AGGLOMERATION AND TECHNOLOGICAL SPECIALIZATION

Documents de travail GREDEG
GREDEG Working Papers Series

Basheer Kalash

GREDEG WP No. 2022-04
https://ideas.repec.org/s/gre/wpaper.html

Agglomeration and technological specialization

Basheer Kalash [a,b]

[a] *Université Côte d'Azur, CNRS, GREDEG, France*

[b] *Sciences Po, OFCE, France*

Address: GREDEG - Building 2 - Campus Azur du CNRS –

250 rue Albert Einstein, 06905 Sophia Antipolis Cedex, France

Emails: basheer.kalash@univ-cotedazur.fr; basheer.kalash@sciencespo.fr

Abstract

Notable attention has been given to the relationship between agglomeration and innovation. However, there is a lack of evidence of how agglomeration affects the type of innovation produced. This study aims to causally assess the impact of a change in agglomeration economies, via transportation improvements, on regional technological specialization. It investigates this relationship using the inauguration of the Öresund Bridge between Sweden and Denmark in 2000 as a quasi-experiment for a difference-in-difference approach. It considers the Öresund area, which consists of Copenhagen and the Swedish Skåne, as the treated regions and the other regions in Denmark and Sweden as a control group. The International Patent Classification (IPC) codes of European Patent Office (EPO) applications are employed to define technology classes for 30 NUTS-3 regions in Sweden and Denmark from 1988 to 2011. The results show that the opening of the Öresund bridge led to an increase in Skåne's highly cited patent technology classes, but no significant change in the specialization of Copenhagen. The results suggest that changes in regions' specializations are not only dependent on the quality of patent technology classes but are also region-specific.

Keywords: Agglomeration; technological specialization; Öresund; transportation infrastructure; innovation
JEL Classification: O31-O33-R11

Acknowledgment
The author would like to thank the University of Luxembourg for offering all the required facilities that helped produce this paper's first version as a chapter of his doctoral dissertation, *Essays on agglomeration, resilience, and regional innovation.* Furthermore, a special thank you is due to Prof. Dr. Christian Fons-Rosen for his thorough revision of the final manuscript and recommendations regarding the writing and adding more information to some tables.

1. Introduction

Innovation activities tend to be highly concentrated due to the significant productivity gains associated with agglomeration economies. Moving to a bigger city with a large cluster of inventors in the same field leads to a higher number and quality of patents produced by an inventor (Moretti, 2021). Improvements in transportation infrastructure can play a crucial role in furthering this process by facilitating the development of more prominent clusters of firms and workers, enhancing the agglomeration effects. Since the seminal work of Krugman (1991), several empirical studies have considered the tendency toward industrial concentration and regional sectoral specialization in response to transportation infrastructure improvements and the resultant cost reductions (e.g., Albalate and Fageda, 2016; Mora and Moreno, 2013; Bougheas et al., 2000). Thus, transportation density can be a source of industrial agglomeration (Mori and Nishikimi, 2002).

In general, agglomeration economies have been documented to raise regional patenting intensity (Carlino et al., 2007; Lobo and Strumsky, 2008). Ejermo et al. (2021) show, for example, that the opening of the Öresund Bridge attracted highly qualified workers from other Swedish regions to the greater region of Malmö, giving the region a greater labor pool. The knowledge production of Malmö, in terms of patenting, subsequently increased. These findings confirm yet again that agglomeration size increases the economy of scale of innovation activities. Furthermore, larger agglomeration economies are usually associated with large regions consisting of a core and neighboring commuting areas. Large regions offer firms greater accessibility to customers, suppliers, and competitors, as well as to knowledge providers in universities, laboratories, consultancy firms, and so forth (Johansson and Lööf, 2008).

Moreover, better accessibility across the Öresund Strait is expected to enhance the knowledge flow embedded in people. This knowledge flow can be seen as a function of the mobility and interaction of individuals who have relevant knowledge, skills, and experience (Andersson and Karlsson, 2007). Although accessibility effects are regionally bounded (Ejermo and Gråsjö, 2008), the accessibility between the nodes of inventors' networks is affected by infrastructural and institutional conditions (Ejermo and Karlsson, 2006). This implies that transportation infrastructure improvements could still enhance the interactions of inventors in a given technological field on both sides of the Öresund bridge. Indeed, in this particular case, the time and cost reduction of commuting after the bridge's opening led to each side of the bridge being within the other side's commuting zone, thereby creating a more prominent bi-national region.[1] This could benefit some technological fields and their inventors, thus increasing the returns to innovation on each side of the bridge, with important effects on regional technological specialization, since some technological fields have a higher tendency to concentrate and others have a higher tendency to be mobile (Mancusi, 2003; Eaton et al., 1999).

Despite the crucial role of knowledge accumulation in driving technological change and economic growth, there is still a lack of evidence on the types of knowledge produced in geographical space (Kogler et al., 2013). Therefore, the current study analyses regional technological specialization by investigating how a change in agglomerations due to infrastructure improvements, i.e., the construction of the Öresund bridge, affects regional technological specialization. More precisely, it tests the hypothesis that a change in a regional agglomeration leads to a change in its technological specialization.[2]

The opening of the Öresund Bridge in 2000, between Copenhagen and Malmö, the capital city of the Swedish Skåne (or Scania in English) region, has immensely improved accessibility between the two sides. Before this fixed-link connection, the commute across the Öresund was mainly achieved by ferries, which took at least 40 minutes. It now takes only about 10 minutes to drive across the new bridge, and roughly up to 40 minutes to commute by train between all the centers of the three main cities of the Öresund area, from Lund through Malmö to Copenhagen.[3] This tangible improvement in accessibility increased the volume of commuting across the Öresund from 3,000 commuters per day in 1999 to 20,000 in 2008 (Organisation for Economic Co-operation and Development, or OECD, 2013).

The total gross domestic product (GDP) of the Öresund economy accounted for roughly 21% of the Swedish and Danish economies in 1988, which rose to approximately 23% in 2011.

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[1] Of note, the Öresund region is not a functional region in the sense of an integrated labor market, because it follows two countries' different administrative and political structures. Therefore, this bi-national region combines two functional regions with better accessibility between them.

[2] See Section 2 for more details.

[3] Lund and Malmö are the two cities of Skåne County. Throughout the study, the Skåne region is denoted NUTS 3 region SE224, while the Copenhagen region is a combination of the NUTS 3 regions DK011 and DK012. In the remainder of the study, the names Skåne and Copenhagen refer to their respective regions.

However, the Danish capital accounts for the larger portion of this ratio. For example, in 1988, Copenhagen's GDP was 41.187 billion euros, compared to 24.416 billion euros in Skåne, making Copenhagen's economy almost 1.7 times larger than Skåne's. This last ratio rose to 1.89 in 2000 before falling to 1.79 in 2011.[4,5] In terms of innovation investment, according to an OECD report on Öresund (2013), the Öresund area accounts for a large share of total Danish and Swedish research and development (R&D) investments (4.9% of GDP), thus ranking the area among Europe's "innovation leaders" (European Commission, 2012). The region mainly specializes in life sciences and information and communications technology. Pharmaceuticals and electromedical equipment are its most high-tech specialization, thanks to the Medicon Valley and information technology (IT) clusters on both sides (OECD, 2013).

The opening of the Öresund Bridge thus provides a unique quasi-experiment for a DiD approach. The current study considers Skåne and Copenhagen as treatment groups and compares them to a control group consisting of the remaining 27 Nomenclature of Territorial Units for Statistics (NUTS) 3 regions of Denmark and Sweden.[6] The pre-treatment period is 1988–1999, and the treatment period is 2000–2011. Finally, the dependent variable, an index of technological specialization, is calculated based on the International Patent Classification (IPC) codes used for patent applications to the European Patent Office (EPO).

The results show that Skåne's technological specialization has increased, mainly in certain higher-quality technology classes. However, there seems to be no significant change in the specialization of the Copenhagen region.

Generally, the results indicate that a change in a regional technological specialization not only depends on the quality of technology classes, but it is also region-specific. This finding implies that regions respond differently in terms of their technological specialization to a change in their agglomeration economies and that this difference in their responses is primarily in higher-quality

[4] The source of these statistics is the European Regional Database (ERD). For more information see the data section and Appendix.

[5] Both the Skåne and Copenhagen regions are similarly sized in terms of total population, and this does not change drastically over time. For example, Skåne's total population in the years 1998, 2000, and 2011 was 1,043,797, 1,125,140, and 1,247,770, respectively. Copenhagen's total population for the same years was 924,015, 1,065,920, and 1,211,666, respectively.

[6] In total, there are 32 NUTS 3 regions in the two countries; we would thus have had 29 regions as a control group. However, two regions, DK014 and SE214, have been dropped from the sample due to having zero patent applications throughout almost the entire period of 1988–2011.

technologies. Finally, the validity of different DiD assumptions are tested, and a set of robustness checks are performed.

The remainder of this paper is organized as follows. Section 2 reviews the background literature. Section 3 discusses the methodology and the specification of the empirical model. Section 4 describes the dataset and variables used in the regressions. Section 5 presents the results, and Section 6 goes into the main results in greater depth. Finally, Section 7 summarizes the findings and makes some concluding remarks.

2. Theoretical background and previous studies

Several studies have found that innovation activities tend to be geographically concentrated (e.g., Audretsch and Feldman, 1996; Ejermo, 2009; Feldman and Kogler, 2010). Firms' tendency to cluster can be explained by the benefits they enjoy from agglomerating economic forces. As summarized by Davis et al. (2014), these forces include input sharing, employer-employee matching, knowledge spillovers that stimulate the adoption of new technologies and the expansion of new specialization opportunities, and lower transportation costs. Indeed, up to a certain level, bigger agglomerations lead to more patenting (Carlino et al., 2007; Lobo and Strumsky, 2008).

From a theoretical point of view, improvements in cross-border transportation infrastructure should attract more firms, and hence more workers, to these adjacent regions, due to the reduction in transportation costs (Puga, 2008).. For instance, Yamamoto (2005) presents a theoretical model which finds that sharply increasing returns due to a combination of low transportation costs and specialization caused by a geographically clustered population lead to the emergence of both industrialization and agglomeration. Industrialization, in this case, is defined as a transition of manufacturing technology from cottage to modern technology.

Empirical evidence supports the above-mentioned theories. For example, an increase in the number of highways in Italy and interstate highways in the US has been shown to affect employment growth (Duranton and Turner, 2012; Percoco, 2016) and firm entry (Percoco, 2016). Improvements in transportation infrastructure and the reduction of travel costs have been proven to increase regional patenting and scientific collaborations (Agrawal et al., 2017; Wang et al., 2018; Catalini et al., 2019). Essentially, improvements in transportation infrastructure help firms minimize their adaptive costs by their participation in clusters of economic networks or agglomerations. This clustering facilitates the creation and commercialization of new knowledge, promoting endogenous economic growth, which, in turn, affects the economy's growth rate (Lakshmanan, 2011).

Despite the crucial role of knowledge accumulation in technological change and economic growth, there is a lack of systematic evidence on the production of different types of knowledge in geographic space, with the vast majority of previous studies focusing on the total amounts of innovation activities in space instead of the kind of knowledge produced (Kogler et al., 2013).

Unlike regional technological specialization, i.e. the type of innovation produced, regional industrial specialization as proxied by sectoral employment and the number of manufacturing establishments has been investigated by different studies that focus on transportation's role and better regional accessibility. Since Krugman's (1991) explanation of the role of a reduction in travel costs on manufacturing firms' tendency to cluster in regions with higher demand, several studies have investigated industrial concentration and regional specialization. For instance, using data on the manufacturing employment of NUTS 2 European regions during 2002–2007, Mora and Moreno (2013) conclude that higher accessibility time costs in a region lead to an increase in its specialization. Using the same geographical unit for the period from 2002 through 2010, Albalate and Fageda (2016) provide evidence on the role of motorways and air services in enhancing high-tech employment growth. Generally, these results are in line with those of Bougheas et al. (2000), who report a positive relationship between infrastructure and the degree of specialization in manufacturing plants in the United States.

However, by using EPO patent classes for the period 1981–2005, Kogler et al. (2017) find a general trend toward regional knowledge specialization in terms of technological relatedness within the EU-15's NUTS 2 regions. On the other hand, by using the Fraunhofer Institute for Systems and Innovation Research (FI) IPC classification codes for countries that applied for patents at the EPO between 1980 and 1996, Mancusi (2003) shows that within this general trend, the field of electronic technologies exhibits distinct properties, such as having the highest degree of concentration and being the least mobile technology. The results of these two papers indicate a general trend toward geographical technological specialization and that some fields are more geographically concentrated than others. Therefore, the current study raises the question of whether transportation infrastructure and travel cost reduction affect the tendency toward specialization and concentration in technology fields, as is the case in employment and manufacturing establishments.

In examining how the change in transportation infrastructure caused by the opening of the Öresund Bridge affects the agglomeration economy of the adjoining regions, this study builds on the findings of Ejermo et al. (2021), who, by using longitudinal data on the individual level for the period 1993-2007, show that the Öresund Bridge led to a significant increase in the number of patents per individual in the Malmö region as compared to the two other major regions in Sweden, Gothenburg, and Stockholm, and that a key mechanism involved was the attraction of highly qualified workers to the Malmö region. Hence, it investigates whether a change in a regional agglomeration economy leads to a change in its technological specialization, as it does for its total innovation output.

3. Methodology

To identify a causal effect, a DiD approach is used to measure how agglomeration, which changed through the opening of the Öresund bridge, affects regional technological specialization. In this setting, a treatment group is compared with a control group to isolate causal effects. However, a causal interpretation requires more careful analysis. Therefore, different treatment groups are selected to validate the effects of the agglomeration change. The Öresund's Skåne and Copenhagen regions are considered the treatment group (for more details, see footnotes 3 and 5 in the introduction). The developments in these regions are compared to those of the control group, which consists of the remaining 27 NUTS 3 regions of Denmark and Sweden, except for Gotlands län (SE214) and Bornholm (DK014). These two regions are excluded because they are rural and have zero patent outputs for many of the years in the period 1982–2011, i.e., eight of these years for Bornholm and 15 for Gotlands län.[7] Additionally, during the main sample period, 1988–2011, Bornholm had zero outputs for six years and Gotlands län for 11 years. The

[7] The period 1982–1987 is added to the main sample period because it will be used in placebo tests of the DiD. For more information, see Sections 4 and 5.

remaining regions produced patents during the entire period in different fields of technology, making them a comparable sample for the research question. Last but not least, the treatment started with the inauguration of the bridge in 2000.

The DiD models require some assumptions to be valid for an inference. First, a key identifying assumption in DiD models, the parallel pre-trends assumption, is that the treated and control groups are characterized by similar trends in the absence of treatment. In the case here, the DiD approach assumes that the gap between the treated group and the control group is caused by unobserved characteristics that remain time-invariant. Therefore, the change between these two groups after the intervention is due to the treatment. Second, the DiD assumes a stable unit treatment value assumption (SUTVA). This assumption means that there should not be any interference or spillover effects between the treated and control groups. Third, the DiD assumes that the treatment does not affect the pre-treatment population, which means that the opening of the bridge should not lead to a change in the technological specialization of the Öresund region prior to the actual opening. A change before the opening could occur if firms and workers started relocating across the Öresund Strait beforehand while the bridge was being planned or constructed. To check the validity of these assumptions, the parallel trend assumption, the SUTVA, and placebo tests are provided in Section 5.

The analysis considers geographical regions at the NUTS 3 level, which is the smallest geographical unit available for the European context. This choice is relevant because it facilitates comparisons across units in both Denmark and Sweden. The units of analysis considered here are used in the literature on innovation and regional studies and are considered to represent cities and local labor markets well (Vinciguerra et al., 2011). Following Breschi and Lissoni's (2009) elaboration on the importance of living in the same geographical area for knowledge exchange and production, Vinciguerra et al. (2011) argue that local labor areas are the most relevant systems of reference in the knowledge production context due to people's tendency to change jobs within the same geographical area, thus contributing to the circulation of knowledge.

The current study investigates the impact of the bridge's opening on the technological specialization of the two central regions of the Öresund area, Skåne and Copenhagen. In this context, the dependent variable is the regions' technological specialization. To approximate technological specialization, two specialization measures are computed. These indexes are calculated using 35 EPO patent classes, which are derived from the IPC codes based on the 2008 FI classification (Schmoch, 2008).[8]

The first measure of specialization is an absolute measure: the conventional Herfindahl–Hirschman Index (*HHI*), whose formula for each region is

$$HHI_i = \sum_{j=1}^{35} s_{ij}^2 \tag{1}$$

where $s_{ij} = \frac{class_{ij}}{\sum_{i=1}^{35} class_{ij}}$ and $class_{ij}$ denotes the patent class j in region i for a given year. The index ranges between zero and one. The index value increases with the degree of specialization, reaching the upper limit of one when the region is specialized in only one technology class. The second measure of specialization, the dissimilarity index (*DS*), is relative, and it is an inequality measure used as a robustness check of the *HHI* results (Goschin et al., 2009; Mora and Moreno, 2013):

$$DS_i = \sum_{j=1}^{35} |s_{ij} - s_j| \tag{2}$$

where s_{ij} is the share of patent class j as part of all patent classes in region i in a given year, and s_j is the average share of each technology class across all regions. This measure of specialization is applied to compare the specialization in each technology class among the sample regions, where the values range between zero, for regions with identical technological specializations, and two, for the case of regions with totally different technological specializations.

The convenience of the *HHI* and its straightforward interpretation make it a desired measurement of specialization in the fields of innovation and regional science. For example, Lobo and Strumsky (2008) employ it to control for the technological specialization of US patent classes in US metropolitan areas, while Mora and Moreno (2013) use it to calculate the degree of industries' employment specialization in European regions. Nevertheless, as shown by Hall (2005), the *HHI* will be biased upward if the total number of patent applications owned by an

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[8] See the Appendix for the technology fields and their patent classes for 2008 (Table A.1) and the structure and aggregation of the IPC classes.

individual or firm is small compared to the number of technology classes to which these patents belong. As a result, some cells will be excluded from the analysis by definition. However, the current study is performed on data aggregated at the regional level, and the technology classes could belong to different patent applications.

This regional level of analysis is different from an inventor- or firm-level analysis. An inventor or firm has a smaller number of patents that can be used in different technologies, whereas a region can have different patents that belong to different applicants. For instance, assume that a region has several patents that can be issued in only one or a few technology classes in a given year. This would decrease the gap between the total number of patent applications and their technological classes. This issue, addressed by Hall (2005), will be more problematic when the *HHI* is calculated for cited technology classes, where *HHI_Cit* = 0.[9] Although Hall suggests a correction for such a bias, the second assumption, that the probability that a citation will fall in one cell is independent of its probability of falling in another cell, is strict and could introduce a different bias to the index. This is because some of these technologies can belong to the same patent. The issue of zero citations and their implication is discussed in Section 5.2.2.

Another limitation of the index is based on the fact that the *HHI* is an absolute measure, which means that a larger share of a region's particular technology could influence the overall specialization index value without considering the relative speciality of other regions in the sample. For example, control regions could develop a different specialization but with a lower patent intensity than the treated regions in their respective specialization, or that some of these regions develop a similar specialization to the treated group but when considered with the rest of the control group they have a lower overall patent intensity in comparison to the treated ones. Therefore, these control regions' relative specialization is not considered due to a significant increase in the *HHI* of treated regions with more patenting overall. That is why the Dissimilarity Index (DS) is used as an additional specialization measure. This index compares the share of regional technological specialization in each technology to the technological speciality of all the

[9] The variable *HHI_Cit* is the *HHI* of technology classes weighted by the number of their EPO forward citations.

other regions with the same technology. Therefore, a larger value for *DS* indicates that regions are more specialized in different technologies.

The main drawback of the *DS* measure is that total segregation within and between the regions is not considered. Therefore, as an additional robustness check, the current study uses a diversification index of the entropy measure. This measure captures the opposite effect of the other two indexes, in addition to giving a higher weight to less frequent technology classes. This will detect whether the region is becoming specialized in different technologies, even for a small number of technologies. The entropy formula reads as follows:

$$Entropy_i = \sum_{j=1}^{35} m_{ij} \tag{3}$$

where $m_{ij} = s_{ij} * \ln(1/s_{ij})$, which means that as s_{ij} rises, $\ln(1/s_{ij})$ falls. Therefore, less frequent technology classes have higher relative weights in this case, which is the opposite of the case of the *HHI*. Therefore, for each technology class, $m_{ij} = 0$ means that the region does not have this class and hence has a smaller $Entropy_i$ value in general, and that the region is more specialized.[10]

The analysis investigates the impact of the bridge on the specialization of Skåne and Copenhagen. In each case, three models are estimated as follows:

Model 1

$$\begin{aligned} Dependent\ Var_{i,t} = \alpha + \beta 1 \cdot Copenhagen_i + \beta 2 \cdot Skåne_i + \beta 3 \cdot Bridge_t \\ + \beta 4 \cdot Copenhagen_i \cdot Bridge_t + \beta 5 \cdot Skåne_i \cdot Bridge_t + \varepsilon_{i,t} \end{aligned} \tag{4}$$

Model 2

$$\begin{aligned} Dependent\ Var_{i,t} = \beta 1 \cdot Copenhagen_i \cdot Bridge_t + \beta 2 \cdot Skåne_i \cdot Bridge_t \\ + \lambda_t + u_i + \varepsilon_{i,t} \end{aligned} \tag{5}$$

In models 1 and 2, the dummy variable $Copenhagen_i$ takes the value of one if the region is Copenhagen and zero otherwise, while the dummy variable $Skåne_i$ takes the value of one if the region is Skåne, and zero otherwise. The interaction of both the Skåne and Copenhagen variables with the bridge's dummy variable, $Bridge_t$, captures the treatment effects on the technological

[10] It is worth to mentioning that Stata considers $m_{ij} = 0$ if $s_{ij} = 0$.

specialization of these two regions. In Model 2, λ_t and u_i stand for vectors of the calendar year and region dummies.

To estimate the treatment effects, a descriptive analysis is first conducted. Model (1) is then estimated by linear ordinary least squares (OLS), and Model (2) by using the within regression estimator fixed effects (FE) model, which allows for time-invariant unobserved characteristics of the panel unit NUTS 3 regions for the current study to potentially be correlated with the explanatory variables. Strict exogeneity not only yields a causal interpretation of the model, but also ensures that the within transformed error is orthogonal to the within transformed regressors in all periods, which is the first-order condition for the panel least squares regression. This implies that the remaining portion of the errors is uncorrelated with the regressors. Hence, the strict assumption of fixed effects models is satisfied.

All the estimations are performed using robust standard errors. The null hypothesis of Breusch and Pagan's (1980) Lagrange multiplier test for random effects—with no significant variation between panels—is rejected at the 1% level of significance. This means the regions are heterogeneous, and the estimation should be conducted in a panel context. Further, the rejection of the null hypothesis of the Sargan–Hansen test of overidentifying restrictions means that the random effects estimations will be inconsistent. Therefore, the fixed effects estimator is used to provide consistent results.[11]

4. Data

The dataset consists of 30 Swedish and Danish NUTS 3 regions for the period 1982–2011. However, the main results are obtained for the period 1988–2011. Because the dataset ends in 2011 and the bridge was opened in 2000, the treatment period is considered to be from 2000 to 2011, and the pre-treatment period consists of the previous 12 years, from 1988 to 2000. Therefore, the period 1988–2011 is chosen for the descriptive analysis as well. However, to perform placebo tests of DiD assumptions, the period from 1982 to 1987 is considered later in the econometric analysis. The primary source of data is the OECD's 2016 REGPAT publications and

[11] See Table A.2 in the Appendix for more details. Given heteroskedastic errors, robust standard errors should be used in the fixed effects and random effects. Therefore, the Hausman test that assumes homoskedasticity (and a balanced panel, a criterion satisfied by this study's data) could not be used to choose between fixed and random effects, so, alternatively, the Sargan–Hansen test is used. This last test is equivalent to the Hausman test under the condition of homoskedasticity.

the patent citation databases for EPO patent applications.[12] The Cambridge Econometrics European Regional Database (ERD) is used as the source for the macroeconomic (GDP and total population) variables.[13]

The EPO patents for the applicants' regions are well suited for the analysis of the impact of the bridge on the Öresund region's technological specialization because they report the location of the regions' establishments and not the inventors' addresses. This is important because inventors could be residents of a region that is different from the workplace where the invention was actually made. Furthermore, some patents are owned by applicants in different regions. Since the focal interest of the study is technological specialization, regions that share a patent are considered to be specialized in the same technology classes of this patent, because they have access to the same technology.[14]

Similarly to the EPO patent data, data for the employment variable used throughout the paper is based on employees' workplace address, whereas the total population variable is the regional resident count. These two last variables are also obtained from the ERD.

Table 1 presents descriptive statistics for key variables: *HHI, DS, Entropy, GDP*, and the total population. For instance, in the entire sample, the minimum value of the *HHI*, 0.04, indicates that the region is active in different technology classes in a given year. The GDP values are deflated to a 2005 constant price, in billions of euros, and the total population is a household-based measure in thousands of people.

[12] The study was performed on the OECD databases released in 2016. To avoid right-truncation problems, I use patent applications submitted up until 2011, because after 2011 the overall number of patents sharply declines.
[13] The structure and combination of databases used in the analysis are explained in the Appendix (the data appendix).

[14] It is interesting that only 2,560 (of 83,540) patents in the current study's sample have a regional share of less than one, which is approximately 3%, a very small portion.

Table 1: Descriptive statistics

	Variable	Obs	Mean	Std. dev.	Min	Max
Whole Sample	*HHI*	720	0.11	0.06	0.04	0.63
	DS	720	0.96	0.24	0.36	1.83
	Entropy	720	2.53	0.42	0.56	3.35
	GDP	720	15.25	15.92	2.85	106.95
	Populations	720	470.93	382.14	127.14	2,061.68
Skåne	*HHI*	24	0.06	0.01	0.04	0.08
	DS	24	0.61	0.16	0.36	0.91
	Entropy	24	3.15	0.09	3.01	3.35
	GDP	24	30.74	5.72	23.40	40.53
	Populations	24	1,134.28	56.06	1,043.80	1,247.77
Copenhagen	*HHI*	48	0.08	0.02	0.06	0.13
	DS	48	0.94	0.12	0.69	1.25
	Entropy	48	2.87	0.13	2.50	3.08
	GDP	48	28.09	6.30	17.72	40.31
	Populations	48	530.15	70.53	442.72	694.04
Control regions	*HHI*	648	0.12	0.06	0.04	0.63
	DS	648	0.98	0.24	0.40	1.83
	Entropy	648	2.48	0.41	0.56	3.33
	GDP	648	13.73	15.94	2.85	106.95
	Populations	648	441.97	379.98	127.14	2,061.68

5. Results

5.1. Descriptive analysis

To investigate the impact of the Öresund Bridge on the technological specialization of Copenhagen and Skåne, I start by descriptively exploring these regions' patenting activities and technological specialization. As presented in Table 2, there was a noticeable increase in the number of patents by Skåne's applicants following the opening of the bridge, with a greater than threefold rise, compared to an 85% increase in Copenhagen's patents.

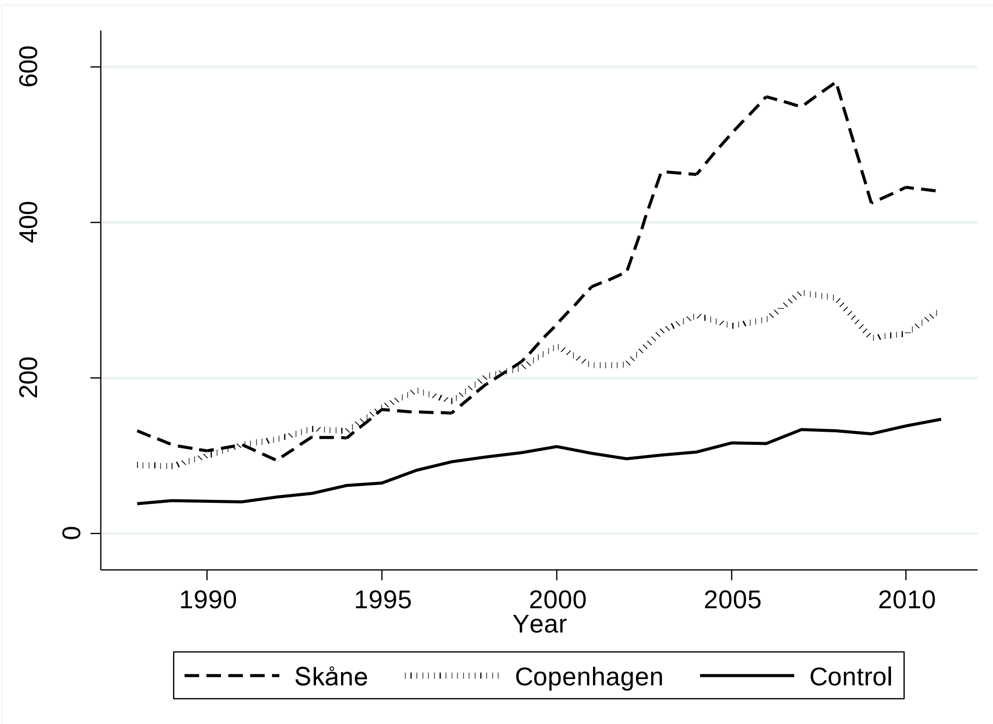
Table 2: Number of patent applications

	Before (1988–1999)	After (2000–2011)	Change (%)
Skåne	1,690	5,365	217
Copenhagen	3,414	6,330	85
Control	20,579	38,490	87

Note: Change (%) = 100*(Before - After)/Before.

For more details about the trends in the treated and control regions, Figure 1 shows the average number of patent applications per year.[15]

Figure 1: Average number of patent applications per region per year



The questions then arise as to whether this increase occurs in specific technological fields or is rather unrelated to any particular field and whether the change in a region's field specialization is due to the bridge's opening. Table 3 shows that there is a significant change in Skåne's technology classes, making electrical engineering the top-ranked field of specialization. The region experienced a remarkable 1,156% increase in patents classified technologically in electrical engineering, making it the top specialization. This represented a radical change for this region, especially because the field occupied one of the bottom positions before the bridge's opening.

[15] Note that the yearly average of Skåne's patent applications is the same as its total number of applications per year, because it consists of only one NUTS3 region, whereas Copenhagen's yearly average is its total number of applications per year divided by two because it consists of two NUTS3 regions, and the control's yearly average is its yearly total applications divided by the number of its NUTS3 regions, 27.

Table 3: Number of patent classes in the five main technology fields

		Periods		Field's share of the total (%)		Change (%)
		Before (1988-1999)	After (2000-2011)	Before	After	(After-Before)/ Before
Skåne	Electrical Engineering	238	2,990	9	37	1,156
	Instruments	496	1,367	19	17	176
	Chemistry	889	1,760	33	22	98
	Mechanical Engineering	774	1,259	29	16	63
	Others	277	627	10	8	126
	Total	2,674	8,003			199
Copenhagen	Electrical Engineering	360	972	6	10	170
	Instruments	632	1,344	10	13	113
	Chemistry	4,103	6,102	66	61	49
	Mechanical Engineering	794	1,110	13	11	40
	Others	306	527	5	5	72
	Total	6,195	10,055			62
Control	Electrical Engineering	7,011	14,523	14	16	107
	Instruments	5,236	8,347	11	9	59
	Chemistry	7,344	11,467	15	13	56
	Mechanical Engineering	9,136	14,733	19	17	61
	Others	2,416	3,977	5	4	65
	Total	48,881	89,163			82

The previous figures become even more pronounced after taking into account the novelty of the patents assigned to those technology classes by weighting each technology class by the number of forward citations received by its patents (Table 4). The number of forward citations received is a good indicator of a patent's importance, as a citation received from a future patent informs us about the technological descendants of the patented invention, and thus its novelty and technological influence, as well as its economic value (Jaffe and Rassenfosse, 2017). In the context of the current study, specialization indexes for highly cited patent classes show the extent to which technologies of higher economic value are concentrated in the regions studied. Additionally, adjusting the patents' quality by their citations allows for a better regional innovation indicator compared to patent counts (Ejermo and Gråsjö, 2008).

However, to avoid comparing patent classes that have different application years, I control for publication date fixed effects, that is, each patent is compared to its counterparts with the same application dates. The ratio of the citation weight (CW) reads as follows:

$$CW = \frac{\text{\# forward citations received by a patent P (and its classes as a result)}}{\text{\# forward citations received by patents that have the same publication year as P}} \quad (6)$$

The total number of citations used in the analysis is the number of forward citations received by EPO patents from EPO patents. Table 4 presents the five aggregated technology fields of the classes weighted by CW, as in (6), for both Skåne and Copenhagen.

Table 4: Number of weighted patent classes in the five main technology fields

		Periods		Field's share of the total (%)		Change (%)
		Before (1988-1999)	After (2000-2011)	Before	After	(After-Before)/Before
Skåne	Electrical Engineering	527.94	12,691.41	9	40	2304
	Instruments	1,114.47	5,170.76	18	16	364
	Chemistry	2,052.66	6,483.26	34	20	216
	Mechanical Engineering	1,737.67	4,857.10	29	15	180
	Others	602.87	2,480.37	10	8	311
	Total	6,035.62	31,682.90			425
Copenhagen	Electrical Engineering	843.41	2,150.97	6	10	155
	Instruments	1,383.73	2,801.09	10	13	102
	Chemistry	9,675.29	12,826.44	67	61	33
	Mechanical Engineering	1,807.45	2,246.77	13	11	24
	Others	637.15	1,095.83	4	5	72
	Total	14,347.03	21,121.10			47
Coontrol	Electrical Engineering	62,365.96	94,484.98	29	28	52
	Instruments	28,990.41	33,533.37	14	10	16
	Chemistry	39,454.27	55,241.62	19	16	40
	Mechanical Engineering	31,332.79	39,692.37	15	12	27
	Others	9,308.27	10,199.13	4	3	10
	Total	212,217.00	338,759.48			60

Finally, in Table 5, it becomes apparent that telecommunications and digital communications in Skåne are the fastest-growing technology classes, with growth rates of 3,596% and 3,033%, respectively.[16]

[16] For the weighted technology classes, see Tables A.3 and A.4 in the Appendix.

Table 5: Number of patent technology classes in Skåne and Copenhagen

		Skåne			Copenhagen		
		1993–1999	2000–2007	Change (%)	1993–1999	2000–2007	Change (%)
Electrical Engineering	Electrical machinery	64	213	233	112	257	129
	Audiovisual tech	42	419	898	66	242	267
	Telecommunications	26	961	3,596	58	112	93
	Digital communications	9	282	3,033	28	60	114
	Basic communications	5	54	980	21	33	57
	Computer tech	76	922	1,113	52	202	288
	IT methods for management	5	82	1,540	9	32	256
	Semiconductors	11	57	418	14	34	143
Instruments	Optics	21	172	719	54	121	124
	Measurement	122	268	120	162	280	73
	Analysis of biological materials	77	162	110	162	311	92
	Control	47	170	262	33	65	97
	Medical tech	229	595	160	221	567	157
Chemistry	Organic fine chemistry	79	95	20	651	833	28
	Biotechnology	125	241	93	1,008	1,678	66
	Pharmaceuticals	167	413	147	792	1,521	92
	Macromolecular chemistry	49	70	43	150	124	–17
	Food chemistry	65	78	20	298	505	69
	Basic materials chemistry	64	108	69	428	398	–7
	Materials, metallurgy	65	127	95	224	264	18
	Surface technology	54	117	117	51	101	98
	Microstructure and nanotech	2	44	2,100	3	13	333
	Chemical engineering	166	362	118	343	466	36
	Environmental tech	53	105	98	155	199	28
Mechanical Engineering	Handling	184	246	34	71	240	238
	Machine tools	73	137	88	55	67	22
	Engines, pumps, turbines	22	95	332	76	119	57
	Textile and paper machines	63	60	–5	228	105	–54
	Other special machines	115	127	10	161	237	47
	Thermal processes and apparatus	90	200	122	80	107	34
	Mechanical elements	133	251	89	85	161	89
	Transport	94	143	52	38	74	95
Other fields	Furniture, games	48	103	115	34	108	218
	Other consumer goods	63	139	121	35	67	91
	Civil engineering	166	385	132	237	352	49

5.2. Econometric analysis

5.2.1. Main results

The descriptive analysis suggests that a change took place in Öresund's technological specialization, but mainly on the Swedish side, as reflected in the number of patents in each technology field. By looking at the general trends of the dependent variable, *HHI* (see Figure 2), we see that only Skåne's trend shows signs of an immediate increase in specialization after the bridge's opening. However, because of its range of [0 1], even a small increase in the *HHI* will, by definition, indicate a region's tendency toward increased specialization. For example, an increase from 0.15 to 0.25 in the index value of a given region means that the region is moving from being unspecialized to a moderate specialization level.

Moreover, as we can see, there is generally no overall increase in the *HHI* trend. Nevertheless, the trends of the treated and control groups begin to converge, with the treated experiencing an increase in their *HHI* value and the control a decline during the immediate period after the bridge's opening. Finally, two major shocks are observed in 1992 and 2007-2008, which could be due to the 1992–1993 collapse of the European exchange rate mechanism and the 2008 economic crisis. The sensitivity of the *HHI* of patent classes to such shocks can be explained by the fact that the analysis considers patent application dates, and those crises affected patent application intensity. The patent application date instead of the date the patent was granted is used because the application date is closer to the time that the invention actually took place. Going forward, the issue of macro shocks will be addressed in the subsections on the parallel pre-trends assumption and robustness checks below.

Figure 2: General *HHI* trend (yearly averages)

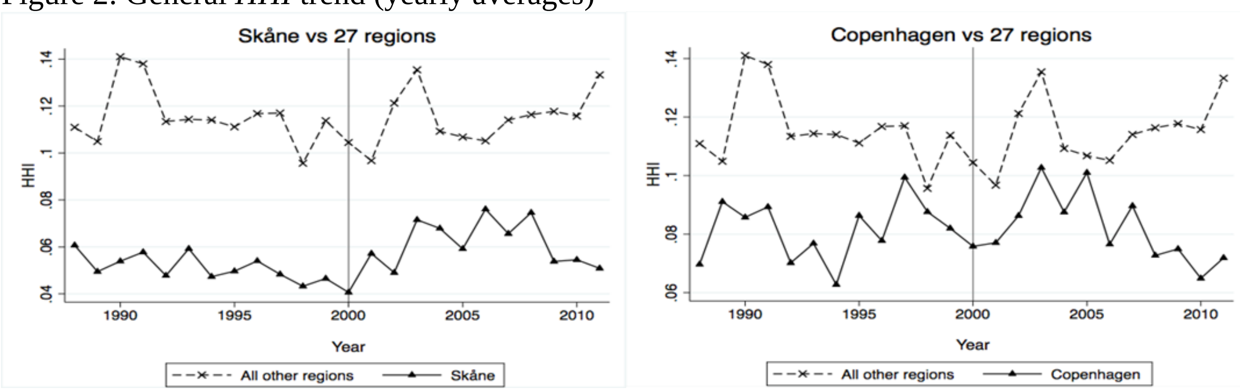
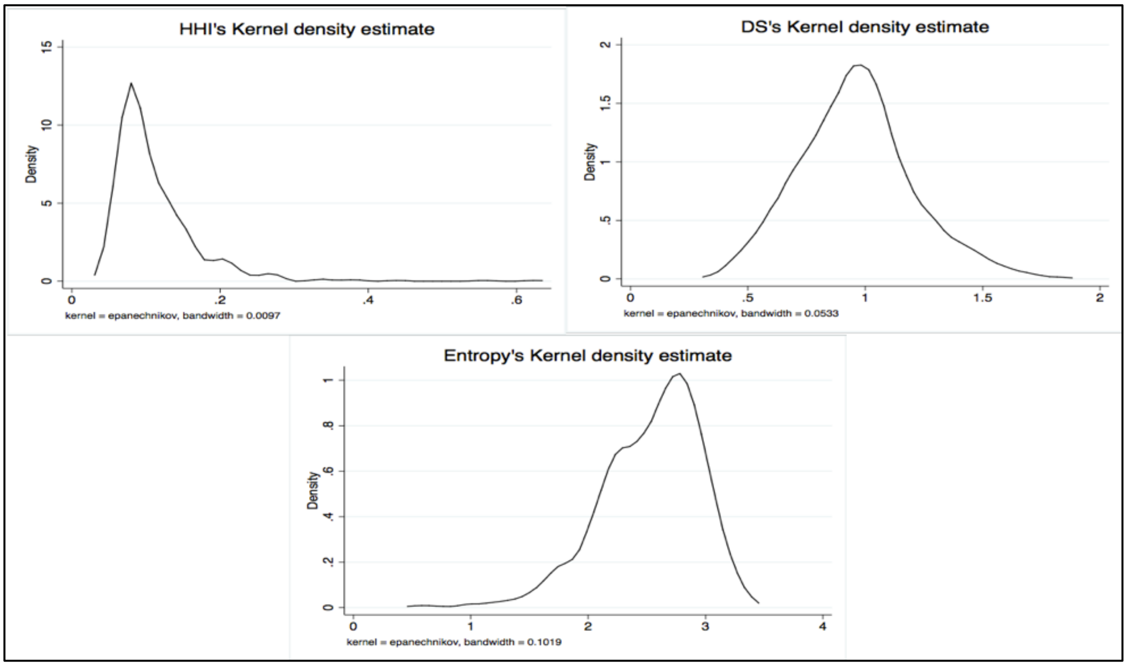


Figure 3 shows the kernel density functions of three different measures of the dependent variable. The *DS* function is generally more evenly distributed around its mean due to its construction (see equation (2)), while *HHI* and *Entropy* are skewed. The variable *HHI* is skewed to the right, meaning that most regional *HHI* values are between zero and 0.2. In contrast, there are fewer regions with higher values. By comparison, the *Entropy* measure is left-skewed, with fewer regions having values of less than two. The distributions of *HHI* and *Entropy* indicate that only a few regions tend to be more specialized in their technologies. On the other hand, regions with higher *DS* values, namely, larger than 1.5, experience a more significant difference in their specialization compared to the other regions. In total, if specialization exists, it will be due to a few technologies in a few regions, but any such specialization will be noticeable.[17]

Figure 3: Kernel density functions of the dependent variable measures



The one-sample Kolmogorov–Smirnov test, however, implies that the distributions of *DS* and *Entropy* are statistically different from the theoretical distribution of *HHI*. The null hypothesis of their sample, drawn from the reference distribution of *HHI*, is rejected at 1%. This result implies that the three distributions are statistically different, which confirms the difference shown in the kernel density functions.

To assess the validity of the descriptive findings, I estimate Models (1) and (2) in Section 3. These estimations, presented in Tables 6.1 to 6.3, show an overall effect of the bridge on Copenhagen's and Skåne's technological specialization, compared to the control regions'

[17] Figure A.1 in the Appendix shows the kernel density functions of the three measures for the treated and control groups.

specialization. Table 6.1 shows that the bridge led to an increase in the technological specialization of Copenhagen by 0.013 in the *HHI* of highly cited technology. Skåne, on the other hand, experienced a greater effect in magnitude and statistical significance when *HHI_Cit* is used as the dependent variable instead of *HHI*, which implies that higher-quality patent classes benefited more from the change in Skåne's agglomeration caused by opening the bridge. In Table 6.2, the dissimilarity index of specialization increases only for Skåne after the bridge opened. For example, from equations (3 & 4), we see that the opening of the bridge increased by 0.35 the value of *DS* in the specialization of Skåne's higher-quality technologies in specific fields, compared to that of the control regions in these same fields. Thus, the nonsignificant coefficient for Copenhagen here implies no significant increase in this region's specific technology classes compared to the control group (consisting of 27 other regions in Sweden and Denmark). Furthermore, the negative effect of the coefficient of the *Skåne*Bridge* interaction on the *Entropy* index means that the region became less diversified after the bridge opened, which is in line with the combined interpretation of the findings in Tables 6.1 and 6.2, i.e. that Skåne has a general tendency toward specialization, and this specialization is more pronounced in specific highly cited patent technology classes.

Table 6.1: Impact of the bridge on the technological specialization measured by *HHI*

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*HHI*	*HHI*	*HHI_Cit*	*HHI_Cit*
Copenhagen	-0.0344***		-0.0153***	
	(0.0047)		(0.0047)	
Skåne	-0.0644***		-0.0454***	
	(0.0036)		(0.0036)	
Bridge	-0.0012		-0.0126***	
	(0.0046)		(0.0046)	
Copenhagen*Bridge	0.0014	0.0014	0.0128**	0.0128*
	(0.0064)	(0.0060)	(0.0064)	(0.0072)
Skåne*Bridge	0.0098*	0.0098*	0.0212***	0.0212***
	(0.0058)	(0.0053)	(0.0058)	(0.0066)
Constant	0.1159***	0.1065***	0.0969***	0.1036***
	(0.0033)	(0.0099)	(0.0033)	(0.0113)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 6.2: Impact of the bridge on the technological specialization measured by *DS*

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*DS*	*DS*	*DS_Cit*	*DS_Cit*
Copenhagen	-0.0252		0.0895***	
	(0.0306)		(0.0346)	
Skåne	-0.4905***		-0.3705***	
	(0.0281)		(0.0320)	
Bridge	-0.0297		-0.1206***	
	(0.0191)		(0.0325)	
Copenhagen*Bridge	-0.0216	-0.0216	0.0659	0.0659
	(0.0382)	(0.0523)	(0.0462)	(0.0655)
Skåne*Bridge	0.2532***	0.2532***	0.3464***	0.3464***
	(0.0465)	(0.0267)	(0.0537)	(0.0473)
Constant	0.9899***	0.9515***	0.8536***	0.9156***
	(0.0137)	(0.0406)	(0.0218)	(0.0607)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 6.3: Impact of the bridge on the technological diversification measured by *Entropy*

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*Entropy*	*Entropy*	*Entropy_Cit*	*Entropy_Cit*
Copenhagen	0.3831***		0.6488***	
	(0.0357)		(0.0569)	
Skåne	0.7068***		0.9725***	
	(0.0322)		(0.0548)	
Bridge	0.0605*		-0.1569**	
	(0.0325)		(0.0794)	
Copenhagen*Bridge	0.0046	0.0046	0.2221**	0.2221**
	(0.0486)	(0.0514)	(0.0872)	(0.1003)
Skåne*Bridge	-0.0677	-0.0677*	0.1498*	0.1498
	(0.0498)	(0.0364)	(0.0879)	(0.0935)
Constant	2.4515***	2.5083***	2.1857***	2.4239***
	(0.0233)	(0.0644)	(0.0501)	(0.0985)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

5.2.1.1. Parallel pre-trends assumption

As discussed in Section 3, for the DiD results to be valid, they should satisfy the parallel pre-trends assumption. In this case, the DiD assumes that the gap between the treated and control groups is caused by unobserved characteristics that remain time-invariant and that the change between these two groups after the intervention is due to treatment effects. In the current study context, there would not have been a change in the regional specialization without the bridge. To test the trend assumption, first, the interaction of the treated regions and years is taken instead of the previous interaction with the bridge period dummy variables (see Table A.5 in the Appendix). Next, the study provides a test for the joint statistical significance of the interaction coefficients of the treated regions prior to 2000 and that of the interaction coefficients of the treated regions after 2000. For the assumption to be satisfied, we need to not reject the null hypothesis of no significant variation among the interaction coefficients before the bridge's opening and to reject the null hypothesis for the period after the bridge opened. However, as we see in Tables A.5.1 to A.5.6, the assumption holds only for the case of the Skåne region for the dependent variables *HHI* and *HHI_Cit*.

Recall that *HHI* is an absolute measure. Therefore, the reported increase in its value in Table 6.1 could be due to changes in patenting activity in only a few technology classes, which is in line with the conclusion to the previous section (5.2.1). To test this hypothesis, patent classes from the field "other" of the FI classification are dropped.[18] Then recalculate the *HHI*, *DS*, and *Entropy* values are recalculated for the remaining 32 technology classes. These specific technologies are dropped because they belong to a field that has only three technology classes, and the number of these technologies exhibits slower growth compared to the other technologies of the other four fields. The parallel trend assumption tests hold for both *HHI_Cit* and *DS_Cit*, but not for the unweighted technology classes or the *Entropy* measure. In the case of *Entropy*, there is no statistical significance in the joint parameters test following the bridge's opening, due to dropping technologies that grew slower after the bridge's opening and that received fewer citations compared to the other technologies that derive the results of both specialization measures. That is because the *Entropy* gives more weight to less frequent classes.[19] Tables A.6

[18] The field "other" consists of technology classes in furniture, games, other consumer goods, and civil engineering (see Table 5).

[19] See Tables A.3 and A.4 for the weighted technology classes.

and A.7 in the Appendix provide the regression estimations of the treated regions, with both specialization measures as dependent variables.

The satisfied parallel trend assumption confirms what Kogler et al. (2017) document in their study on EPO patents in the European Union's NUTS 2 regions for the period 1981–2005, in terms of a general trend toward regional specialization. The parallel trend assumption test confirms only the results regarding Skåne's tendency to specialize intensely in a few technology classes that belong to patents of higher quality and economic value, in terms of the number of citations received. In other words, the bridge increased Skåne's competitiveness in technological specializations of high economic value compared to other regions in Sweden and Denmark.

5.2.1.2. SUTVA test

The current study assumes that the opening of the Öresund Bridge did not affect the technological specialization of the control regions. However, Ejermo et al. (2021) find that the inauguration of the bridge led to a substantial increase in the number of patents in the greater region of Malmö, the capital city of Skåne, compared to the other two central regions in Sweden, namely, Stockholm and Gothenburg, due to the attraction of highly skilled labor from these two Swedish regions after 2000. Hence, the attraction of these workers could have affected the technological specialization of these two regions.

Due to data limitations regarding the accurate addresses of the workplace and residence of inventors, it is not possible to directly check whether there are spillover effects of this type on the technological specialization of the control regions. Nevertheless, the study attempts to check for potential violation of the SUTVA by clustering errors at the country level in the models presented in Table 6.1, where the pre-trend assumption holds for the Skåne region. Clustering errors at the country level takes into account unobserved output components caused by within-country correlations. In other words, countries are expected to be independent of each other, whereas regions can experience interdependence (e.g., Audretsch and Belitski, 2013). Because the only cross-border regions of Denmark and Sweden that have a fixed link, Skåne and Copenhagen, are treated regions, not taking into account their bilateral spillovers is considered to not violate the SUTVA in the current analysis. Hence, clustering at the country level should be sufficient to test the validity of the SUTVA in this case.

Table 6.1.1 shows that we obtain the same coefficients as in Table 6.1 by clustering errors at the country level. Furthermore, the statistical significance for *HHI* of highly cited technology classes is greater for Copenhagen after 2000, whereas the coefficients of estimations (1) and (2) become nonsignificant. With the main results holding for Skåne, it is argued that the SUTVA is satisfied.

Table 6.1.1: Impact of the bridge on the technological specialization measured by *HHI*

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent Variable	*HHI*	*HHI*	*HHI_Cit*	*HHI_Cit*
Copenhagen	-0.0344		-0.0153	
	(0.0111)		(0.0039)	
Skåne	-0.0644		-0.0454*	
	(0.0111)		(0.0039)	
Bridge	-0.0012		-0.0126***	
	(0.0064)		(0.0001)	
Copenhagen*Bridge	0.0014	0.0014	0.0128***	0.0128***
	(0.0064)	(0.0065)	(0.0001)	(0.0001)
Skåne*Bridge	0.0098	0.0098	0.0212***	0.0212***
	(0.0064)	(0.0065)	(0.0001)	(0.0001)
Constant	0.1159*	0.1065**	0.0969**	0.1036**
	(0.0111)	(0.0053)	(0.0039)	(0.0035)
Regions fixed-effects		Yes		Yes
Year dummies		Yes		Yes
Observations	720	720	720	720

Note that OLS stands for the ordinary least squares estimator, FE stands for the fixed-effects (within regression) estimator, the fixed-effects panel unit is NUTS–3 regions, standard errors (clustered on country level) are reported in parentheses and that *** (**, *) indicate a significance level of 1% (5%, 10%).

5.2.1.3. Pre-treatment and placebo tests

Another essential assumption of the DiD method is that the treatment does not affect the pre-treatment population, which means that the bridge should not change the technological specialization of the Öresund area prior to its opening (if firms and workers started relocating while the bridge was being planned or constructed). Therefore, the study considers first the date the bridge agreement was signed, in 1991, as the starting point of the treatment. Then it regards 1995, when the bridge's construction started, as the start of the following treatment. In the first case, the parallel trend assumption holds only for the *Entropy* of cited technology in the Skåne region, that is, in terms of technological diversification, not specialization. This result means that, before the bridge opened, Skåne tended to diversify in terms of its technology classes without specific specialization. However, the trend test is barely significant at the 10% level. Table 7 shows that, from 1991 to 1999, the Skåne region experienced a diversification in its technology classes, with a 0.2 increase in its *Entropy* measure of highly cited patent technology classes, compared both to the control regions over the same period and to 1982–1990. In the latter case, the *Bridge* dummy variable takes the value of one for 1991–1999 and zero for the previous period.

In the second case, when considering 1995 as the starting point of the treatment, the bridge dummy will take the value of one for 1995–1999, and zero for 1990–1994. Here the regression analysis indicates technological specialization in Copenhagen during 1995–1999. However, the parallel trend assumption does not hold in this case.[20]

Table 7: Impact of the bridge on the technological diversification measured by *Entropy* for the period 1982-1999

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent Variable	*Entropy*	*Entropy*	*Entropy_cit*	*Entropy_cit*
Copenhagen	0.3879***		0.5613***	
	(0.0437)		(0.0608)	
Skåne	0.6747***		0.8482***	
	(0.0323)		(0.0532)	
Bridge	0.0672*		-0.0770	
	(0.0381)		(0.0795)	
Copenhagen*Bridge	-0.0016	-0.0016	0.1426	0.1426
	(0.0589)	(0.0645)	(0.0912)	(0.0996)
Skåne *Bridge	0.0418	0.0418	0.1859**	0.1859*
	(0.0480)	(0.0501)	(0.0846)	(0.0910)
Constant	2.3948***	2.2764***	2.2214***	2.1458***
	(0.0283)	(0.0597)	(0.0508)	(0.1043)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	540	540	540	540

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

An additional time placebo test is provided to check whether the main effects documented in Section 5.2.1 are not caused by other events in the Öresund area during the studied period, such as the launch of the European Single Market (ESM) in 1993. Although this event is common across all regions, some might respond differently to the impact of being part of a bigger market,

[20] The results are available upon request.

as reflected in their firms' technological specialization strategy. For example, they could subsequently face more competition from other European regions. In this case, the treatment period is defined as 1993 to 1999, and the pre-treatment period from 1986 to 1992. Here again, the parallel trend assumption holds only for the diversification measure of highly cited technology classes (*Entropy_Cit*). Moreover, Table 8 shows that, during 1993–1999, Skåne diversified its highly cited technology classes more than the control group, with a 0.2 increase in the *Entropy* measure value. However, the *Bridge* dummy variable would be replaced with a dummy for the ESM that takes the value of one for the period 1993–1999, and zero otherwise.

Table 8: Impact of the bridge on the technological diversification measured by *Entropy* for the sample of the period 1986-1999

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent Variable	*Entropy*	*Entropy*	*Entropy _Cit*	*Entropy _Cit*
Copenhagen	0.3868***		0.5393***	
	(0.0505)		(0.0681)	
Skåne	0.6956***		0.8481***	
	(0.0404)		(0.0610)	
Bridge	0.0865**		-0.1086	
	(0.0422)		(0.0904)	
Copenhagen*Bridge	-0.0300	-0.0300	0.1651	0.1651*
	(0.0680)	(0.0570)	(0.1050)	(0.0971)
Skåne*Bridge	-0.0001	-0.0001	0.1950**	0.1950**
	(0.0570)	(0.0408)	(0.0982)	(0.0886)
Constant	2.4025***	2.4445***	2.2500***	2.3573***
	(0.0318)	(0.0551)	(0.0556)	(0.1137)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	420	420	420	420

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Note that in all the analyses of this subsection, the treatment stopped in 1999 so as not to intervene with the actual treatment period that started in 2000.

5.2.2. Robustness checks

To obtain the main results presented previously, in Section 5.2.1., the analysis was done on a sample ranging from 12 years before to 12 years after the bridge was inaugurated. The reasoning behind choosing the period 1988–2011 for the main analysis is based on the availability of reliable patent data until 2011 in the REGPAT database. Since patent applications take, on average, from three to five years to be granted and their technology classes observed. it may take a relatively long time for the bridge to have a substantial effect.

Note that this period includes two major economic events: a major economic shock in 1992 and the economic crisis in 2008 that might affect regions heterogeneously (Fingleton et al., 2012), so their impact might not be fully captured by the year fixed effects, which might, in turn, affect the study findings as a result. However, Table A.5 in the Appendix shows that only Skåne suffered an adverse effect from the 1992 shock in terms of its specialization in specific technologies, based on the impact on the dissimilarity index. As for the 2008 crisis, while its overall effect on technological specialization and diversification was negative, interestingly, we find that Skåne increased its technological specialization in that year. The overall negative effect of 2008 can be measured by the reduction in patent applications, which are the source of technology classes in the current study. Therefore, fewer patents mean fewer technology classes and, therefore, less specialization and diversification.

Given the overall severe impact of the 2008 crisis and Skåne's different reaction to it, as a robustness check, the post-bridge period is shortened to end in 2007 (instead of 2011), for a period of eight years before the bridge opening, 1992–1999, to eight years after it, 2000–2007. Here again, the parallel trend assumption holds only for the Swedish side of the bridge, for both the *HHI* and the dissimilarity index, and only for the case of highly cited patents. These findings confirm the main results discussed above in the Parallel pre-trends assumption subsection. Table 9.1 shows that the opening of the bridge increased the *HHI* of Skåne's highly cited technology classes by 0.02, compared to the control group. Table 9.2 indicates that this increase in Skåne's specialization occurred in specific technology classes, since the region experienced a 0.33 increase in its dissimilarity index of highly cited technology classes. In other words, the rise in the technological specialization of the Skåne region occurred in specific technology classes, and this increase exceeds by 0.33 the average specialization value of the entire sample in these particular classes.[21]

[21] The results for *Entropy* as a dependent variable are not significant, but are available upon request.

Table 9.1: Impact of the bridge on the technological specialization measured by *HHI* for the sample of the period 1992-2007

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent Variable	*HHI*	*HHI*	*HHI_Cit*	*HHI_Cit*
Copenhagen	-0.0317***		-0.0122**	
	(0.0053)		(0.0058)	
Skåne	-0.0625***		-0.0430***	
	(0.0036)		(0.0043)	
Bridge	-0.0004		-0.0087	
	(0.0052)		(0.0055)	
Copenhagen*Bridge	0.0071	0.0071	0.0154**	0.0154**
	(0.0075)	(0.0057)	(0.0077)	(0.0067)
Skåne*Bridge	0.0118*	0.0118**	0.0201***	0.0201***
	(0.0067)	(0.0055)	(0.0070)	(0.0066)
Constant	0.1120***	0.1083***	0.0925***	0.0951***
	(0.0032)	(0.0065)	(0.0040)	(0.0085)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	480	480	480	480

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 9.2: Impact of the bridge on the technological specialization measured by *DS* for the sample of the period 1992-2007

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent Variable	*DS*	*DS*	*DS_Cit*	*DS_Cit*
Copenhagen	-0.0141		0.1176***	
	(0.0377)		(0.0434)	
Skåne	-0.5279***		-0.3860***	
	(0.0254)		(0.0327)	
Bridge	-0.0260		-0.0750*	
	(0.0229)		(0.0398)	
Copenhagen*Bridge	0.0183	0.0183	0.0628	0.0628
	(0.0444)	(0.0363)	(0.0548)	(0.0564)
Skåne*Bridge	0.2900***	0.2900***	0.3344***	0.3344***
	(0.0558)	(0.0242)	(0.0649)	(0.0485)
Constant	0.9785***	0.9560***	0.8232***	0.8495***
	(0.0156)	(0.0320)	(0.0275)	(0.0646)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	480	480	480	480

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Lastly, as a final robustness check, the current study uses a different source of patent classification, namely, the dataset constructed by researchers at Bocconi University (Caffano and Tarasconi, 2014).[22] These authors assign EPO patents by mapping their main applicants' ID numbers to the respective NACE classification sector, as well as according to FI's 30 and 35 technology classes. Because the current study already uses FI's technological classifications, I use the sectoral classification from this database as an alternative robustness check of my main dataset. Nevertheless, FI's technological classification is the most appropriate in the context of the current study, since I focus on studying the type of technology produced rather than the industry that uses it. That is why these data could be used as extra information that could also reflect the economic value of the patents, since they are already in current use and therefore have an established market value. There are a total of 45 industrial classes. The specialization and diversification indexes are calculated by using the same formulas as in equations (1) to (3) after setting the maximum value at j = 45 instead of j = 35. Tables 10.1 to 10.3 show that the bridge opening affected the region's industrial specialization in much the same way as its technological specialization.

Table 10.1: Impact of the bridge on the industrial specialization measured by *HHI* for the NACE's sample

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*HHI*	*HHI*	*HHI_Cit*	*HHI_Cit*
Copenhagen	0.0292**		0.0509***	
	(0.0114)		(0.0115)	
Skåne	-0.0689***		-0.0471***	
	(0.0043)		(0.0045)	
Bridge	0.0073		-0.0080	
	(0.0054)		(0.0060)	
Copenhagen*Bridge	-0.0111	-0.0111	0.0042	0.0042
	(0.0163)	(0.0202)	(0.0165)	(0.0205)
Skåne*Bridge	0.0195**	0.0195**	0.0348***	0.0348***
	(0.0080)	(0.0088)	(0.0084)	(0.0093)
Constant	0.1426***	0.1311***	0.1209***	0.1265***
	(0.0036)	(0.0105)	(0.0039)	(0.0125)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%,

[22] The data are available at http://www.icrios.unibocconi.eu/wps/wcm/connect/cdr/icrios/home/resources/databases/patents-icrios+database.

and 10%, respectively.

Table 10.2: Impact of the bridge on the industrial specialization measured by *DS* for the NACE's sample

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*DS*	*DS*	*DS_Cit*	*DS_Cit*
Copenhagen	-0.0998***		0.0409	
	(0.0272)		(0.0327)	
Skåne	-0.5167***		-0.3712***	
	(0.0248)		(0.0309)	
Bridge	-0.0191		-0.1280***	
	(0.0195)		(0.0356)	
Copenhagen*Bridge	-0.0353	-0.0353	0.0655	0.0655
	(0.0372)	(0.0486)	(0.0473)	(0.0629)
Skåne*Bridge	0.2678***	0.2678***	0.3702***	0.3702***
	(0.0397)	(0.0282)	(0.0497)	(0.0505)
Constant	1.1040***	1.0422***	0.9527***	1.0014***
	(0.0141)	(0.0379)	(0.0237)	(0.0622)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 10.3: Impact of the bridge on the industrial diversification measured by *Entropy* for the NACE's sample

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*Entropy*	*Entropy*	*Entropy_Cit*	*Entropy_Cit*
Copenhagen	0.1289***		0.3727***	
	(0.0462)		(0.0612)	
Skåne	0.6255***		0.8693***	
	(0.0327)		(0.0518)	
Bridge	0.0310		-0.1572**	
	(0.0313)		(0.0724)	
Copenhagen*Bridge	0.0599	0.0599	0.2481***	0.2481**
	(0.0675)	(0.0595)	(0.0939)	(0.1037)
Skåne*Bridge	-0.1494***	-0.1494***	0.0388	0.0388
	(0.0521)	(0.0476)	(0.0835)	(0.0973)
Constant	2.2231***	2.2738***	1.9794***	2.2063***
	(0.0216)	(0.0597)	(0.0456)	(0.0914)
Regions fixed-effects	No	Yes	No	Yes
Years fixed-effects	No	Yes	No	Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

The parallel trend assumption holds for the *HHI* of Skåne's highly cited patents. The results serve as additional evidence of the economic value of highly cited patents.

6. Discussion

The results of Table 6 show that the inauguration of the Öresund Bridge led to an increase in Skåne's highly cited patent technology classes by roughly 2% of the *HHI* value. However, this finding mainly indicates Skåne's general tendency toward greater technological specialization after the bridge's opening, without identifying whether it is in the same or different technology classes in which the control group regions are specialized; therefore, the dissimilarity index is used as a relative measure of specialization. The results indicate that Skåne's specialization increases in some technologies, relative to the control group regions, by roughly 0.35 in the value of *DS*. In addition, the negative effect of the bridge on Skåne's technological diversification, proxied by the *Entropy* measure of diversification, indicates that Skåne generally became less diversified after the bridge opened. By considering the effects on the three different indexes, I conclude that there is an increase in Skåne's technological specialization and that this rise in specialization is not in all the technology classes. Of note, the main results on the increase in technological specialization of Skåne are valid, based on different DiD assumption tests and the robustness checks discussed in Section 5.

The findings are in line with Ejermo (2005), who reports that the number of patent applications in Swedish regions is highly and positively dependent on regional technological specialization. Archibugi and Pianta (1991), on the other hand, find greater and faster technological specialization in US and EPO patent citations for 16 countries from 1975 to 1988, than in the patent counts. However, the effect is not the same for Copenhagen, Skåne's bigger sibling, for various reasons. First, smaller economies have a greater tendency toward technological specialization than larger ones (Eaton et al., 1999). Second, Skåne's absorptive capacity could play a role here since Mancusi (2008) shows that countries' absorptive capacity increases their innovation elasticity to international spillover. However, as shown in Sections 1 and 4, Skåne is smaller in terms of innovation and economic size than Copenhagen, which could make it more flexible in adapting to change, namely, technological change. Third, countries' economies converge by becoming more different and grow by becoming more specialized (Archibugi and Pianta, 1994), which could be an approach that policymakers follow on the Swedish side at the regional level. For instance, after the completion of the Interreg-funded initiative, the Öresund IT cluster continued only on the Swedish side of the Öresund, under the name Cluster55° (OECD, 2013). Sweden has also developed a national innovation system, with world-class clusters in automobile, telecommunication, bioscience, and other sectors (Park and Lee, 2004). The public policy seems to play a crucial role when it comes to regional clusters and regional and industrial specialization (Aseim and Moodysson, 2008; Zheng and Kuroda, 2013; Teskeris and Vogiatzoglou, 2014). Finally, as seen in Table 4, Skåne's technological specialization switched from chemistry to electrical engineering, a change that could be due to the distinct characteristics of these technology fields, i.e., whereas the field of electronics has the highest degree of specialization and is the least mobile (Mancusi, 2003), chemistry is the most internationally mobile (Eaton et al., 1999). Ultimately, both regions have similar access to chemistry innovation, with Copenhagen enjoying a greater absolute advantage in terms of its size, while Skåne seems to focus on electronics and to enjoy more comparative advantages.

Moreover, the difference in technological specialization between the two sides of the Öresund Strait could be the main reason behind the low number of EPO citations (19) between Copenhagen and Malmö from 1993 to 2007, as reported in Ejermo et al (2021).This finding thus confirms one of the explanations for the lack of collaboration, proxied by the number of patent citations, between the two sides of the bridge.

7. Conclusion

The current study represents an effort to contribute to the literature on agglomeration and regional technological specialization. The main objective is to investigate how a change in the Öresund area's agglomeration economies due to the Öresund Bridge's inauguration in 2000, affected its regional technological specialization. The findings confirm a change in the technological specialization of the Skåne region due to the change in the agglomeration. Further, the results show that this change in specialization is region-specific, since Copenhagen does not show a similar pattern. This indicates that regions respond differently to a change in agglomeration based at least in part on their existing technological specialization.

Previously, in Section 5, I discussed different theories behind the heterogeneity in regions' responses. However, the mechanisms that give rise to these different reactions could be founded at the micro-level, such as the influx of human capital (Ejermo et al., 2021), or at the macro level, such as regional policy (Aseim and Moodysson, 2008; Zheng and Kuroda, 2013; Teskeris and Vogiatzoglou, 2014). One possible mechanism to check would be to reference the change in the number of inventors and run the same estimation on the technology classes associated with their patent applications, and then to compare the results with the main findings of the current analysis. This investigation could be done by constructing the patent data based on inventors' addresses, in addition to constructing the patent data on applicants' locations, as here. This step could indicate whether the new human inflows caused the change in the technological specialization in Skåne after the bridge inauguration, which appears to be a crucial mechanism behind the increase in Malmö's patenting immediately after the bridge opening (Ejermo et al., 2021). Nevertheless, this approach would suffer from the limitation that, in the aggregate, we cannot identify whether previous inventors remained in the region or whether there is also a change in their portfolio, besides an increase in their numbers. Additionally, a future research avenue could be to study the interrelationship between agglomeration size and technological specialization over time.

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Appendix

Data appendix

The primary source of the current study's data is the Organisation for Economic Co-operation and Development (OECD) REGPAT and Citations Database. Both databases are available at the patent applicant level.

I start the data construction with REGPAT's International Patent Classification (IPC) database, which contains applicant identifiers, both the patent's application and grant dates, and the IPC classes. Following the IPC codes provided by the Fraunhofer Institute for Systems and Innovation Research (FI) in Table A1, I generate the technology class variables. Each technology is represented by a binary dummy variable that takes the value of one if the associated patent is classified in this class, and zero otherwise. However, some patents have more than one eight-digit IPC code, which is why the data were collapsed based on the applicant's ID and application year variables, so as to have a single observation for each patent application. This collapsing leads to some technology classes taking on a value higher than one, which is then replaced with the value one.

Next, the data are merged with REGPAT's regional database, which contains information on the applicant's address, name, region, country, and application share. The regional breakdowns provided in REGPAT correspond to the Nomenclature of Territorial Units for Statistics (see Eurostat's 2010 typologies and local information corresponding to NUTS 3) for European countries. The merge is carried out using the applicant's ID, which is the identification variable in both sets. The new dataset is then collapsed by the application year and regional code variables. The resulting data set is a data panel at the region–year level for EPO patents and technology class variables. For simplicity, I refer to this dataset as the patent–region panel. To resolve the issue of gaps within some panels, the data were inflated and missing values were replaced with zeros. Unreported patents (missing values) for a region in a given year mean that there was no EPO patent for that particular region–year observation. Then, the patent–region panel is merged with the Cambridge Econometrics European Regional Database (ERD), using regional codes and year variables as merging identifiers, to incorporate the economic variables required by the model. This new dataset is referred to as the REGPAT–ERD dataset. Finally, the OECD citation count database is merged with REGPAT's regional database, using the applicant ID identifier. The resulting data are then merged with REGPAT–ERD, using regional codes and application year variables as merging identifiers, which yields the final dataset used in the analysis.

Two additional points are worth mentioning: 1) The FI patent classification adopted in this study is designed for the purpose of country comparisons, and the FI therefore sets specific requirements for the patent classification, namely, that it covers all technology fields, that it has a balanced field size, that it be based exclusively on IPC codes, and that its fields be appropriately differentiated and clearly distinguished. 2) For accuracy, 3,645 (two withdrawn and 3,643 duplicate applications) out of 2,897,258 observations are dropped from the Citations Database before merging it with REGPAT–ERD.

Table A.1: FI's IPC code classification

	Area, field	IPC code
I	**Electrical engineering**	
1	Electrical machinery, apparatus, energy	F21#, H01B, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01R, H01T, H02#, H05B, H05C, H05F, H99Z.
2	Audiovisual technology	G09F, G09G, G11B, H04N-003, H04N-005, H04N-009, H04N-013, H04N-015, H04N-017, H04R, H04S, H05K.
3	Telecommunications	G08C, H01P, H01Q, H04B, H04H, H04J, H04K, H04M, H04N- 001, H04N-007, H04N-011, H04Q.
4	Digital communication	H04L.
5	Basic communication processes	H03#.
6	Computer technology	(G06# not G06Q), G11C, G10L.
7	IT methods for management	G06Q.
8	Semiconductors	H01L.
II	**Instruments**	
9	Optics	G02#, G03B, G03C, G03D, G03F, G03G, G03H, H01S.
10	Measurement	G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, (G01N not G01N-033), G01P, G01R, G01S; G01V, G01W, G04#, G12B, G99Z.
11	Analysis of biological materials	G01N-033.
12	Control	G05B, G05D, G05F, G07#, G08B, G08G, G09B, G09C, G09D.
13	Medical technology	A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61L, A61M, A61N, H05G.
III	**Chemistry**	
14	Organic fine chemistry	(C07B, C07C, C07D, C07F, C07H, C07J, C40B) not A61K, A61K-008, A61Q.
15	Biotechnology	(C07G, C07K, C12M, C12N, C12P, C12Q, C12R, C12S) not A61K.
16	Pharmaceuticals	A61K not A61K-008.
17	Macromolecular chemistry, polymers	C08B, C08C, C08F, C08G, C08H, C08K, C08L.
18	Food chemistry	A01H, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, C12C, C12F, C12G, C12H, C12J, C13D, C13F, C13J, C13K.
19	Basic materials chemistry	A01N, A01P, C05#, C06#, C09B, C09C, C09F, C09G, C09H, C09K, C09D, C09J, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M, C10N, C11B, C11C, C11D, C99Z.
20	Materials, metallurgy	C01#, C03C, C04#, C21#, C22#, B22#.
21	Surface technology, coating	B05C, B05D, B32#, C23#, C25#, C30#.
22	Microstructure and nanotechnology	B81#, B82#.
23	Chemical engineering	B01B, B01D-000#, B01D-01##, B01D-02##, B01D-03##, B01D- 041, B01D-043, B01D-057, B01D-059, B01D-06##, B01D-07##, B01F, B01J, B01L, B02C, B03#, B04#, B05B, B06B, B07#, B08#, D06B, D06C, D06L, F25J, F26#, C14C, H05H.
24	Environmental technology	A62D, B01D-045, B01D-046, B01D-047, B01D-049, B01D-050, B01D-051, B01D-052, B01D-053, B09#, B65F, C02#, F01N, F23G, F23J, G01T, E01F-008, A62C.
IV	**Mechanical engineering**	
25	Handling	B25J, B65B, B65C, B65D, B65G, B65H, B66#, B67#.
26	Machine tools	B21#, B23#, B24#, B26D, B26F, B27#, B30#, B25B, B25C, B25D, B25F, B25G, B25H, B26B.
27	Engines, pumps, turbines	F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02#, F03#, F04#, F23R, G21#, F99Z.
28	Textile and paper machines	A41H, A43D, A46D, C14B, D01#, D02#, D03#, D04B, D04C, D04G, D04H, D05#, D06G, D06H, D06J, D06M, D06P, D06Q, D99Z, B31#, D21#, B41#.
29	Other special machines	A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01L, A01M, A21B, A21C, A22#, A23N, A23P, B02B, C12L, C13C, C13G, C13H, B28#, B29#, C03B, C08J, B99Z, F41#, F42#.
30	Thermal processes and apparatus	F22#, F23B, F23C, F23D, F23H, F23K, F23L, F23M, F23N, F23Q, F24#, F25B, F25C, F27#, F28#.
31	Mechanical elements	F15#, F16#, F17#, G05G.
32	Transport	B60#, B61#, B62#, B63B, B63C, B63G, B63H, B63J, B64#.
V	**Other fields**	
33	Furniture, games	A47#, A63#.
34	Other consumer goods	A24#, A41B, A41C, A41D, A41F, A41G, A42#, A43B, A43C, A44#, A45#, A46B, A62B, B42#, B43#, D04D, D07#, G10B, G10C, G10D, G10F, G10G, G10H, G10K, B44#, B68#, D06F, D06N, F25D, A99Z.
35	Civil engineering	E02#, E01B, E01C, E01D, E01F-001, E01F-003, E01F-005, E01F-007, E01F-009, E01F-01#, E01H, E03#, E04#, E05#, E06#, E21#, E99Z.

Table A.2: Panel tests

	Breusch and Pagan (random effects vs. OLS)	Fixed vs. random effects
Öresund	χ^2 (01) = 1095.28 Prob > χ^2 = 0.0000	Sargan–Hansen statistic 21.719 χ^2 (3) *p*-Value = 0.0001
Copenhagen + Skåne	chibar2(01) = 1077.38 Prob > chibar2 = 0.0000	Sargan–Hansen statistic 181.38 χ^2 (3) *p*-Value = 0.0000

Table A.3: Number of technology classes weighted by the absolute number of received citations

		Skåne			Copenhagen		
		1993–1999	2000–2007	Change (%)	1993–1999	2000–2007	Change (%)
Electrical Engineering	Electrical machinery	2,647	11,158	322	4,655	6,588	42
	Audiovisual tech	1,442	22,406	1,454	2,177	7,950	265
	Telecommunications	1,062	59,938	5,544	2,120	3,296	55
	Digital communications	314	16,848	5,266	1,024	1,761	72
	Basic communications	143	3,525	2,365	783	1,170	49
	Computer tech	2,365	45,110	1,807	1,267	5,102	303
	IT methods for management	157	3,886	2,375	224	941	320
	Semiconductors	311	2,755	786	530	943	78
Instruments	Optics	875	8,734	898	1,782	3,099	74
	Measurement	4,534	13,478	197	6,156	8,067	31
	Analysis of biological materials	3,172	6,963	120	5,151	8,166	59
	Control	1,865	7,693	312	1,061	1,414	33
	Medical tech	10,148	30,867	204	8,740	17,038	95
Chemistry	Organic fine chemistry	3,648	4,515	24	25,347	24,679	–3
	Biotechnology	5,088	10,906	114	39,562	47,866	21
	Pharmaceuticals	7,712	21,807	183	30,875	43,076	40
	Macromolecular chemistry	2,382	3,355	41	6,011	3,595	–40
	Food chemistry	3,144	3,890	24	10,167	12,959	27
	Basic materials chemistry	2,702	5,016	86	18,878	12,269	–35
	Materials, metallurgy	2,300	6,134	167	8,793	7,879	–10
	Surface technology	2,302	4,714	105	1,933	3,157	63
	Microstructure and nanotech	64	2,217	3,364	196	528	169
	Chemical engineering	7,340	17,591	140	13,556	13,016	–4
	Environmental tech	2,278	4,533	99	5,747	5,285	–8
Mechanical Engineering	Handling	8,575	14,249	66	2,849	5,408	90
	Machine tools	3,168	6,573	107	2,078	1,939	–7
	Engines, pumps, turbines	1,074	4,379	308	1,772	3,023	71
	Textile and paper machines	3,007	2,275	–24	9,604	3,235	–66
	Other special machines	5,253	5,265	0	6,783	6,933	2
	Thermal processes and apparatus	3,547	9,812	177	2,955	2,528	–14
	Mechanical elements	4,600	15,061	227	2,722	4,380	61
	Transport	3,685	7,216	96	1,249	1,603	28
Other fields	Furniture, games	1,968	5,479	178	1,106	2,859	158
	Other consumer goods	2,872	6,314	120	1,158	1,642	42
	Civil engineering	5,948	21,424	260	8,787	9,715	11

Table A.4: Number of technology classes weighted by the citation weights of equation (6)

		Skåne			Copenhagen		
		1993–1999	2000–2007	Change (%)	1993–1999	2000–2007	Change (%)
Electrical Engineering	Electrical machinery	144.40	861.92	497	292.85	564.98	93
	Audiovisual tech	93.48	1,761.18	1,784	146.17	570.95	291
	Telecommunications	59.44	4,399.14	7,302	140.13	264.48	89
	Digital communications	19.69	1,266.09	6,330	61.88	126.85	105
	Basic communications	9.60	261.54	2,626	54.14	79.27	46
	Computer tech	167.26	3,608.86	2,058	93.52	407.75	336
	IT methods for management	11.30	314.97	2,686	17.89	62.69	251
	Semiconductors	22.78	217.71	856	36.83	74.00	101
Instruments	Optics	49.18	681.86	1,286	123.76	241.76	95
	Measurement	264.42	1,024.57	287	346.58	585.46	69
	Analysis of biological materials	168.69	489.31	190	307.63	597.51	94
	Control	107.61	617.92	474	67.41	105.40	56
	Medical tech	524.58	2,357.10	349	538.35	1,270.97	136
Chemistry	Organic fine chemistry	189.84	342.90	81	1,534.21	1,710.32	11
	Biotechnology	282.40	786.35	178	2,403.41	3,598.60	50
	Pharmaceuticals	397.15	1,585.60	299	1,833.91	3,141.27	71
	Macromolecular chemistry	116.78	271.15	132	341.79	261.59	–23
	Food chemistry	154.60	299.24	94	637.45	937.52	47
	Basic materials chemistry	140.87	413.11	193	1,111.28	912.72	–18
	Materials, metallurgy	137.13	477.37	248	564.90	599.11	6
	Surface technology	122.20	358.96	194	120.35	235.57	96
	Microstructure and nanotech	4.37	166.44	3,709	9.21	34.49	275
	Chemical engineering	386.18	1,408.95	265	798.36	960.13	20
	Environmental tech	121.15	373.17	208	320.42	435.12	36
Mechanical Engineering	Handling	420.96	1,038.80	147	159.54	415.69	161
	Machine tools	165.58	485.68	193	115.94	134.07	16
	Engines, pumps, turbines	51.10	350.17	585	115.77	235.27	103
	Textile and paper machines	147.18	170.73	16	600.27	232.57	–61
	Other special machines	266.37	394.14	48	410.32	527.23	28
	Thermal processes and apparatus	203.55	775.21	281	150.34	214.17	42
	Mechanical elements	277.51	1,077.39	288	175.61	350.25	99
	Transport	205.42	564.98	175	79.64	137.52	73
Other fields	Furniture, games	105.47	423.11	301	69.20	216.31	213
	Other consumer goods	142.43	495.24	248	71.16	128.72	81
	Civil engineering	354.97	1,562.01	340	496.79	750.79	51

Figure A.1: Kernel density function of the dependent variable measures for the treated and control regions

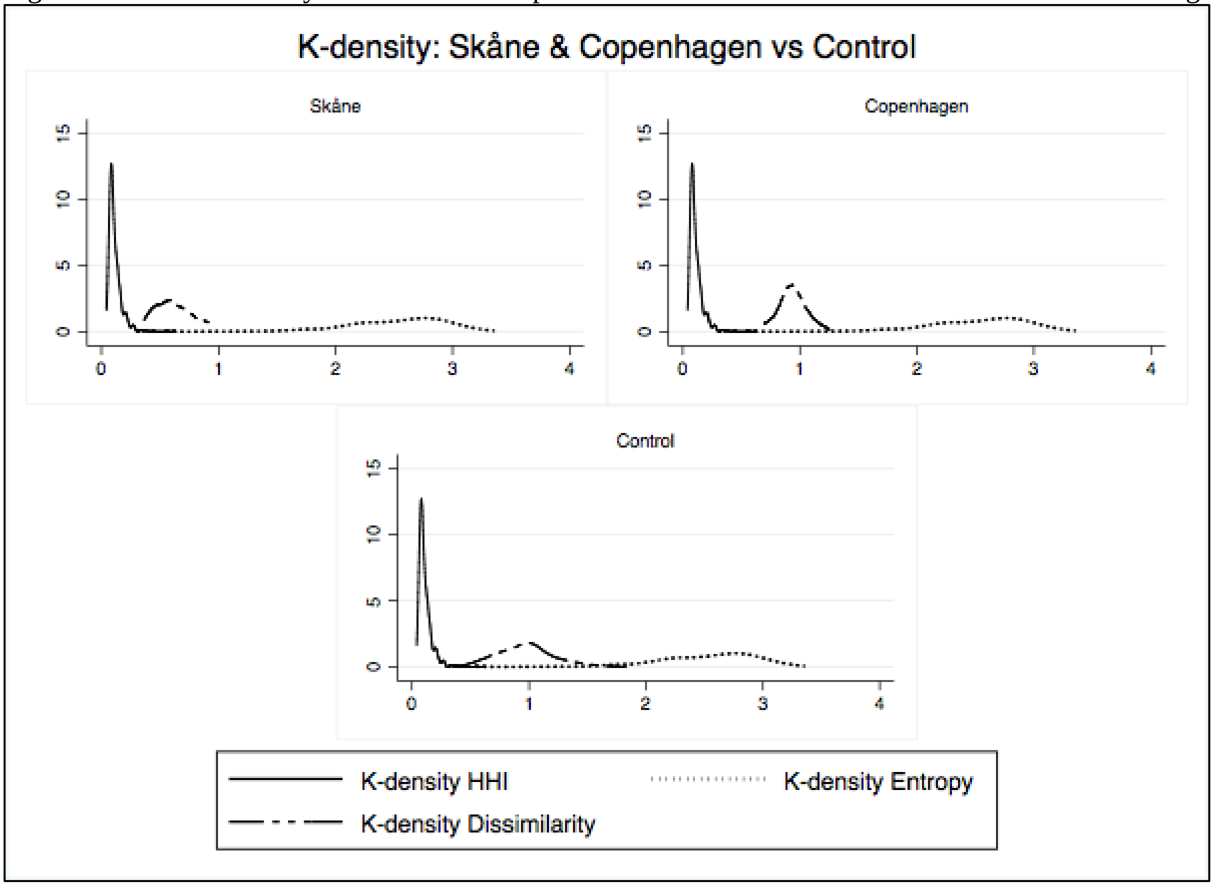

Table A.5: Copenhagen–year and Skåne–year interactions

Column	(1)	(2)	(3)	(4)	(5)	(6)
Model	FE	FE	FE	FE	FE	FE
Dependent variable	*HHI*	*HHI_Cit*	*DS*	*DS_Cit*	*Entropy*	*Entropy _Cit*
*Copenhagen*1989*	0.0275**	0.0288**	0.2061***	0.2069***	–0.2328***	–0.2474***
	(0.0129)	(0.0128)	(0.0382)	(0.0361)	(0.0687)	(0.0665)
*Copenhagen*1990*	–0.0140	0.0192	0.0728	0.1916	–0.0184	0.0451
	(0.0118)	(0.0214)	(0.0634)	(0.1304)	(0.0711)	(0.1478)
*Copenhagen*1991*	–0.0074	0.0175	–0.0057	0.0975	0.0492	0.1353
	(0.0238)	(0.0217)	(0.1378)	(0.1494)	(0.1693)	(0.1840)
*Copenhagen*1992*	–0.0019	0.0095	–0.0013	0.0740	0.0155	0.1670
	(0.0141)	(0.0145)	(0.0571)	(0.0689)	(0.0974)	(0.1711)
*Copenhagen*1993*	0.0037	0.0048	0.0837*	0.0647	–0.0679	–0.0715
	(0.0099)	(0.0129)	(0.0490)	(0.0870)	(0.0677)	(0.1216)
*Copenhagen*1994*	–0.0100	0.0166	–0.0887	0.1034	0.0944	0.5065**
	(0.0129)	(0.0123)	(0.0547)	(0.0898)	(0.0800)	(0.2188)
*Copenhagen*1995*	0.0165	0.0408**	0.0969	0.2771***	–0.1486	0.1490
	(0.0150)	(0.0158)	(0.0604)	(0.0951)	(0.1077)	(0.2082)
*Copenhagen*1996*	0.0023	0.0178	0.0983	0.1673	–0.0804	0.0587
	(0.0163)	(0.0197)	(0.0592)	(0.1110)	(0.0982)	(0.1913)
*Copenhagen*1997*	0.0237	0.0417	0.2014	0.3198	–0.2150	0.0058
	(0.0336)	(0.0340)	(0.2483)	(0.2508)	(0.2601)	(0.3036)
*Copenhagen*1998*	0.0333	0.0530**	0.2749*	0.4394**	–0.2285	0.2247
	(0.0206)	(0.0240)	(0.1615)	(0.1917)	(0.1618)	(0.2536)
*Copenhagen*1999*	0.0095	0.0223	0.1563	0.2525*	–0.0567	0.2010
	(0.0154)	(0.0184)	(0.1142)	(0.1459)	(0.0970)	(0.2141)
*Copenhagen*2000*	0.0126	0.0386*	0.1665	0.3371**	–0.1250	0.2944
	(0.0181)	(0.0191)	(0.1154)	(0.1323)	(0.1347)	(0.2489)
*Copenhagen*2001*	0.0216	0.0330*	0.1157	0.2028	–0.1212	0.1525
	(0.0154)	(0.0177)	(0.1027)	(0.1292)	(0.1143)	(0.2404)
*Copenhagen*2002*	0.0063	0.0383	0.0980	0.2959*	–0.0659	0.1869
	(0.0228)	(0.0275)	(0.1406)	(0.1741)	(0.1711)	(0.2427)
*Copenhagen*2003*	0.0085	0.0484**	0.2017	0.3642**	–0.1859	0.0965
	(0.0281)	(0.0189)	(0.1660)	(0.1693)	(0.1860)	(0.2552)
*Copenhagen*2004*	0.0195	0.0503***	0.1554	0.3452**	–0.1361	0.2512
	(0.0147)	(0.0159)	(0.1220)	(0.1429)	(0.1038)	(0.2103)
*Copenhagen*2005*	0.0355*	0.0520**	0.1434	0.2515	–0.2337	0.0180
	(0.0196)	(0.0224)	(0.1419)	(0.1732)	(0.1619)	(0.2403)
*Copenhagen*2006*	0.0126	0.0322*	0.0650	0.2419	–0.0591	0.4004
	(0.0143)	(0.0181)	(0.1251)	(0.1573)	(0.1006)	(0.2604)
*Copenhagen*2007*	0.0169	0.0368*	0.0730	0.2338	–0.1287	0.2022
	(0.0162)	(0.0208)	(0.0929)	(0.1388)	(0.1006)	(0.2078)
*Copenhagen*2008*	–0.0023	0.0354*	–0.0047	0.2399	–0.0192	0.4570**
	(0.0185)	(0.0198)	(0.1088)	(0.1442)	(0.1191)	(0.2161)
*Copenhagen*2009*	–0.0015	0.0427**	0.0174	0.3254*	–0.0045	0.6634**
	(0.0128)	(0.0206)	(0.1298)	(0.1637)	(0.1280)	(0.2538)
*Copenhagen*2010*	–0.0095	0.0129	–0.0605	0.1030	0.0816	0.5205**
	(0.0176)	(0.0236)	(0.1294)	(0.1746)	(0.1468)	(0.2378)
*Copenhagen*2011*	–0.0201	0.0053	–0.1356	0.0444	0.1640	0.5960**
	(0.0161)	(0.0210)	(0.1598)	(0.1931)	(0.1576)	(0.2692)
*Skåne*1989*	–0.0051	–0.0038	–0.0410	–0.0464	0.0885	0.0739
	(0.0109)	(0.0108)	(0.0377)	(0.0360)	(0.0629)	(0.0605)
*Skåne*1990*	–0.0368***	–0.0037	–0.0552	0.0495	0.2057***	0.2691*

	(0.0118)	(0.0214)	(0.0485)	(0.1246)	(0.0706)	(0.1476)
*Skåne*1991*	–0.0299	–0.0050	–0.2263***	–0.1298	0.2360**	0.3222**
	(0.0192)	(0.0165)	(0.0546)	(0.0892)	(0.1014)	(0.1245)
*Skåne*1992*	–0.0154	–0.0039	–0.2414***	–0.1602**	0.1851**	0.3366*
	(0.0139)	(0.0143)	(0.0536)	(0.0674)	(0.0905)	(0.1673)
*Skåne*1993*	–0.0049	–0.0038	–0.1743***	–0.1629*	0.0190	0.0154
	(0.0099)	(0.0129)	(0.0454)	(0.0865)	(0.0672)	(0.1213)
*Skåne*1994*	–0.0164	0.0101	–0.1139**	0.0634	0.1795**	0.5917**
	(0.0125)	(0.0119)	(0.0460)	(0.0859)	(0.0787)	(0.2184)
*Skåne*1995*	–0.0112	0.0131	–0.1680***	0.0020	0.1404	0.4379**
	(0.0144)	(0.0152)	(0.0557)	(0.0930)	(0.0998)	(0.2042)
*Skåne*1996*	–0.0125	0.0031	–0.2105***	–0.1166	0.0575	0.1966
	(0.0156)	(0.0191)	(0.0539)	(0.1100)	(0.0980)	(0.1913)
*Skåne*1997*	–0.0184	–0.0003	–0.1580**	–0.0367	0.1248	0.3456*
	(0.0178)	(0.0186)	(0.0585)	(0.0890)	(0.0948)	(0.1830)
*Skåne*1998*	–0.0021	0.0176	–0.2022***	–0.0294	0.0672	0.5205**
	(0.0145)	(0.0190)	(0.0622)	(0.1273)	(0.0962)	(0.2177)
*Skåne*1999*	–0.0170	–0.0042	–0.1603***	–0.0662	0.2229**	0.4806**
	(0.0132)	(0.0166)	(0.0521)	(0.1096)	(0.0840)	(0.2085)
*Skåne*2000*	–0.0136	0.0125	–0.0178	0.1506	0.1638*	0.5832**
	(0.0136)	(0.0150)	(0.0537)	(0.0897)	(0.0876)	(0.2269)
*Skåne*2001*	0.0107	0.0221	0.1143*	0.2054*	–0.0756	0.1980
	(0.0144)	(0.0167)	(0.0613)	(0.1029)	(0.0961)	(0.2323)
*Skåne*2002*	–0.0219	0.0100	–0.0661	0.1288	0.2084*	0.4612**
	(0.0153)	(0.0218)	(0.0691)	(0.1274)	(0.1099)	(0.2042)
*Skåne*2003*	–0.0136	0.0262*	0.1505**	0.3168***	0.0522	0.3346
	(0.0251)	(0.0140)	(0.0710)	(0.0878)	(0.1219)	(0.2130)
*Skåne*2004*	0.0089	0.0397**	0.1129*	0.3268***	–0.0421	0.3452
	(0.0133)	(0.0146)	(0.0629)	(0.1017)	(0.0895)	(0.2035)
*Skåne*2005*	0.0026	0.0192	0.1319**	0.2443*	0.0209	0.2726
	(0.0138)	(0.0175)	(0.0617)	(0.1231)	(0.0922)	(0.2000)
*Skåne*2006*	0.0211*	0.0407**	0.2923***	0.4818***	–0.1274	0.3321
	(0.0122)	(0.0165)	(0.0658)	(0.1205)	(0.0870)	(0.2555)
*Skåne*2007*	0.0018	0.0217	0.2460***	0.4111***	0.0104	0.3413
	(0.0150)	(0.0198)	(0.0655)	(0.1248)	(0.0983)	(0.2067)
*Skåne*2008*	0.0085	0.0462**	0.2656***	0.5260***	–0.0906	0.3855*
	(0.0173)	(0.0186)	(0.0522)	(0.1108)	(0.0972)	(0.2049)
*Skåne*2009*	–0.0137	0.0306	0.0544	0.3753***	0.1203	0.7883***
	(0.0114)	(0.0197)	(0.0577)	(0.1201)	(0.0846)	(0.2350)
*Skåne*2010*	–0.0109	0.0115	0.0346	0.2017	0.1693*	0.6082***
	(0.0163)	(0.0227)	(0.0589)	(0.1344)	(0.0977)	(0.2111)
*Skåne*2011*	–0.0321**	–0.0067	–0.0319	0.1553	0.3051***	0.7371***
	(0.0123)	(0.0182)	(0.0557)	(0.1295)	(0.0841)	(0.2339)
1989	–0.0061	–0.0074	–0.0259	–0.0317	0.0356	0.0502
	(0.0109)	(0.0108)	(0.0377)	(0.0360)	(0.0629)	(0.0605)
1990	0.0301**	–0.0031	0.0915*	–0.0284	–0.1517**	–0.2151
	(0.0118)	(0.0214)	(0.0485)	(0.1246)	(0.0706)	(0.1476)
1991	0.0270	0.0021	0.1140**	0.0035	–0.1715	–0.2577**
	(0.0192)	(0.0165)	(0.0546)	(0.0892)	(0.1014)	(0.1245)
1992	0.0024	–0.0090	0.0091	–0.0702	–0.0102	–0.1617
	(0.0139)	(0.0143)	(0.0536)	(0.0674)	(0.0905)	(0.1673)
1993	0.0034	0.0023	0.0393	0.0477	–0.0124	–0.0088
	(0.0099)	(0.0129)	(0.0454)	(0.0865)	(0.0672)	(0.1213)
1994	0.0031	–0.0235*	0.0183	–0.1758**	–0.0157	–0.4278*

	(0.0125)	(0.0119)	(0.0460)	(0.0859)	(0.0787)	(0.2184)
1995	0.0002	–0.0241	0.0333	–0.1512	0.0134	–0.2841
	(0.0144)	(0.0152)	(0.0557)	(0.0930)	(0.0998)	(0.2042)
1996	0.0058	–0.0097	0.0016	–0.0780	0.0209	–0.1182
	(0.0156)	(0.0191)	(0.0539)	(0.1100)	(0.0980)	(0.1913)
1997	0.0061	–0.0120	0.0070	–0.1215	0.0254	–0.1954
	(0.0178)	(0.0186)	(0.0585)	(0.0890)	(0.0948)	(0.1830)
1998	–0.0153	–0.0351*	–0.0625	–0.2377*	0.1597	–0.2936
	(0.0145)	(0.0190)	(0.0622)	(0.1273)	(0.0962)	(0.2177)
1999	0.0028	–0.0100	0.0038	–0.1033	0.0222	–0.2354
	(0.0132)	(0.0166)	(0.0521)	(0.1096)	(0.0840)	(0.2085)
2000	–0.0065	–0.0325**	–0.1015*	–0.2826***	0.1501*	–0.2693
	(0.0136)	(0.0150)	(0.0537)	(0.0897)	(0.0876)	(0.2269)
2001	–0.0142	–0.0256	–0.0644	–0.1616	0.1715*	–0.1022
	(0.0144)	(0.0167)	(0.0613)	(0.1029)	(0.0961)	(0.2323)
2002	0.0103	–0.0217	0.0327	–0.1739	0.0034	–0.2494
	(0.0153)	(0.0218)	(0.0691)	(0.1274)	(0.1099)	(0.2042)
2003	0.0245	–0.0154	0.0266	–0.1447	–0.0302	–0.3126
	(0.0251)	(0.0140)	(0.0710)	(0.0878)	(0.1219)	(0.2130)
2004	–0.0017	–0.0324**	–0.0483	–0.2475**	0.0768	–0.3106
	(0.0133)	(0.0146)	(0.0629)	(0.1017)	(0.0895)	(0.2035)
2005	–0.0042	–0.0207	–0.0069	–0.1222	0.0719	–0.1799
	(0.0138)	(0.0175)	(0.0617)	(0.1231)	(0.0922)	(0.2000)
2006	–0.0058	–0.0253	–0.0073	–0.1938	0.0948	–0.3647
	(0.0122)	(0.0165)	(0.0658)	(0.1205)	(0.0870)	(0.2555)
2007	0.0031	–0.0168	0.0113	–0.1568	0.0422	–0.2887
	(0.0150)	(0.0198)	(0.0655)	(0.1248)	(0.0983)	(0.2067)
2008	0.0054	–0.0324*	–0.0146	–0.2704**	0.0621	–0.4140*
	(0.0173)	(0.0186)	(0.0522)	(0.1108)	(0.0972)	(0.2049)
2009	0.0068	–0.0375*	–0.0285	–0.3467***	0.0569	–0.6111**
	(0.0114)	(0.0197)	(0.0577)	(0.1201)	(0.0846)	(0.2350)
2010	0.0048	–0.0177	–0.0031	–0.1781	0.0308	–0.4081*
	(0.0163)	(0.0227)	(0.0589)	(0.1344)	(0.0977)	(0.2111)
2011	0.0223*	–0.0031	0.0770	–0.1161	–0.0884	–0.5204**
	(0.0123)	(0.0182)	(0.0557)	(0.1295)	(0.0841)	(0.2339)
Constant	0.1065***	0.1036***	0.9515***	0.9156***	2.5083***	2.4239***
	(0.0102)	(0.0117)	(0.0414)	(0.0620)	(0.0663)	(0.1012)
Observations	720	720	720	720	720	720

In this table, FE stands for the fixed effects (within regression) estimator, the fixed effects panel unit is a NUTS 3 region, robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A.5.1: Joint significance test of region–year interactions

HHI	
testparm Copenhagen*1989-Copenhagen*1999	testparm Skåne*1989-Skåne*1999
(1) Copenhagen*1989 = 0	(1) Skåne*1989 = 0
(2) Copenhagen*1990 = 0	(2) Skåne*1990 = 0
(3) Copenhagen*1991 = 0	(3) Skåne*1991 = 0
(4) Copenhagen*1992 = 0	(4) Skåne*1992 = 0
(5) Copenhagen*1993 = 0	(5) Skåne*1993 = 0
(6) Copenhagen*1994 = 0	(6) Skåne*1994 = 0
(7) Copenhagen*1995 = 0	(7) Skåne*1995 = 0
(8) Copenhagen*1996 = 0	(8) Skåne*1996 = 0
(9) Copenhagen*1997 = 0	(9) Skåne*1997 = 0
(10) Copenhagen*1998 = 0	(10) Skåne*1998 = 0
(11) Copenhagen*1999 = 0	(11) Skåne*1999 = 0
F(11, 29) = 7.50	F(11, 29) = 1.66
Prob > F = 0.0000	Prob > F = 0.1347
testparm Copenhagen*2000-Copenhagen*2011	testparm Skåne*2000-Skåne*2011
(1) Copenhagen*2000 = 0	(1) Skåne*2000 = 0
(2) Copenhagen*2001 = 0	(2) Skåne*2001 = 0
(3) Copenhagen*2002 = 0	(3) Skåne*2002 = 0
(4) Copenhagen*2003 = 0	(4) Skåne*2003 = 0
(5) Copenhagen*2004 = 0	(5) Skåne*2004 = 0
(6) Copenhagen*2005 = 0	(6) Skåne*2005 = 0
(7) Copenhagen*2006 = 0	(7) Skåne*2006 = 0
(8) Copenhagen*2007 = 0	(8) Skåne*2007 = 0
(9) Copenhagen*2008 = 0	(9) Skåne*2008 = 0
(10) Copenhagen*2009 = 0	(10) Skåne*2009 = 0
(11) Copenhagen*2010 = 0	(11) Skåne*2010 = 0
(12) Copenhagen*2011 = 0	(12) Skåne*2011 = 0
F(12, 29) = 6.30	F(12, 29) = 11.54
Prob > F = 0.0000	Prob > F = 0.0000

Table A.5.2: Joint significance test of region–year interactions

DS	
testparm Copenhagen*1989-Copenhagen*1999	testparm Skåne*1989-Skåne*1999
(1) Copenhagen*1989 = 0	(1) Skåne*1989 = 0
(2) Copenhagen*1990 = 0	(2) Skåne*1990 = 0
(3) Copenhagen*1991 = 0	(3) Skåne*1991 = 0
(4) Copenhagen*1992 = 0	(4) Skåne*1992 = 0
(5) Copenhagen*1993 = 0	(5) Skåne*1993 = 0
(6) Copenhagen*1994 = 0	(6) Skåne*1994 = 0
(7) Copenhagen*1995 = 0	(7) Skåne*1995 = 0
(8) Copenhagen*1996 = 0	(8) Skåne*1996 = 0
(9) Copenhagen*1997 = 0	(9) Skåne*1997 = 0
(10) Copenhagen*1998 = 0	(10) Skåne*1998 = 0
(11) Copenhagen*1999 = 0	(11) Skåne*1999 = 0
F(11, 29) = 26.30	F(11, 29) = 6.91
Prob > F = 0.0000	Prob > F = 0.0000
testparm Copenhagen*2000-Copenhagen*2011	testparm Skåne*2000-Skåne*2011
(1) Copenhagen*2000 = 0	(1) Skåne*2000 = 0
(2) Copenhagen*2001 = 0	(2) Skåne*2001 = 0
(3) Copenhagen*2002 = 0	(3) Skåne*2002 = 0
(4) Copenhagen*2003 = 0	(4) Skåne*2003 = 0
(5) Copenhagen*2004 = 0	(5) Skåne*2004 = 0
(6) Copenhagen*2005 = 0	(6) Skåne*2005 = 0
(7) Copenhagen*2006 = 0	(7) Skåne*2006 = 0
(8) Copenhagen*2007 = 0	(8) Skåne*2007 = 0
(9) Copenhagen*2008 = 0	(9) Skåne*2008 = 0
(10) Copenhagen*2009 = 0	(10) Skåne*2009 = 0
(11) Copenhagen*2010 = 0	(11) Skåne*2010 = 0
(12) Copenhagen*2011 = 0	(12) Skåne*2011 = 0
F(12, 29) = 10.03	F(12, 29) = 46.47
Prob > F = 0.0000	Prob > F = 0.0000

Table A.5.3: Joint significance test of region–year interactions

Entropy	
testparm Copenhagen*1989-Copenhagen*1999	testparm Skåne*1989-Skåne*1999
(1) Copenhagen*1989 = 0	(1) Skåne*1989 = 0
(2) Copenhagen*1990 = 0	(2) Skåne*1990 = 0
(3) Copenhagen*1991 = 0	(3) Skåne*1991 = 0
(4) Copenhagen*1992 = 0	(4) Skåne*1992 = 0
(5) Copenhagen*1993 = 0	(5) Skåne*1993 = 0
(6) Copenhagen*1994 = 0	(6) Skåne*1994 = 0
(7) Copenhagen*1995 = 0	(7) Skåne*1995 = 0
(8) Copenhagen*1996 = 0	(8) Skåne*1996 = 0
(9) Copenhagen*1997 = 0	(9) Skåne*1997 = 0
(10) Copenhagen*1998 = 0	(10) Skåne*1998 = 0
(11) Copenhagen*1999 = 0	(11) Skåne*1999 = 0
F(11, 29) = 13.87	F(11, 29) = 5.17
Prob > F = 0.0000	Prob > F = 0.0002
testparm Copenhagen*2000-Copenhagen*2011	testparm Skåne*2000-Skåne*2011
(1) Copenhagen*2000 = 0	(1) Skåne*2000 = 0
(2) Copenhagen*2001 = 0	(2) Skåne*2001 = 0
(3) Copenhagen*2002 = 0	(3) Skåne*2002 = 0
(4) Copenhagen*2003 = 0	(4) Skåne*2003 = 0
(5) Copenhagen*2004 = 0	(5) Skåne*2004 = 0
(6) Copenhagen*2005 = 0	(6) Skåne*2005 = 0
(7) Copenhagen*2006 = 0	(7) Skåne*2006 = 0
(8) Copenhagen*2007 = 0	(8) Skåne*2007 = 0
(9) Copenhagen*2008 = 0	(9) Skåne*2008 = 0
(10) Copenhagen*2009 = 0	(10) Skåne*2009 = 0
(11) Copenhagen*2010 = 0	(11) Skåne*2010 = 0
(12) Copenhagen*2011 = 0	(12) Skåne*2011 = 0
F(12, 29) = 6.15	F(12, 29) = 38.43
Prob > F = 0.0000	Prob > F = 0.0000

Table A.5.4: Joint significance test of region–year interactions

HHI_Cit	
testparm Copenhagen*1989-Copenhagen*1999	testparm Skåne*1989-Skåne*1999
(1) Copenhagen*1989 = 0	(1) Skåne*1989 = 0
(2) Copenhagen*1990 = 0	(2) Skåne*1990 = 0
(3) Copenhagen*1991= 0	(3) Skåne*1991= 0
(4) Copenhagen*1992 = 0	(4) Skåne*1992 = 0
(5) Copenhagen*1993= 0	(5) Skåne*1993= 0
(6) Copenhagen*1994 = 0	(6) Skåne*1994 = 0
(7) Copenhagen*1995 = 0	(7) Skåne*1995 = 0
(8) Copenhagen*1996= 0	(8) Skåne*1996= 0
(9) Copenhagen*1997 = 0	(9) Skåne*1997 = 0
(10) Copenhagen*1998 = 0	(10) Skåne*1998 = 0
(11) Copenhagen*1999 = 0	(11) Skåne*1999 = 0
F(11, 29) = 5.46	F(11, 29) = 1.63
Prob > F = 0.0001	Prob > F = 0.1412
testparm Copenhagen*2000-Copenhagen*2011	testparm Skåne*2000-Skåne*2011
(1) Copenhagen*2000 = 0	(1) Skåne*2000 = 0
(2) Copenhagen*2001 = 0	(2) Skåne*2001 = 0
(3) Copenhagen*2002 = 0	(3) Skåne*2002 = 0
(4) Copenhagen*2003 = 0	(4) Skåne*2003 = 0
(5) Copenhagen*2004 = 0	(5) Skåne*2004 = 0
(6) Copenhagen*2005 = 0	(6) Skåne*2005 = 0
(7) Copenhagen*2006 = 0	(7) Skåne*2006 = 0
(8) Copenhagen*2007= 0	(8) Skåne*2007= 0
(9) Copenhagen*2008 = 0	(9) Skåne*2008 = 0
(10) Copenhagen*2009 = 0	(10) Skåne*2009 = 0
(11) Copenhagen*2010 = 0	(11) Skåne*2010 = 0
(12) Copenhagen*2011 = 0	(12) Skåne*2011 = 0
F(12, 29) = 4.00	F(12, 29) = 4.80
Prob > F = 0.0011	Prob > F = 0.0003

Table A.5.5: Joint significance test of region–year interactions

DS_Cit	
testparm Copenhagen*1989-Copenhagen*1999	testparm Skåne*1989-Skåne*1999
(1) Copenhagen*1989 = 0	(1) Skåne*1989 = 0
(2) Copenhagen*1990 = 0	(2) Skåne*1990 = 0
(3) Copenhagen*1991= 0	(3) Skåne*1991= 0
(4) Copenhagen*1992 = 0	(4) Skåne*1992 = 0
(5) Copenhagen*1993= 0	(5) Skåne*1993= 0
(6) Copenhagen*1994 = 0	(6) Skåne*1994 = 0
(7) Copenhagen*1995 = 0	(7) Skåne*1995 = 0
(8) Copenhagen*1996= 0	(8) Skåne*1996= 0
(9) Copenhagen*1997 = 0	(9) Skåne*1997 = 0
(10) Copenhagen*1998 = 0	(10) Skåne*1998 = 0
(11) Copenhagen*1999 = 0	(11) Skåne*1999 = 0
F(11, 29) = 11.70	F(11, 29) = 2.40
Prob > F = 0.0000	Prob > F = 0.0292
testparm Copenhagen*2000-Copenhagen*2011	testparm Skåne*2000-Skåne*2011
(1) Copenhagen*2000 = 0	(1) Skåne*2000 = 0
(2) Copenhagen*2001 = 0	(2) Skåne*2001 = 0
(3) Copenhagen*2002 = 0	(3) Skåne*2002 = 0
(4) Copenhagen*2003 = 0	(4) Skåne*2003 = 0
(5) Copenhagen*2004 = 0	(5) Skåne*2004 = 0
(6) Copenhagen*2005 = 0	(6) Skåne*2005 = 0
(7) Copenhagen*2006 = 0	(7) Skåne*2006 = 0
(8) Copenhagen*2007= 0	(8) Skåne*2007= 0
(9) Copenhagen*2008 = 0	(9) Skåne*2008 = 0
(10) Copenhagen*2009 = 0	(10) Skåne*2009 = 0
(11) Copenhagen*2010 = 0	(11) Skåne*2010 = 0
(12) Copenhagen*2011 = 0	(12) Skåne*2011 = 0
F(12, 29) = 3.96	F(12, 29) = 7.73
Prob > F = 0.0012	Prob > F = 0.0000

Table A.5.6: Joint significance test of region–year interactions

Entropy_Cit	
testparm Copenhagen*1989-Copenhagen*1999	testparm Skåne*1989-Skåne*1999
(1) Copenhagen*1989 = 0	(1) Skåne*1989 = 0
(2) Copenhagen*1990 = 0	(2) Skåne*1990 = 0
(3) Copenhagen*1991 = 0	(3) Skåne*1991 = 0
(4) Copenhagen*1992 = 0	(4) Skåne*1992 = 0
(5) Copenhagen*1993 = 0	(5) Skåne*1993 = 0
(6) Copenhagen*1994 = 0	(6) Skåne*1994 = 0
(7) Copenhagen*1995 = 0	(7) Skåne*1995 = 0
(8) Copenhagen*1996 = 0	(8) Skåne*1996 = 0
(9) Copenhagen*1997 = 0	(9) Skåne*1997 = 0
(10) Copenhagen*1998 = 0	(10) Skåne*1998 = 0
(11) Copenhagen*1999 = 0	(11) Skåne*1999 = 0
F(11, 29) = 7.23	F(11, 29) = 2.54
Prob > F = 0.0000	Prob > F = 0.0220
testparm Copenhagen*2000-Copenhagen*2011	testparm Skåne*2000-Skåne*2011
(1) Copenhagen*2000 = 0	(1) Skåne*2000 = 0
(2) Copenhagen*2001 = 0	(2) Skåne*2001 = 0
(3) Copenhagen*2002 = 0	(3) Skåne*2002 = 0
(4) Copenhagen*2003 = 0	(4) Skåne*2003 = 0
(5) Copenhagen*2004 = 0	(5) Skåne*2004 = 0
(6) Copenhagen*2005 = 0	(6) Skåne*2005 = 0
(7) Copenhagen*2006 = 0	(7) Skåne*2006 = 0
(8) Copenhagen*2007 = 0	(8) Skåne*2007 = 0
(9) Copenhagen*2008 = 0	(9) Skåne*2008 = 0
(10) Copenhagen*2009 = 0	(10) Skåne*2009 = 0
(11) Copenhagen*2010 = 0	(11) Skåne*2010 = 0
(12) Copenhagen*2011 = 0	(12) Skåne*2011 = 0
F(12, 29) = 2.75	F(12, 29) = 3.96
Prob > F = 0.0128	Prob > F = 0.0012

Table A.6: Impact of the bridge on the technological specialization measured by *HHI* for the 32 technology classes sample

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*HHI*	*HHI*	*HHI_Cit*	*HHI_Cit*
Copenhagen	-0.0486***		-0.0248***	
	(0.0060)		(0.0055)	
Skåne	-0.0799***		-0.0562***	
	(0.0052)		(0.0046)	
Bridge	-0.0060		-0.0175***	
	(0.0066)		(0.0057)	
Copenhagen*Bridge	0.0071	0.0071	0.0187**	0.0187**
	(0.0080)	(0.0080)	(0.0073)	(0.0087)
Skåne*Bridge	0.0160**	0.0160**	0.0275***	0.0275***
	(0.0077)	(0.0074)	(0.0070)	(0.0082)
Constant	0.1369***	0.1281***	0.1132***	0.1249***
	(0.0049)	(0.0159)	(0.0042)	(0.0178)
Regions fixed-effects		Yes		Yes
Years fixed-effects		Yes		Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A.7: Impact of the bridge on the technological specialization measured by *DS* for the 32 technology classes sample

Column	(1)	(2)	(3)	(4)
Model	OLS	FE	OLS	FE
Dependent variable	*DS*	*DS*	*DS_Cit*	*DS_Cit*
Copenhagen	-0.0211		0.0987***	
	(0.0287)		(0.0336)	
Skåne	-0.5073***		-0.3802***	
	(0.0273)		(0.0316)	
Bridge	-0.0305		-0.1240***	
	(0.0206)		(0.0336)	
Copenhagen*Bridge	-0.0296	-0.0296	0.0627	0.0627
	(0.0379)	(0.0465)	(0.0465)	(0.0637)
Skåne*Bridge	0.2804***	0.2804***	0.3759***	0.3759***
	(0.0471)	(0.0263)	(0.0545)	(0.0489)
Constant	1.0153***	0.9731***	0.8735***	0.9365***
	(0.0147)	(0.0425)	(0.0226)	(0.0650)
Regions fixed-effects		Yes		Yes
Years fixed-effects		Yes		Yes
Observations	720	720	720	720

In this table, OLS and FE stand for the ordinary least squares estimator and the fixed effects (within regression) estimator, respectively, and the fixed effects panel unit is a NUTS 3 region. Robust standard errors are reported in parentheses, and ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

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