Innovation in Malmö after the Öresund Bridge

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Abstract

We analyse the effect of the Öresund Bridge, a combined railway and motorway bridge between Swedish Malmö and the Danish capital Copenhagen, on inventive activity in the region of Malmö. Applying difference-in-difference estimation on individual level data, our findings suggest that the Öresund Bridge has led to a significant increase in the number of patents per individual with a background prone to patenting in the Malmö region as compared to the Gothenburg and Stockholm regions. Further, we show that the dominating mechanism is the attraction of highly qualified workers to the Malmö region following the construction of the bridge.

Keywords: transport infrastructure, innovation, Öresund Bridge, cross-border regions; patents; inventors; agglomeration effects

JEL Classification: O31-O33-R11-L91

1. Introduction

The results in Krugman's (1991) seminal paper on demand pooling effects suggest that investments in physical transport infrastructure benefits regional performance by reducing transport costs (cf. Klepper, 2007). Since then, a host of empirical evidence on the beneficial role of transport infrastructure has accumulated analysing various dimensions of economic performance. Fernald (1999) shows that roads and interstate highways affect industrial productivity. Others find positive effects on growth (Chandra & Thompson, 2000), employment growth (Duranton & Turner, 2012, Percoco, 2016), urbanization (Atack et al., 2009), firm entry (Percoco, 2016), trade (Donaldson, 2018, Duranton et al., 2014), regional wealth (Banerjee et al., 2012), and the reallocation of residents and economic activity within the region (Ahlfeldt et al., 2015, Baum-Snow, 2017). There is also evidence on effects of infrastructure investments on regional innovation activities (Klein & Luu, 2003, La Porta et al., 1999, Parent & Riou, 2005, Agrawal et al., 2017).

Despite the overall positive effects documented by the literature, we know little about the underlying mechanisms. An important question not addressed by the literature is whether innovation increases because knowledge flows more efficiently into the region or because of inflows of human capital to the region (cf. Duranton & Turner, 2011). The relative importance of the two mechanisms has important and distinctive implications for policy. While improved efficiency of knowledge flows is socially desirable, the attraction of human capital may be, at least partially, at the expense of the regions from which the human capital left. In this study, we contribute to the literature by assessing the importance of the effects of infrastructure improvements on regional innovation and by identifying the share of the effect that is attributable to inflow of human capital from other regions. Our theoretical considerations are tested by an empirical analysis focusing on the opening of the Öresund bridge between Denmark and Sweden.

The Öresund "region" labels the land areas surrounding the Öresund strait, which constitutes the border between Sweden and Denmark. However, it is important to note that the term "Öresund region" does not describe an administrative region, but was coined to market the region. The political and administrative power remains firmly embedded in national structures on either side of the national border. The Öresund region covers an area of 20.859 km^2 and consists of roughly three parts, the metropolitan area of Copenhagen, its suburban area and Scania (Skåne) on the Swedish side (see Figure 1). The Öresund region is not a functional region either, as for instance in the sense of an integrated labour market.

Figure 1 here

Before the opening of the bridge, the two landsides divided by the Öresund were only connected by ferry-traffic, implying that travelling was inflexible and inconvenient. Therefore, the Danish and the Swedish part of the Öresund region were largely separated labour markets, which is indicated by a relatively low number of 2,600 daily commuters in 1999, the year before the bridge was opened. Despite the fact that the bridge reduced travel time between Malmö and Copenhagen by only ten minutes to 35 minutes, the number of daily commuters reached 19,800 in 2008 as it established a direct connection between the two centres of economic activity. A large share of the new commuters were Danes who relocated to Sweden encouraged by large price differences in housing between the two countries (Öresundstat, 2020). Also, Swedes started commuting more intensively responding to a labour shortage on the Danish side (Öresundstat, 2020). Although these commuter figures are low compared to the 70,000 people who commuted daily between Malmö and its surroundings and the 225,000 people within the Greater Copenhagen Area who travel to and from Copenhagen every day (Greater Copenhagen Authority, 2001, OECD, 2003), the bridge offered more varied modes of transport and, importantly, Sweden's best direct access to an international airport - the Copenhagen Airport.

The Öresund region was already before the construction of the bridge of great economic importance. In 1999, one year before the bridge was inaugurated, the total GDP of the Öresund region was US$ 130 billion. The Swedish part of the region contributed 11% to Sweden's total GDP (OECD, 2003, p. 65). Despite their geographical proximity, the regions of Copenhagen and the Malmö differed, significantly in terms of industrial structure. Before the bridge, in particular in the city of Malmö itself, declining traditional industries was a feature of the local economy, although neighbouring Lund had a strong presence of science- and engineering based industry (OECD, 2013, p.16). At the same time, Copenhagen had a much stronger emphasis on future technologies such as biotech, pharmaceuticals and knowledge-intensive services. After the opening of the bridge, the Swedish part of the Öresund region began to prosper and saw an increase in GDP of 21% from 2000 to 2010 (as compared to an increase of 12% for the Danish side) and an increase in employment of 17% (as compared to an increase of 4% for the Danish side).[1] Business research and development (R&D) expenditure as a percentage of GDP reached 3.5% in the South of Sweden as compared to 2.5% Swedish average in 2009 (OECD, 2013, p. 18). The Malmö region ranked fourth among OECD metropolitan areas for patent intensity in 2013 and is now described as a "host for creative industries" (OECD, 2013, p. 16).

[1] The information is taken from Orestat database: http://www.orestat.se/sv/oresundsdatabasen-engelsk

Co-occurrences between the opening of the bridge and subsequent economic development remain suggestive and a causal interpretation requires careful analysis. This paper uses a unique micro-level individual dataset to investigate the effect of the bridge on the patent productivity of the inventive labour force in the region of Malmö. Many evaluations of infrastructure projects focus on the regional level. While these studies focus on contextual regional factors and their interactions with regional policies, the individual level allows us to get insights into the behaviour of people in response to policy changes. An individual level analysis is required to answer our research question which aims at disentangling the effect of human capital inflow embodied in talented workers from intangible knowledge inflows in response to the bridge.

Our identification strategy relies on difference-in-difference analysis where we compare the patent productivity of individuals with an educational background prone to patenting located in the Malmö region, to their counterparts in Gothenburg, Sweden's second largest region, and Stockholm, the largest region and the capital of Sweden.[2] We use individual level data from the longitudinal integrated database for health insurance and labour market studies (LISA), a database covering all individuals residing in Sweden, provided by Statistics Sweden (SCB). These data are linked to the population of Swedish inventors, which one of the authors of this study identified from addresses in the patent data from the European Patent Office (EPO).[3]

The results of our study show that the average number of patents produced by individuals in the region of Malmö increased by 30-35% (depending on the estimator) after the bridge

[2] The regional units Stockholm, Gothenburg and Malmö are functionally based on commuting patterns (local labour market regions) and follow the definition of Tillväxtverket, the Swedish Agency for Economic and Regional Growth. The full list of municipalities in each of the three regions is given in the Appendix. Notably, Uppsala belongs to the Stockholm region and Lund and Helsingborg to the Malmö region.

[3] Note that our sample consists of individuals with an educational background that enables patenting. In contrast, we use the term inventor to describe a person who appears at least once in her lifetime as inventor on a patent document.

was inaugurated as compared to the control regions. We find that this increase in patents is largely explained by individuals that move to Malmö after the completion of the bridge. These individuals new to the Malmö region contribute 78% to the total increase in patents. Our results, hence, suggest that the dominant effect of the bridge on innovation stem from the attraction of human capital.

2. History of existing evidence on the Öresund bridge

Despite a short geographical distance between the countries Denmark and Sweden, it took many decades from discussions to building a bridge over the Öresund strait which separates them. In the beginning of the 1990s, both the Swedish and Danish governments were ready to start political talks in earnest. Despite environmental concerns, an agreement was finally signed, and the bridge was officially opened on July 1st, 2000. Long-term crises on the Swedish side with the de-industrialization of Malmö and the Danish capital Copenhagen were factors that contributed to a willingness to raise investments in the region. Investments to increase accessibility between the Danish capital, Western Jutland and with Germany and Sweden were seen as important to raise its economic potential. Thus, a decision had been taken to build the Storebælt bridge between Zealand and Funen (inaugurated in 1998), which would in turn, further raise the benefits of an Öresund bridge. Many inquiries had investigated the prospects for the bridge. Much of the focus in these inquiries was on passenger volumes and environmental effects. Critics were worried that noise pollution would rise, that larger traffic volumes would raise emissions and there were concerns about water flows to the Baltic sea.

To finance the undertaking, the states opted for a fee-based solution where motorized vehicles would pay comparably large fees for crossing, whereas public train transport would pay less. Official inquiries focused little on the effects of the bridge on knowledge production, research and innovation. The focus on transport, volumes and costs was natural given its consequences on government budgets. The Swedish inquiry (SOU 1989:4) mentions that the bridge should lead to higher levels of trade, increased integration of business across the sound, integration of labour and housing markets, increased travel abroad through Copenhagen airport.

Academic scholars started to investigate potential effects on knowledge production, knowledge flows and innovation. Johansson (1988) argues that the Malmö region (in his analysis the municipalities Malmö, Lund, Staffanstorp, Lomma, Burlöv and Svedala) would develop strongly based on the increased connectivity given by the international Danish airport in Copenhagen. The arguments were based on the increased competitiveness given to product development in manufacturing and services, attained through the ability to reach customers more easily, learn about their preferences and obtain knowledge internationally more easily. Especially advanced service jobs would benefit.

Another strong proponent for the advancement of knowledge creation and also creativity is the work by Andersson and Wichmann Matthiesen (1993) who wrote an influential book about the prospects for knowledge creation in the region which resulted from the bridge. The authors rely on an international comparison with prominent regions who built their success on innovation. Examples of expected benefits that the authors highlighted were increased collaboration in science, among businesses, and in healthcare. Andersson and Wichmann Matthiesen (1993) conclude that a strong potential existed for increased collaboration within the region as well as with the outside world, but also highlighted the need for complementary investments to link up Swedish regions in the hinterland raising the possibilities for interaction. Moreover, they indicated a need for political institutions to be adapted to the changing landscape. The full potential of the bridge is yet to be realized as the region remains politically fragmented and unable to create unified institutional and administrative

Indeed, there have been attempts to create cross-border institutions, the most prominent being the formation of the Öresund University. Started in 1997, this initiative aimed to integrate research and education between 9-11 universities in the region involving 150,000 students and 14,000 staff in 2009.[4] For various reasons, including the lack of anchoring of activities at Lund University (Glimberg, 2001), the introduction of student fees in Denmark and the funding which was still coming from national sources, the project was, however, stopped in 2010.

It is thus not a priori clear to what extent the Öresund bridge can be expected to have contributed to knowledge creation and innovation. On the one hand, the region has now a more integrated labour market and improved accessibility in particular on the Swedish side. On the other hand, there appears to have been a lack of (successful) investments in (cross-border) knowledge infrastructure. We therefore review the nascent literature on the importance of infrastructure on innovation, with an emphasis on potential theoretical implications.

Innovation and transport infrastructure

Traditionally, investments in physical transport infrastructure have been suggested to improve agglomeration economies, arising from demand pooling effects and reduced transport costs, thereby strengthening supply in an economy (Krugman 1991, Klepper 2007). The literature has documented positive effects of transport infrastructure on a variety of economic outcomes. Roads and interstate highways, for instance, have been shown to affect

[4] https://sv.wikipedia.org/wiki/%C3%96resundsuniversitetet

industrial productivity (Fernald, 1999) and economic growth (Chandra & Thompson, 2000), employment growth (Duranton & Turner, 2012), urbanization (Atack et al., 2009), employment growth and firm entry (Percoco, 2016), inflow of new workers (Duranton & Turner, 2011), trade (Donaldson, 2018, Duranton et al., 2014), regional wealth (Banerjee et al., 2012), the reallocation of economic activity within the region (Ahlfeldt et al., 2015) and of working residents within metropolitan areas (Baum-Snow, 2017).

The idea that investments in transport infrastructure could also benefit innovation, has not been thoroughly examined, probably because the link between investments into concrete and innovation appears to be indirect. Only recently has the innovation-spurring effects of transport infrastructure been discussed more extensively and empirical evidence of potentially sizeable effects has accumulated (Klein & Luu, 2003, La Porta et al., 1999, Parent & Riou, 2005, Agrawal et al., 2017). This literature shows that investments in transport infrastructure directly affect the rate and timing of knowledge exchange between places by reducing travel costs.

Focusing on 335 European regions over the period 1989 – 1999, Parent and Riou (2005) show that infrastructure polarizes knowledge spillovers. Well-connected places learn more from each other than their geographic proximity suggests, while places which are close to each other but lack the support of advanced transport infrastructure show learning at a lower rate than would be expected. Using data on metropolitan areas in the U.S., Agrawal et al. (2017) show that regional highways result in an increase in regional patenting because of facilitated knowledge flows between previously less well-connected places. Focusing on air transport, Catalini et al. (2019) find that, in response to the opening of a new route by Southwest Airlines, scientific collaboration among chemists increased by between 30% and 110%. Finally, Wang et al. (2018) show that a 10% improvement in road density increases the average number of approved patents per firm by 0.71% because of market size enlargement (in terms of sales) and facilitates knowledge spillovers from star innovators within a city.

While empirical evidence on the role of transport infrastructure on innovation has accumulated, a theoretical background is still missing. In this subsection, we make an effort to provide a unified view on the link between transport infrastructure and innovation by drawing on the concept of knowledge recombination. Our framework suggests the existence of microeconomic effects of improved transport infrastructure that benefit the innovation processes in a region through increased efficiency, and by attracting skilled human capital to the region. The former effects do not negatively affect neighbouring regions and therefore provide a source of additionality in terms of innovation. Those effects that work through the mechanism of attracting skilled human capital could result in an improved allocation of labour, although negative effects on the regions that lose human capital cannot be ruled out. Providing evidence about the role of the inflow of human capital is the main goal and contribution of this paper.

Since Schumpeter's famous works, innovation has been considered to be based on the recombination of existing knowledge. Still today, the idea of recombination is as topical as ever in innovation studies and is discussed at various levels, including the innovation team (Haas and Ham, 2015), sectors or technologies (Gruber et al., 2013), but also (regional) geographical borders (Wagner et al., 2019, Choudhury and Kim, 2019). The fact that innovation is based on recombination of knowledge has a number of theoretical implications. First, the innovative potential of a given pool of knowledge increases with the size of the pool because the number of possibly valuable recombinations increases. Second, as knowledge cannot be transferred, and thus recombined, without costs, even within a region, the innovative potential also depends on the accessibility of the knowledge. Transferred to a geographical setting, the innovative potential of a regional unit (in our case the Öresund region) should be positively affected because the actors can more easily exchange and combine knowledge from other actors. The bridge effectively increases the knowledge pool available within the region.

In case of transport infrastructure projects for long travel distances (such as airports), it can also increase the access to knowledge pools held outside the region.

We argue that there are at least two types of mechanisms through which knowledge reaches a region following an investment in infrastructure. The first group of mechanisms provides additionality effects, because they are based on making the exchange or recombination of knowledge more efficient. The second type of mechanisms gives rise to effects working through the redistribution of people across regions, e.g. when human capital is attracted to the focal region. Such redistribution effects could be of concern for policy makers depending on if they create additional value, e.g. by improving employee-employer matching across regional borders, or whether they merely redistribute human capital from one region to another.

Additionality mechanisms

Additionality of transport infrastructure results from intra-regional increases in the efficiency or the returns to scale of the innovation process. A primary mechanism that speaks in favour of additionality relates to the stickiness of knowledge. Even if knowledge is legally unprotected, it typically has tacit components that make it difficult to be transferred from one actor to another (Szulanski, 2000). Thus, transferring and exchanging knowledge requires close geographical proximity (Jaffe et al., 1993). Improved transport infrastructure does not reduce the geographical distance, but it improves accessibility by reducing transport costs and travel time. Accessibility within the region but also to knowledge pools outside the region is improved. This is likely to hold for the Öresund region, in particular, because the bridge connects two regions, where accessibility, not least the flexibility of accessibility, has drastically improved. Another important factor, in particular, for the Swedish part is the better access to Copenhagen's international airport, which may benefit the Malmö region by improving its connectedness to international knowledge pools and also nationally, in particular the Stockholm-Uppsala region. One implication is that previously unexplored potentials for knowledge recombination emerge as transport costs (and allegedly the costs of knowledge recombination) decline.

A substantial literature from the 1990s and the 2000s has made arguments in this vein, crystallized in the hope that firms, universities, and other innovation-relevant actors would move closer together and thereby contribute to improved knowledge sharing. Several authors centred around Jönköping International Business School conducted studies focused on accessibility (Weibull, 1976). While the role of accessibility had been investigated for matters related to productivity and commuting (e.g. Johansson and Forslund, 1995, Ohlsson, 2001), in the 2000s only, this concept was used to improve our understanding of the importance of proximity to knowledge in the form of R&D, inferred by exponentially-weighted time-distances based on commuting patterns in Swedish data. The findings of this literature largely confirm a role of proximity to R&D and human capital for patent production (e.g., Andersson and Ejermo, 2005, Gråsjö, 2006, Karlsson and Johansson, 2019). This literature aimed at understanding the effects of proximity but did not focus on changes in accessibility, e.g., through changes in road travel times.

Another important additionality mechanism relates to indivisibilities relating to the use of shared inputs. Highly differentiated innovation processes require the use of specialized inputs such as sophisticated technology and services including market research, product testing, patent lawyers and the availability of financing (Feldman, 1994; Porter, 1998) which are often shared among firms to achieve scale effects (Helsley & Strange, 2002). . Small regions are often not able to sustain such inputs because the small market size limits the demand. Innovation therefore typically clusters in larger metropolitan regions (Audretsch & Feldman, 1996a, Feldman & Kogler, 2010, Carlino & Kerr, 2014). Improved research infrastructure can increase the effective market size by reducing transport costs and therefore sustain ever more specialized shared inputs within the region. This, obviously, already holds true for incremental improvements to transport infrastructure such as a better road system, but it is even more likely to appear for large infrastructure projects such as the Öresund bridge, which connects two formerly sharply separated regions through a big one-off investment.

Finally, urban economists an well as labour market economists have stressed that colocation creates thicker labour markets which provide access to specialized human capital (Berliant et al., 2006) increasing the chance of better matches between employers and employees (Wheeler, 2001, Berliant et al., 2006, Strange et al., 2006). Better employer-employee matches include matches between inventors or scientists and high-tech firms and, hence, contribute to elevated innovativeness.

The mechanisms described above share the feature that they increase the efficiency of the innovative activities in the focal region without compromising them in other regions. The type of mechanism described in the next section, in contrast, does not genuinely increase innovative efficiency. These mechanisms work by attracting qualified human capital to the focal region instead, thereby redistributing human capital across regions.

Redistribution mechanisms

Rational agents respond to incentives set by costs and returns to their actions. Because additionality effects are based on reducing the costs of transport, knowledge exchange and the provision of shared inputs, individual agents adapt their behaviour, at least in the long run. For example, individuals living in other regions may be attracted to the Öresund region because of local amenities (Glaeser et al., 2001; Heuermann & Schmieder, 2018) or in particular larger labour markets (Niedomysl & Hansen, 2010). Thus, transport infrastructure may induce second-order effects for innovation which work largely by attracting highly skilled employees from other regions.

While it is certainly true that cross-border relocation of human capital increases the match quality between employers and employees in the target region, one undesired side effect can be an associated loss of human capital in the donor region. From a policy perspective, attraction mechanisms could, therefore, be of concern. A priori, it is unclear whether and to which extent benefits for one region outweigh potential losses through redistribution effects of human capital for another region. It is also unclear whether such redistribution diminishes innovation at the origin region.

3. Empirical model specification

Our analysis aims at investigating the impact of the Öresund bridge on innovation produced by individuals located in the region of Malmö. In order to identify a causal effect, we use a difference-in-difference (DiD) approach where we consider the year 2000, the year of the inauguration of the bridge, as the starting point of the treatment. Our DiD compares individuals that were exposed to the treatment, i.e. the bridge, to a comparable set of individuals that were not affected by the treatment. In order to create a clean control group, we require that all our individuals in the sample are observed both in 1999 and 2000 and are unambiguously either treated or untreated throughout the entire observation period. That implies that we drop individuals, who moved to or out of Malmö after the bridge was opened. Our treated individuals reside in the Malmö region in 1999 and 2000. A control individual is thus not residing in the Malmö region in either 1999, 2000 or both years.

We make two further restrictions to the sample. First, we focus only on those individuals with an educational background in natural sciences, technology or medicine (NTM). Furthermore, we restrict the sample to the three urban regions Malmö (treatment region), Gothenburg and Stockholm (control regions). The control regions were chosen, since together with the region of Malmö they are the most important centres of inventive activity (Ejermo, 2004), and the three largest population centres in Sweden, with roughly more than half of Sweden's population residing there during the period of our study.[5]

To disentangle the accessibility and the labour influx effect, we track individuals who move from the control regions during the period of our study 1993-2007 to the Malmö region. A newcomer to the Malmö region is defined as an individual who ever resided in the region for the first time in 2000 or after. Those movers identify which share of the total effect of the bridge can be attributed to the relocation of human capital to the Malmö region.

Since we are interested in analysing the effect of the bridge on innovation, our dependent variable captures the number of patents filed. Using patent applications as a measure of innovation has the advantage of having a direct measure of inventive output that occurs at an intermediate stage of the innovation process, i.e. when the invention was completed successfully, but before the commercialization phase started. Input-based measures such as

[5] Authors' calculation. Source: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/#_Tablesandgraphs

R&D expenses have the drawback of not capturing the success of the innovation process. Most important for our analysis, patents can, in contrast to R&D, be pin-pointed geographically precisely and be monitored on the individual level, which enables us to control for many aspects of the inventive process.

We use a fractional count of patents as our dependent variable, i.e. we weigh the patent application by the number of inventors listed to account for the contribution of the individual inventors.[6] This weighting ensures that regional inventors do not receive disproportional credit for patents which are co-invented by inventors residing in different geographical areas.

Our empirical specification of the main model reads:

$$Patents_{i,t} = \alpha + \beta 1\, Post_{i,t} + \beta 2\, Malmö_i + \beta 3\, Malmö_i * Post_{i,t} + \beta 4\, X_{i,t} + \varepsilon_{i,t} \qquad \text{(I)}$$

where $Patents_{i,t}$ is our measure of fractional patent count for individual *i* in year *t*. $Post_{i,t}$ is a dummy variable that takes the value zero for the pre-bridge period 1993-1999 and one for the period 2000-2007. $Malmö_i$ is a time-invariant dummy indicating whether the individual is part of the treatment group. $Malmö_i * Post_{i,t}$ is the interaction term of $Malmö_i$ and $Post_{i,t}$. It captures the treatment effect on the treated, i.e. the potential increase in patent applications per inventor in the Malmö region after the bridge has been built. The coefficient α is an intercept, $X_{i,t}$ a set of control variables and $\varepsilon_{i,t}$ the error term.

In order to distinguish the effect of relocation of human capital to the Malmö region from knowledge accessibility effects, we employ a second specification:

$$Patents_{i,t} = \alpha + \beta 1\, Post_{i,t} + \beta 2\, Malmö_i + \beta 3\, Malmö_i * Post_{i,t} + \beta 4\, NEW_i + \beta 5\, NEW_i * Post_{i,t} + \beta 6 X_{i,t} + \varepsilon_{i,t} \qquad \text{(II)}$$

[6] For example, a patent application with two inventors is counted as 0.5 patent applications for each individual.

The variable NEW_i is time-invariant and set to one for individuals who moved to Malmö after the opening of the bridge for the very first time. The interaction term with the variable $Post_{i,t}$ allows the newcomer effect to vary. If $\beta 5$ is significantly different from zero, the effect of newcomers differs between the period before the bridge compared to after. Together with $\beta 3$, the coefficient therefore informs us about how much of the overall effect of the bridge that can be attributed to newcomers to the region. We estimate both models using quasi Poisson models in order to account for the count data nature of the dependent variable (Hausman et al., 1984).[7] We show pooled cross-sectional regressions without individual fixed effects as well as pre-sample mean (PSM) estimations which account for unobservable individual specific factors, such as differences in talent or taste for patenting (Blundell et al., 2002). The PSM is defined as the average of the dependent variable of the five years prior to the first sample year, i.e. the period 1987-1992. In addition, we use fixed effects Poisson models, quasi-maximum likelihood Poisson models, which correct for biased standard error due to overdispersion as well as negative binomial models with and without fixed effects and OLS models in order to show robustness of our findings.

4. Data

The main data source is LISA, an annual longitudinal dataset held by Statistics Sweden with rich information on individuals living in Sweden such as information on the residence area and workplace. We merge the individual level data with patent data from the EPO.

[7] Our dependent variable is a fractional variable and, hence, does not contain integers only. Count data models are nevertheless appropriate because the distribution of the variable resembles those of count data.

The matching of patents to individuals was done in a project by one of the authors for the Swedish agency of Growth Policy Analysis in 2011 and was updated in January 2015 (Ejermo, 2011). An analysis of the demographic characteristics of Swedish inventors and a description of the matching process is provided in Jung and Ejermo (2014).

Applying the restrictions to the sample described in the previous section, from LISA we select all residents of the regions of Malmö, Stockholm and Gothenburg, which amount to 2,093,544 individuals in the period 1993-2007..

Table 1 shows descriptive statistics for the NTM sample. The average number of patent applications in Malmö increased by 140% after the construction of the bridge. In the control regions, the growth in patent applications corresponds to 50%, which already suggests that the bridge might have had an effect.

Table 1 also shows the age of the individuals, the patent application stock and the firm size of the employer of the individuals as extracted from LISA in our NTM sample, which we use as a control variables in later regressions. The patent stock is defined as: Patent $stock_t$ = patent $stock_{t-1}$ * (1- 0.15) + patent $applications_t$, where we assume a depreciation rate of 15% per year. Table 1 also displays an increase in the patent stock over time which can be driven by an increase of patent output by local inventors or by individuals relocating to the respective region. Regarding the age variable, Table 1 shows a mechanical increase since we observe our individuals before and after the inauguration of the bridge. Lastly, we observe a decline in firm size of the individuals' employers, which is stronger in the Malmö region than in the control regions.

Table 1 here

5. Results

Common trend assumption

In order to infer a causal relationship between the bridge and the increase in patents of the individuals in the Malmö region, it is crucial to test whether the patenting activity of individuals in the Malmö region and the control regions was following a common trend over time before the year 2000. The test of the so-called "common trend assumption" is important for our setup as the planning and construction of the bridge took several years and could have affected decisions and behaviour of firms and individuals well before its opening.

We start with a visual inspection of the trends. Figure 2 shows the evolution of patent applications per inventor in the treatment and control regions over time. A common upward trend is visible until the year 1999, one year before the bridge was opened. After the inauguration of the bridge, patenting of the individuals in the Malmö region increased relative to the other regions.

Figure 2 here

While Figure 2 relies on the raw data from the restricted sample of NTM, Table A.2 in the Appendix provides a formal test of the common trend assumption. Here, we replace the *Post* dummy with individual year effects. The interaction of the individual year dummies with the Malmö region dummy informs us about a common trend before the bridge. The estimated coefficients confirm a common trend before the year 2000 as they are jointly not statistically significant. After 2000, the interactions of the Malmö region dummy and the year dummies become statistically significant suggesting an effect of the bridge. An F-test of joint significance of the interacted year dummies before and after the inauguration of the bridge confirms this finding, suggesting that the common trend assumption implicit DiD is not violated.

Main results

The estimation results presented in Table 2 show that the bridge has increased patenting by individuals in the Malmö region. The different estimators show a robust, positive and significant effect of the interaction term (*Post*Malmö*). This suggests that individuals with an appropriate educational background in the Malmö region become more productive in terms of patent applications than comparable individuals in the control regions after the opening of the bridge. The effect size is also quite robust to the employment of different estimators (see models 1-6). The increase in the average number of patents for Malmö's inventors, compared to inventors in Stockholm and Gothenburg, corresponds to 30%-35% for models 1-4.[8] For the Poisson model in column 1, this corresponds to an increase of 0.00017 patents per inventor and year ((exp(0.298)-1) * 0.0005 baseline patents per year and inventor, see Table 1) or 542 patents in total (0.00017*3,120,079 inventor year observations in Malmö after the bridge).

The positive and significant coefficient for the variable *Post* in Table 2 indicates an increase in patenting over time. The negative coefficient of the Malmö dummy (model 1, 2 and 5) indicates a lower level of patenting than in the other regions over the entire time period. The effect vanishes once individual fixed effects are included (models 3 and 4). The

[8] These percentages are derived from the non-linear regressions' coefficient of *Malmö*Post* interaction, by an exponential transformation of the coefficient subtracted by the constant one, then multiplied by one hundred, expressed in the following equation:

$$\widehat{\beta_3}\% = \left(e^{\widehat{\beta_3}} - 1\right) * 100$$

where $\widehat{\beta_3}$, is the estimated coefficient of *Malmö*Post* interaction.

pre-sample mean (models 2 and 5) has the expected positive sign indicating that unobserved individual factors such as talent or a taste for patenting (which increased pre-sample patent output) have a positive effect on the individuals' patent productivity.

Table 2 here

Adding control variables

Table 3 shows that the results hold when we control for the individuals' age, age squared, the logarithm of the patent stock lagged one period, past productivity in terms of the patent stock and the firm size of the employer. The treatment effect (*Post*Malmö*) is still statistically significant and positive and barely decreases in coefficient size.

The control variables have the expected signs and significance levels. We find a non-linear effect of age (for models 3-6), which shows that inventor productivity increases over the life cycle up to a certain point after which it decreases (Levin et al., 1991). The lagged patent stock variable is negative. Lastly, firm size has a positive effect. This may be reflective of large firms offering valuable resources which inventors can draw on.

Table 3 here

Labour inflow as mechanism

This section investigates whether the attraction of human capital (Puga, 2008; Daranton and Turner, 2012) is responsible for the positive effect of the bridge or whether original residents of the Malmö region realize positive effects from the integrated area (De la Roca and Puga, 2017). We therefore estimate model (II) which adds a variable indicating newcomers to the region of Malmö (*NEW*) as well as an interaction with the variable *POST* which informs us whether and to which extent individuals relocating to the region of Malmö after the inauguration of the bridge contribute to the overall positive effect of the bridge on the patent output of individuals.

Table 4 shows the results. It appears that newcomers to the region of Malmö over the complete sample period (*NEW*) are less productive than residents. However, individuals that move to the Malmö region are significantly more productive in terms of patent applications after the bridge was built and are also more productive than incumbent residents as a comparison between the estimated effect for the term $Malmö_i *Post_{i,t}$ and $NEW_{i,} * Post_{i,t}$ indicates. On average, the effect of newcomers is stronger after the year 2000 and contributes 78% to the relative increase in patents in Malmö, compared to the control regions.[9] Therefore, we conclude that the increase in patent applications in the Malmö region is largely attributable to an inflow of human capital.

While it is true that not all selection and agglomeration effects are cleanly separated in this paper, we think that the decomposition of the overall effect on Malmo from before-the-bridge residents, and those that arrive later has some value in this regard, because those that reside before are less susceptible to selection and probably more clearly to an agglomeration effect. However, admittedly whether the inflow of individuals should be regarded as selection or agglomeration can be a matter of dispute, as their choice to settle in Malmo is not an experimental decision.

[9] These percentages are derived from the non-linear regressions' coefficient of $New_i *Post_{i,t}$ and $Malmö_i *Post_{i,t}$ by calculating the associated increases in patents following the formulae above and then calculating shares.

Table 4 here

6. Conclusion

This paper investigates the effect of the opening of the Öresund bridge on the innovativeness of the Swedish region of Malmö, the previously less innovative part of the Öresund region. Results from a difference-in-difference estimation that compares the patent application output of individuals in the Malmö region to the patent records of individuals in the regions of Stockholm and Gothenburg reveal that the Öresund Bridge has led to an increase in the Malmö region's patent filings by 30%-35%. The inflow of human capital in form of new highly skilled individuals to the Malmö region contributes 78% to the total increase in patent applications.

Individuals new to the region increase the size, degree of specialization and diversity of the local labour pool (Strange et al., 2006). The thickening of the regional labour market allows for better employer-employee matches (Wheeler, 2001, Berliant et al., 2006, Strange et al., 2006) and increases the productivity of individual inventors. This helps explaining the large effect of new inventors to the region on regional patent outcome.

Our results suggest that the increase of talent in the Malmö region, whether arriving before or after the bridge was built, was caused by an outflow of knowledge workers in Gothenburg and Stockholm. The outflows in Gothenburg and Stockholm need not imply a zero-sum game in which Malmö gained at the expense of other regions because attraction of human capital across regional borders may have resulted in better matches, i.e. we cannot know whether these individuals would counterfactually have been innovative had they stayed. In addition, our analysis does not account for talent inflow to the control regions from elsewhere or the flow of human capital from Malmö to the control regions. However, it does not seem unreasonable to assume that there was some element of human capital loss implied for Gothenburg and Stockholm. Policy should therefore evaluate how the benefits accruing to the Malmö region compare to potential losses of human capital elsewhere. Because our analysis has only provided some first indications on potential trade-offs focusing on a specific mechanism, a more complete picture of all mechanisms behind an increased regional patent productivity following an infrastructure improvement project is of high relevance for policy makers. For a complete policy evaluation, one would need to account for all regional inflows and outflows of knowledge workers. Moreover, an additional experimental attraction factor could account for a proper counterfactual analysis. However, such additional types of (natural) experimental data are unlikely to exist in connection with infrastructural projects.

A data limitation prevents us from exploiting the bilateral relationship between both sides of the Öresund. Despite the richness of our dataset, it only provides information on the Swedish residents because it comes from official sources and includes sensitive information about Swedish residents. Thus, it is not possible to merge it with data on the Danish side. Therefore, for future research, it would be of great interest to understand how each part of the binational region benefits or affects the other part.

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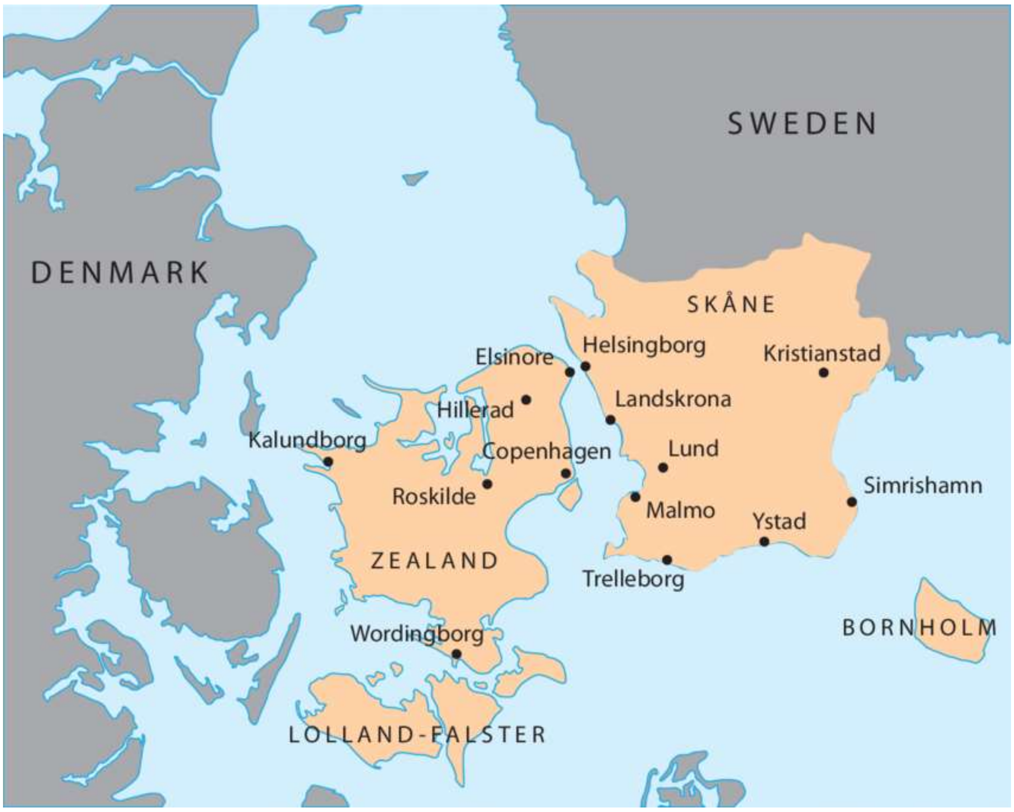
Appendix

Tables A1 and A2 here

Figures and tables

Figure 1: Öresund region



Source: Anderberg and Clark (2013)

Figure 2: Evolution of patents per person over time – NTM sample

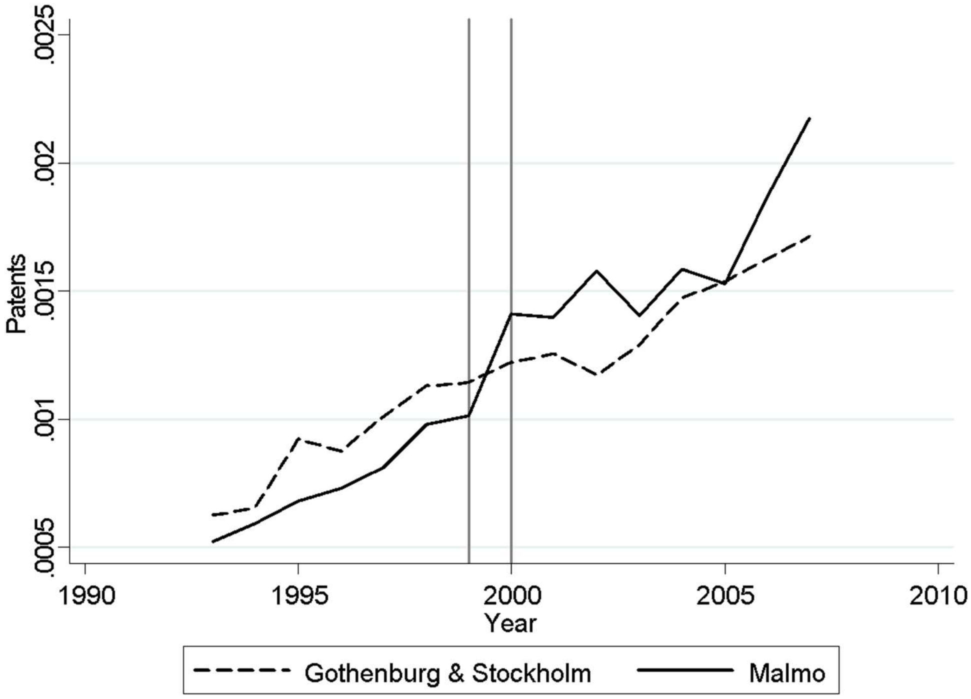


Table 1: Descriptive statistics

		Before 1993-1999	After 2000-2007	Change (%)
	Variable	Mean (SD)	Mean (SD)	
Malmö	Patents	0.0005 (0.0255)	0.0012 (0.0458)	140%
	Age	39.7961 (11.7514)	42.6272 (11.9568)	7%
	Patent stock	0.0021 (0.058)	0.0049 (0.1282)	133%
	Firm size	4.8231 (2.3855)	4.3724 (2.4458)	-9%
Gothenburg / Stockholm	Patents	0.0008 (0.0329)	0.0012 (0.0416)	50%
	Age	38.7407 (11.7493)	41.7801 (11.8376)	8%
	Patent stock	0.0031 (0.0825)	0.0053 (0.1195)	71%
	Firm size	5.0408 (2.6449)	4.6624 (2.6686)	-29%

Table 2: The impact of the Öresund bridge on the number of patent applications

Model	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	Poisson	Poisson	Quasi-ML Poisson Fixed effects	Negative Binomial Fixed effects	OLS	OLS Fixed effects
Post	0.4418***	0.4571***	0.4644***	0.4664***	0.0006***	0.0006***
	(0.0288)	(0.0286)	(0.0274)	(0.0205)	(0.0000)	(0.0000)
Malmö	-0.2503***	-0.2257***		-0.1061	-0.0002***	
	(0.0603)	(0.0612)		(0.6475)	(0.0000)	
Malmö x Post	0.2989***	0.3022***	0.2736***	0.2666***	0.0003***	0.0003***
	(0.0622)	(0.0622)	(0.0607)	(0.0460)	(0.0001)	(0.0001)
PSM		4.8056***			0.5724***	
		(0.2185)			(0.0387)	
Constant	-6.8909***	-6.9534***		2.6345***	0.0007***	0.0010***
	(0.0280)	(0.2185)		(0.2799)	(0.0000)	(0.0000)
Observations	10,899,187	10,899,187	131,492	131,492	10,899,187	10,899,187

Robust standard errors are in parentheses (except for Quasi-ML Poisson Fixed-effects and Negative Binomial Fixed-effects). PSM = pre-sample mean.* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: The impact of the Öresund bridge on the number of patents - Adding control variables

Model	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	Poisson	Poisson	Quasi-ML Poisson Fixed effects	Negative Binomial Fixed effects	OLS	OLS Fixed effects
Post	-0.0267	0.0400	0.0138	0.0245	0.0002***	-0.0003***
	(0.0310)	(0.0317)	(0.0515)	(0.0420)	(0.0001)	(0.0001)
Malmö	-0.1401**	-0.1210		-1.4204**	-0.0002**	
	(0.0626)	(0.0698)		(0.7169)	(0.0001)	
Malmö x Post	0.3339***	0.3222***	0.2337***	0.2278***	0.0007***	0.0005***
	(0.0690)	(0.0698)	(0.0794)	(0.0639)	(0.0001)	(0.0001)
Age	0.0784	0.0844	0.5075***	0.5070***	0.0003***	0.0005***
	(0.0107)	(0.0107)	(0.0235)	(0.0166)	(0.0000)	(0.0000)
Age_sq	-0.0011	-0.0012	-0.0046***	-0.0046***	-0.0000***	-0.0000***
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0000)	(0.0000)
Lag_log_ Pstock	0.3471***	0.3419 ***	-0.0466***	-0.0478***	0.0081***	0.0006***
	(0.0023)	(0.0023)	(0.0034)	(0.0023)	(0.0003)	(0.0000)
Log_size	0.1002***	0.1037***	0.0640***	0.0621***	0.0003***	0.0002***
	(0.0061)	(0.0060)	(0.0119)	(0.0089)	(0.0000)	(0.0000)
PSM		1.0340***			0.3025***	
		(0.1167)			(0.0451)	
Constant	-3.6329***	-3.8387***		-9.0388***	0.1256***	-0.0015*
	(0.0061)	(0.2831)		(0.7047)	(0.0041)	(0.0008)
Observations	4,942,436	4,942,436	75,679	75,679	4,942,436	4,942,436

Robust standard errors are in parentheses (except for Quasi-ML Poisson Fixed-effects and Negative Binomial Fixed-effects).

PSM = pre-sample mean.* p < 0.1, ** p < 0.05, *** p < 0.01

Table 4: The effect of inflow of labour on the number of patents

Model	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	Poisson	Poisson	Quasi-ML Poisson Fixed effects	Negative Binomial Fixed effects	OLS	OLS Fixed effects
Post	0.4342***	0.4496***	0.4597***	0.4616***	0.0006***	0.0006***
	(0.0288)	(0.0287)	(0.0274)	(0.0203)	(0.0000)	(0.0000)
Malmö	-0.2506***	-0.2253***		-0.1476	-0.0002***	
	(0.0603)	(0.0613)		(0.6521)	(0.0000)	
Malmö*Post	0.3064***	0.3098***	0.2784**	0.2714***	0.0003***	0.0014***
	(0.0622)	(0.0623)	(0.0607)	(0.0460)	(0.0001)	(0.0003)
NEW	-0.0224	0.0286		-1.3085	0.0000	
	(0.1749)	(0.1742)		(1.0150)	(0.0002)	
NEW*Post	0.8272***	0.8204***	0.5095***	0.4920***	0.0019***	0.0014***
	(0.2174)	(0.2171)	(0.2061)	(0.1595)	(0.0006)	(0.0003)
PSM		4.8083***			0.5724***	
		(0.2184)			(0.0387)	
Constant	-6.8906***	-6.9540***		2.6754***	0.0007***	0.0009***
	(0.0282)	(0.0269)		(0.2913)	(0.0000)	(0.0000)
Observations	10,899,187	10,899,187	131,492	131,492	10,899,187	10,899,187

Robust standard errors are in parentheses (except for Quasi-ML Poisson Fixed-effects and Negative Binomial Fixed-effects).
PSM = pre-sample mean.
* p < 0.1, ** p < 0.05, *** p < 0.01.

Table A. 1: List of municipalities in the three regions.

Region	Municipality code	Municipality name	Region	Municipality code	Municipality name	Region	Municipality code	Municipality name
Stockholm	114	Upplands Väsby	Gothenburg	1383	Varberg	Malmö	1214	Svalöv
	115	Vallentuna		1384	Kungsbacka		1230	Staffanstorp
	117	Österåker		1401	Härryda		1231	Burlöv
	120	Värmdö		1402	Partille		1233	Vellinge
	123	Järfälla		1407	Öckerö		1257	Örkelljunga
	125	Ekerö		1415	Stenungsund		1260	Bjuv
	126	Huddinge		1419	Tjörn		1261	Kävlinge
	127	Botkyrka		1421	Orust		1262	Lomma
	128	Salem		1440	Ale		1263	Svedala
	136	Haninge		1441	Lerum		1264	Skurup
	138	Tyresö		1442	Vårgårda		1265	Sjöbo
	139	Upplands-Bro		1443	Bollebygd		1266	Hörby
	140	Nykvarn		1445	Essunga		1267	Höör
	160	Täby		1462	Lilla Edet		1270	Tomelilla
	162	Danderyd		1463	Mark		1275	Perstorp
	163	Sollentuna		1466	Herrljunga		1276	Klippan
	180	Stockholm		1480	Göteborg		1277	Åstorp
	181	Södertälje		1481	Mölndal		1278	Båstad
	182	Nacka		1482	Kungälv		1280	Malmö
	183	Sundbyberg		1489	Alingsås		1281	Lund
	184	Solna					1282	Landskrona
	186	Lidingö					1283	Helsingborg
	187	Vaxholm					1284	Höganäs
	188	Norrtälje					1285	Eslöv
	191	Sigtuna					1286	Ystad
	192	Nynäshamn					1287	Trelleborg
	305	Håbo					1291	Simrishamn
	330	Knivsta					1292	Ängelholm
	331	Heby						
	360	Tierp						
	380	Uppsala						
	381	Enköping						
	382	Östhammar						
	461	Gnesta						
	486	Strängnäs						
	488	Trosa						

Source: Tillväxtverket (2020).

Table A.2: Trend coefficients' joint significance test

Poisson, FE	Neg. bin., FE
Malmö*1994-Malmö*1999	Malmö*1994-Malmö*1999
chi2(6) = 4.53 Prob > chi2 = 0.6059	chi2(6) = 3.10 Prob > chi2 = 0.7962
Malmö*2000-Malmö*2007	Malmö*2000-Malmö*2007
chi2(8) = 33.43 Prob > chi2 = 0.0001	chi2(8) = 26.20 Prob > chi2 = 0.0010