hindered the free movement of people and resources, it became more challenging to sustain such cross-border collaborations, resulting in a loss of shared knowledge, innovation, and economic benefits. Overall, policymakers should consider negative consequences and seek ways to mitigate them while balancing the need for health security and other policy objectives.

3.5 Conclusion

Since the Schengen establishment, the border restrictions imposed during the pandemic have been the most stringent than anything previously experienced within the Schengen Area. Using unconventional data sources, NASA's Black Marble Nighttime Lights products, I evaluate the potential economic cost of border control during the COVID-19 pandemic. This paper has several important findings. First, the effect of border controls varies across cities. Border cities, particularly small ones, experienced more significant economic losses than interior cities. Second, border municipalities of New Member States recorded a much larger drop in NTL radiance than the Old Member States.

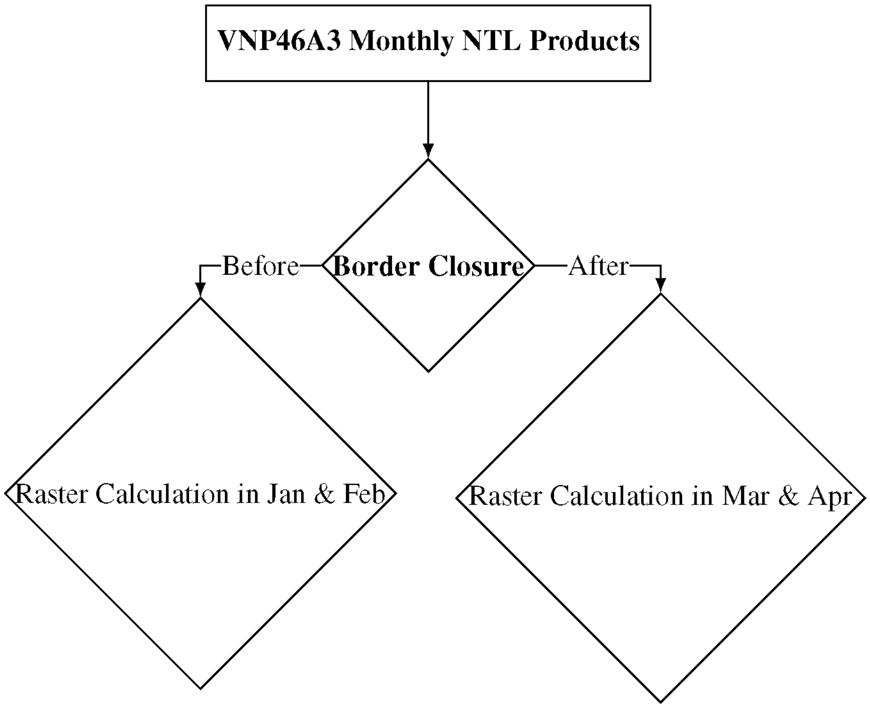
Third, the adverse effect of temporary segregation is largest in border municipalities specializing in manufacturing, consumer, and service-oriented industries. These municipalities tend to be more negatively affected by border restrictions, indicating that economic activities reliant on cross-border interactions have been disrupted. Fourth, there is a significant reduction in NTL in cities where residents frequently commute to foreign cross-border areas for business, shopping, and leisure. Lastly, the largest drop in NTL is observed in those border municipalities where the majority of residents have a high awareness of EU-funded cross-border activities and perceive living near the international border as having economic potential rather than being a barrier.

Overall, the study demonstrates that such a short-term border closure can be detrimental for municipalities close to country borders. The fact that the negative effect is larger for New member states than old member states should have important policy implications. It encourages policies that are targeted to border municipalities, especially in new member states where the full integration process is still in the development stage, and additional policies should further facilitate this process.

This paper also opens up the possibilities for future research. As the border restrictions were in place for only a limited time and the policies have been shifted back again, it would be interesting to study which border municipalities managed to recover quickly and go back to the pre-pandemic economic development and which had a slow and difficult recovery. The other margins of the border restriction policies can also be studied, e.g., how border restrictions affect housing prices and business dynamism. It is also interesting to distinguish whether the reduction of economic activities during the border restrictions inside cities comes from the slowdown of activities in residential or business areas.

3.6 Appendix A: NASA Black Marble Processing

Figure 3.A.1: Data Processing



Notes: The overall workflow of NTL data before and after the border controls during the COVID-19 pandemic using NASA's Black Marble monthly products. The data retrieval process, as described below, involves several steps:

- *Downloading h5 Files:* The first step involves downloading h5 files for the 16 land tiles. These files were downloaded for the months of January, February, March, and April.
- *File Format Conversion:* In the second step, the 64 product files' format are converted to TIFF format. This conversion allows for compatibility and ease of processing in subsequent steps.
- *Merging Tiles:* The third step involves merging the individual land tiles into a single layer that represents the entire region of Europe. This merged layer combines the data from the previously converted TIFF files.
- *Adding Shape Files and Zonal Statistics:* In the fourth step, shape files of the LAU-2 spatial level are added to the merged layer.

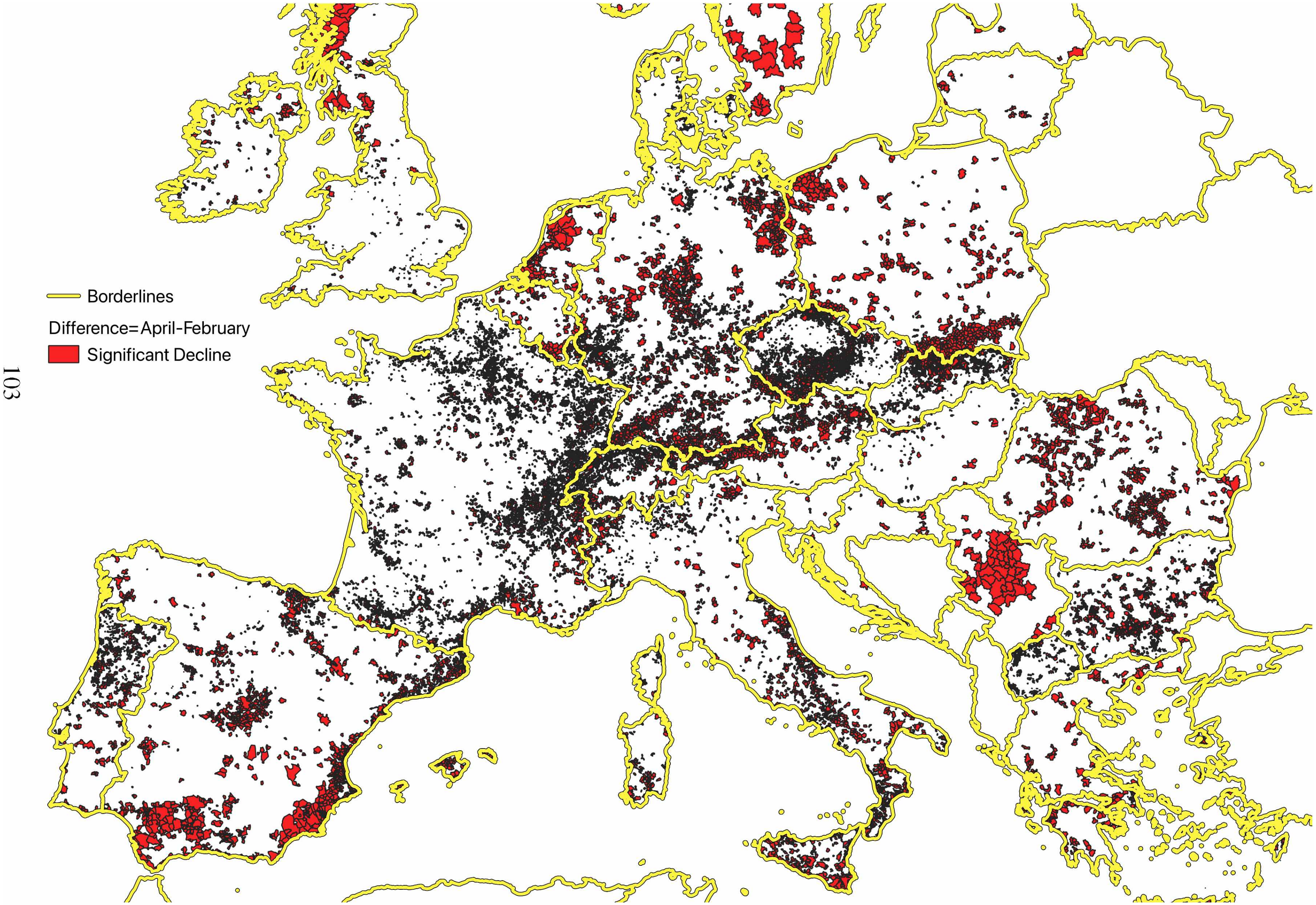
Table 3.A.1: Descriptive Statistics of log[NTL+(≈ 0.001)] in February, 2020

Countries	LAU-2	Mean	SD	Min	Max
OMS - West					
AT	2100	1.764462	1.1219	0	7.143505
DE	11160	1.735669	1.281327	0	10.3973
ES	7991	1.781889	1.473215	0	8.00765
FR	35775	1.446495	1.394471	0	9.298748
IT	8003	3.13918	1.24129	.059157	9.301953
PT	2882	2.921992	1.423006	0	9.715172
BE	589	3.714317	1.107357	1.322403	7.117976
LU	105	3.399937	.9657596	2.014249	7.295933
NL	390	4.065071	1.917735	.2911244	10.95112
NMS - East					
CZ	6258	1.940798	1.482806	0	10.8453
PL	2478	2.115067	1.677914	0	9.746455
SK	2927	1.357514	1.106135	0	8.694381
HU	3155	1.073345	.8801249	0	7.202508
SI	212	1.72807	.9074985	0	5.046938
EE	213	1.198067	1.522058	0	6.1257
LT	527	1.082879	1.622757	0	7.920162
LV	119	1.150955	1.472138	.0045958	5.716861
Total	84884	1.800253	1.485371	0	10.95112

Table 3.A.2: Descriptive Statistics of log[NTL+(≈ 0.001)] in April, 2020

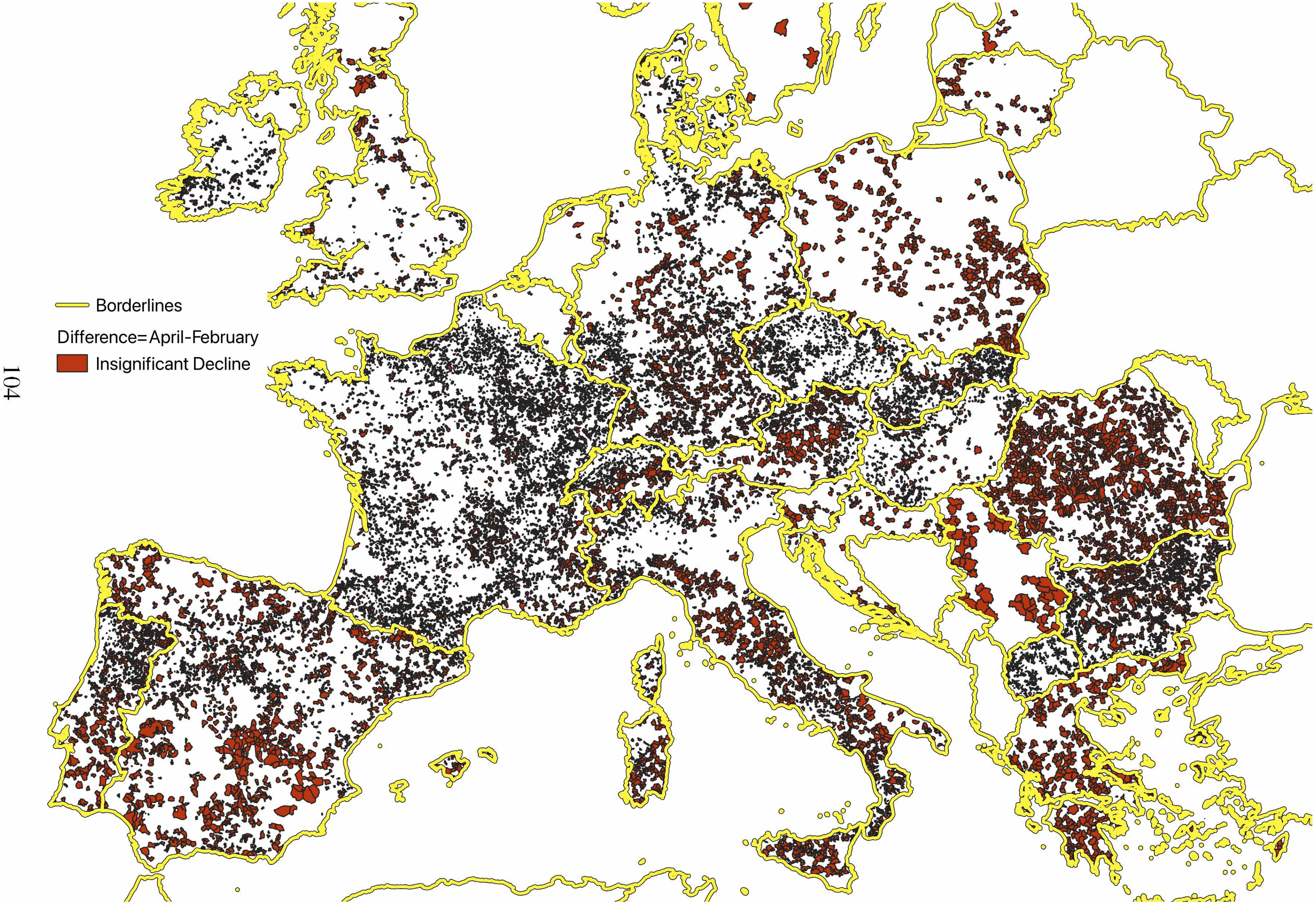
Countries	LAU-2	Mean	SD	Min	Max
OMS - West					
AT	2100	1.517459	1.15729	0	6.345119
DE	11160	1.439356	1.163355	0	7.776486
ES	7991	1.68191	1.530335	0	8.16815
FR	35775	1.290988	1.487559	0	9.298672
IT	8003	3.115321	1.303362	.0273241	9.341333
PT	2882	2.857564	1.500629	0	9.886707
BE	589	3.785746	1.095681	.5319132	7.027092
LU	105	3.334347	.9840552	1.878582	5.871408
NL	390	4.024683	1.830927	.2409158	10.94152
NMS - East					
CZ	6258	1.45786	1.092941	0	5.783825
PL	2478	1.845369	1.429313	0	8.11095
SK	2927	1.008953	1.083937	0	6.748408
HU	3155	1.005199	.8927955	0	5.598272
SI	212	1.716657	.9361971	0	4.868653
LT	527	1.014831	1.651084	0	6.678394
LV	119	1.718844	2.014665	.014045	7.895646
Total	84884	1.621624	1.514629	0	10.94152

Figure 3.A.2: Spatial Distribution of Negative Significant Changes



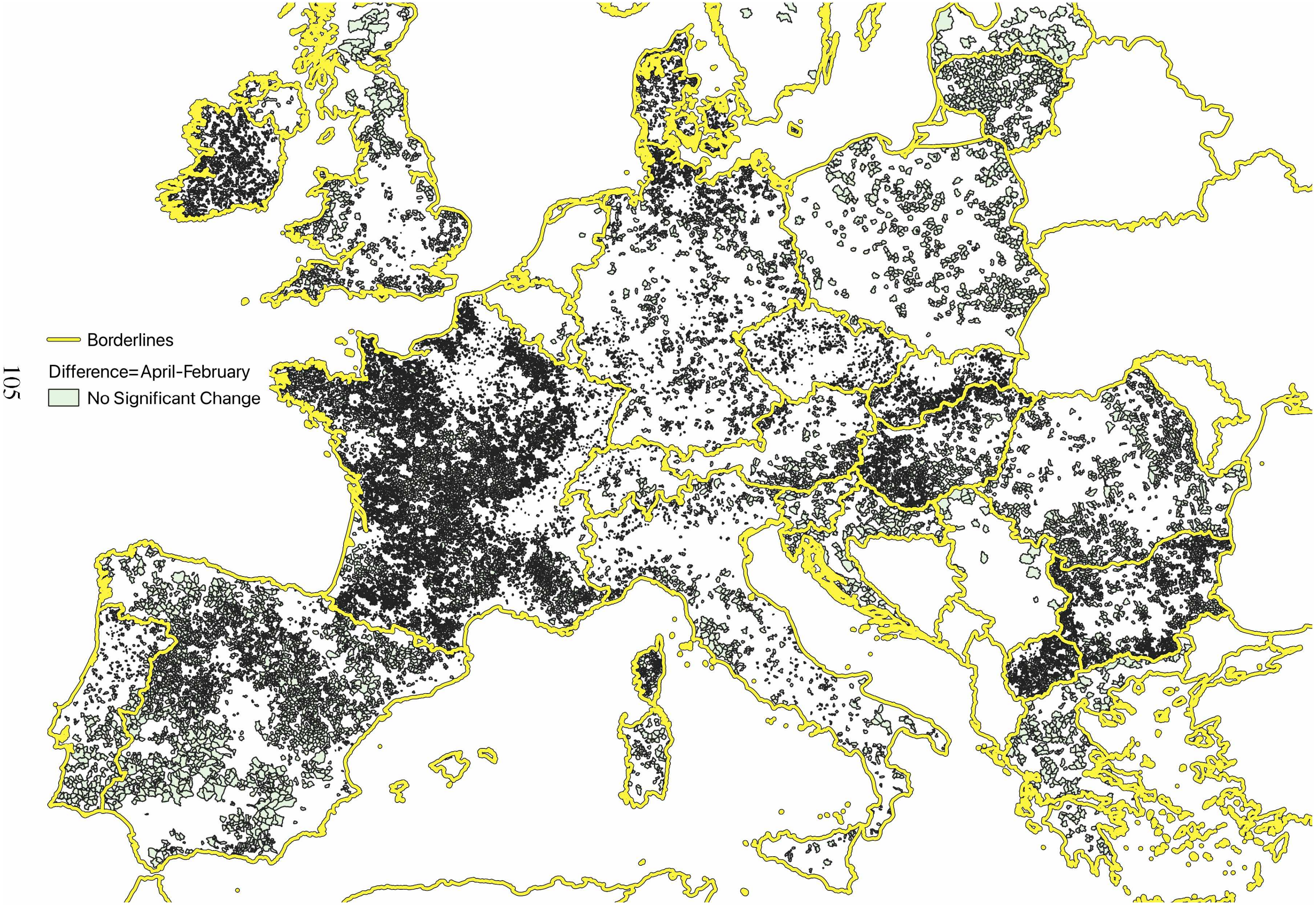
Notes: Author`s own elaboration in QGIS based on Eurostat statistics and the GISCO shapefiles.

Figure 3.A.3: Spatial Distribution of Insignificant Negative Changes



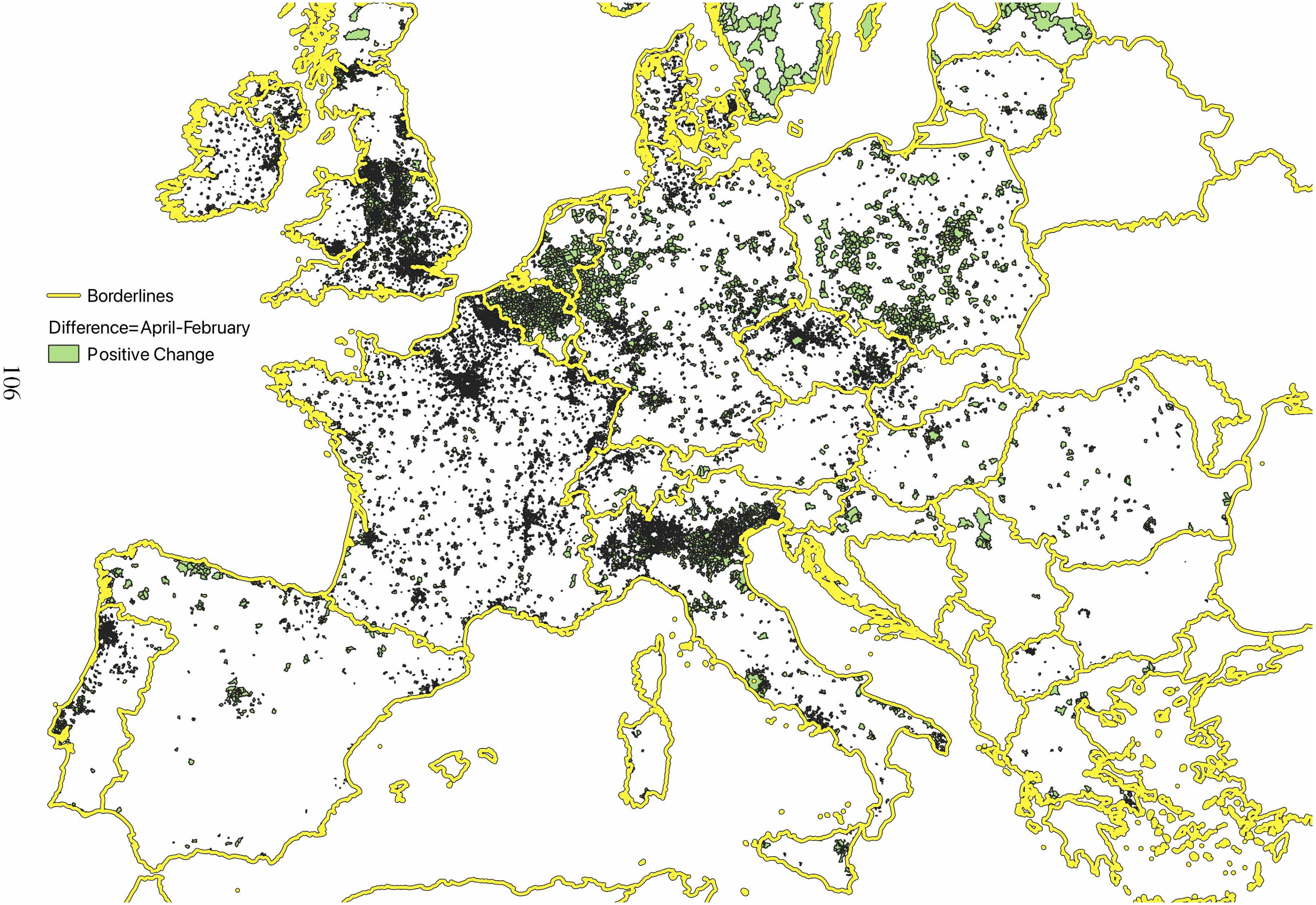
Notes: Author`s own elaboration in QGIS based on Eurostat statistics and the GISCO shapefiles.

Figure 3.A.4: Spatial Distribution of Insignificant Changes



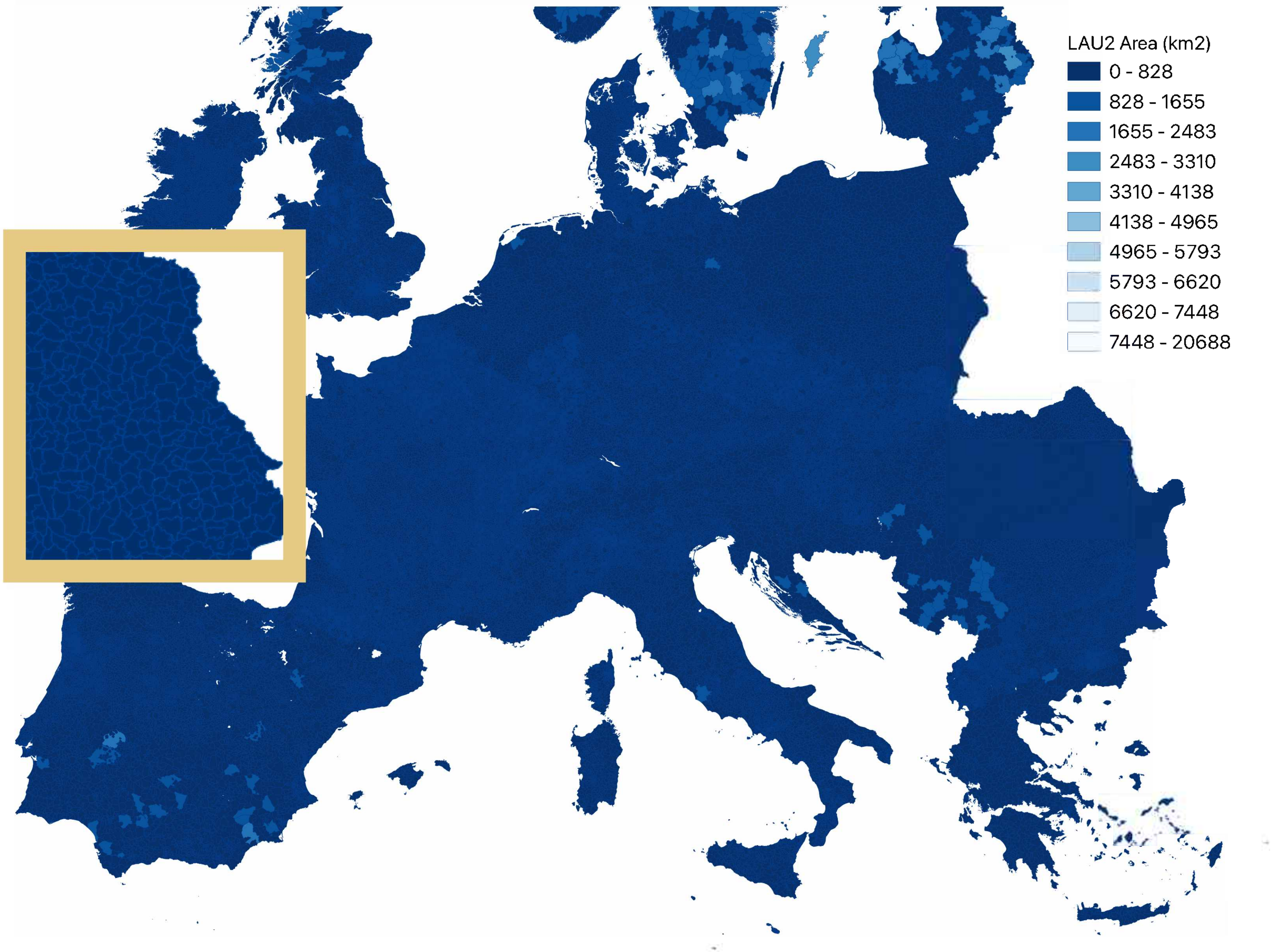
Notes: Author`s own elaboration in QGIS based on Eurostat statistics and the GISCO shapefiles.

Figure 3.A.5: Spatial Distribution of Positive Changes



Notes: Author`s own elaboration in QGIS based on Eurostat statistics and the GISCO shapefiles.

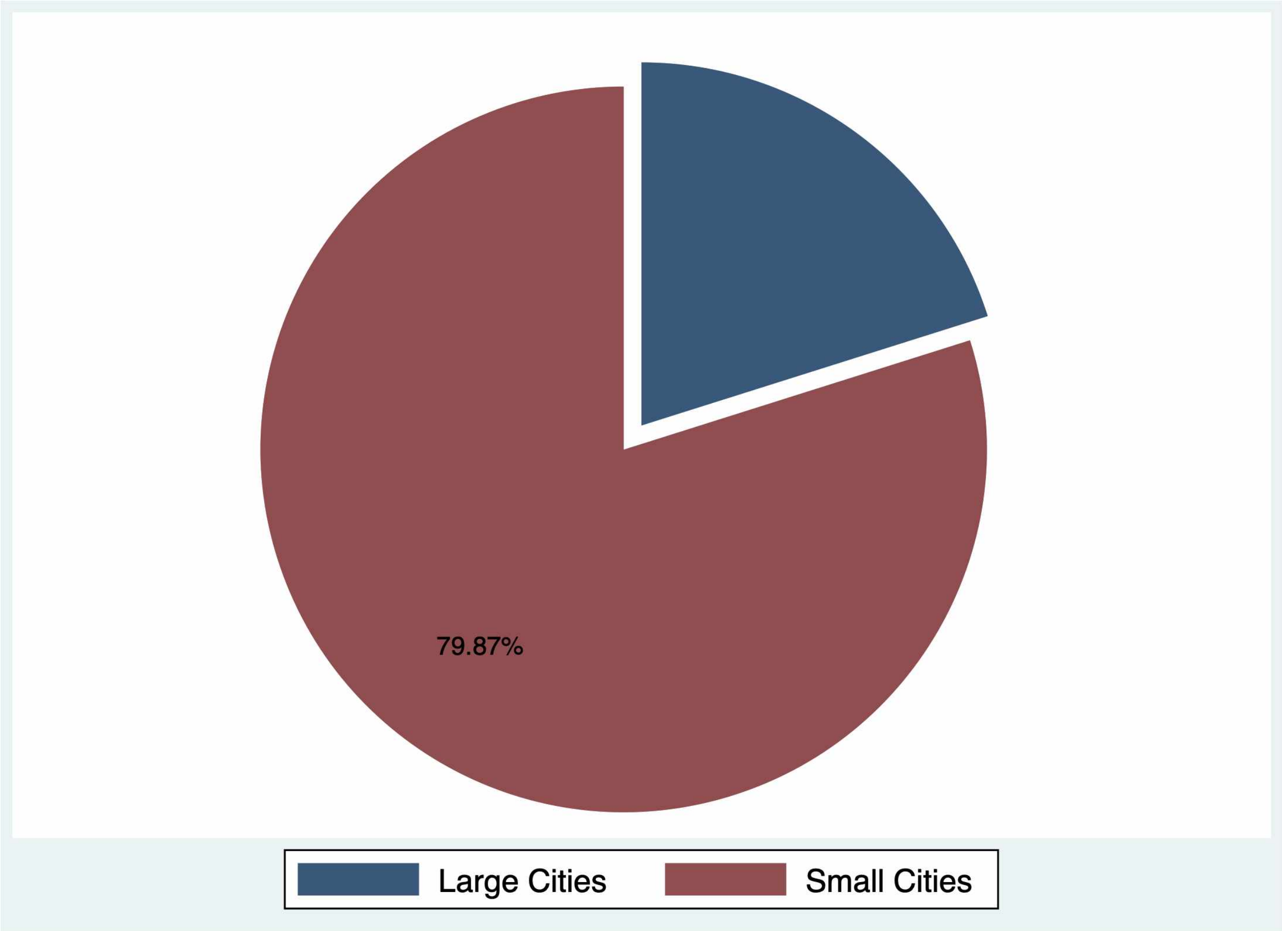
Figure 3.A.6: Spatial Distribution of Geographical Area (km2)



Notes: Author`s own elaboration in QGIS based on Eurostat statistics and the GISCO shapefiles.

3.7 Appendix B: Cross Border Cooperation survey

Figure 3.B.1: Respondents living in large and small cities according to the CBC survey



Notes: Author's own elaboration based CBC survey in 2020.

Table 3.B.1: **Cross Border Mobility**[a]

How often?					
		Once a month or more often	Several times a year	Once a year or less often	Never
1	To visit family	1	2	3	4
2	To visit friends	1	2	3	4
3	To use services	1	2	3	4
4	To shop	1	2	3	4
5	To work	1	2	3	4
6	To leisure	1	2	3	4

[a] Q2 How often do you go to [COUNTRY FROM PROGRAMME] for each of the following reasons?

Table 3.B.2: **Cross Border Experience I**

Q1	Have you heard about any EU-funded cross-border cooperation activities in the region where you live?	
	(READ OUT – ONE ANSWER ONLY)	
	Yes, and you know what they are	
	Yes, but you do not know exactly what they are	
	No	

Table 3.B.3: **Cross Border Experience II**

Q5	Would you say that living near the border with [COUNTRY FROM PROGRAMME] represents . . .	
	(READ OUT – ONE ANSWER ONLY)	
	More of an obstacle	
	More of an opportunity	
	It has no impact	

Table 3.B.4: **Socio-economic Status**

D4	How old were you when you stopped full-time education?	
	equal or more than 20 years, then coded as *High Education*	
	less than 20 year, then coded as *Low Education*	
D5a	Would you say you are employed or not?	

3.8 Appendix C: Supplementary

Figure 3.C.1: A temporary border barrier in France

Source: Photo by Thierry Thorel

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