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Fly to learn: interregional integration and firms innovative productivity

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Abstract

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Fly to learn: Interregional integration and firms' innovative productivity

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Abstract

In this paper we investigate the role of interregional knowledge integration as a driver of innovative performance. We exploit the airline liberalization in Germany and find that the shift from monopolistic to more competitive aeronautic markets affected the interregional knowledge integration of regions (measured as the geographic dispersion of the knowledge sources of inventions developed in a region and of co-patenting activities). We adopt an unbalanced panel of 3,733 innovative companies in Germany between 1992 and 2009, for a total of 14,518 observations, and study their innovative productivity. We find that firms located in regions where the airline liberalization induced a higher level of interregional knowledge integration increased significantly their innovative productivity.

1. Introduction

Knowledge diffusion is a determinant of technological progress and, consequently, of economic growth (Grossman and Helpman, 1993; Romer, 1990). Accordingly, firms' innovative performance depends on the access to diverse knowledge sources, beyond their own efforts in internal Research and Development (R&D) expenditures (Cohen and Levinthal, 1990; Jaffe, 1986). A notable literature found geographic proximity to be an antecedent of knowledge spillovers among firms located in geographical clusters (Audretsch and Feldman, 1996; Jaffe, et al. 1993; Marshall, 1891; Porter, 1998; Singh and Marx, 2013). However, other authors have documented the existence of knowledge flows crossing regional and national boarders (Coe and Helpman, 1995; Keller, 2004; Mancusi, 2008; Maurseth and Verspagen, 2002), and have discussed the role of non-geographic proximity dimensions as drivers of knowledge diffusion (Boschma, 2005; Breschi and Lissoni, 2001; Crescenzi, 2014; Kerr, 2008; Singh, 2005). Moreover, there is some evidence that the distance to which knowledge diffuses is increasing over time under the effects of transportation costs and information technology improvements (Keller, 2002). As a consequence, interregional knowledge integration, which we define as the a region's degree of access to and adoption of knowledge developed in other geographically dispersed regions, is an increasing phenomenon often at center of the attention of firms and policy makers (Chessa et al., 2013).

While there is extensive empirical evidence on the effects of localized knowledge diffusion, only recently scholars have started to devote more attention to the role of interregional knowledge integration for firms' innovative performance (Breschi and Lenzi, 2012; Crescenzi, 2014). Some authors have pointed out the presence of a dichotomy between the benefits emerging from the local diffusion of knowledge in geographical clusters and the need to access distant knowledge in order to trigger and sustain innovation (Arikan, 2009; Bathelt, et al., 2004;

Boschma, 2005). Indeed, historical evidence demonstrates that the most innovative and competitive regions often show higher level of knowledge integration with other regions (Bresnahan et al., 2001; Saxenian, 1994, 2005; Kerr, 2008). However, empirical evidence supporting the existence of a causal relationship between interregional knowledge integration and innovative performance is still limited.

We exploit the airline liberalization realized in Europe as a source of exogenous shock to the interregional knowledge integration of German regions. The main result of the liberalization has been the entry of low cost carriers (LCC) that introduced new direct connections and offered flights at extremely inferior prices as compared to previous traditional airlines (Calder and Laker, 2002; Dobruszkes, 2006). More generally, the entry of new airlines in an airport delimits the shift from mainly monopolistic markets regulated by bilateral agreements towards more competitive markets. The airline liberalization in Europe was formally accomplished in 1992 but it became gradually effective only starting from 1997. Furthermore the entry of LCC in different European regions was not instantaneous but distributed in a period of approximately five years. Delays in the entry of LCC were usually determined by factors independent from the strategic timing of the new entrants, such as the lack of available slots in the airports or the resistance of local administrations to effectively adopt the liberalization mandate (Calder and Laker, 2002).

We measure interregional knowledge integration as the geographic dispersion of patent backward citations of the region towards other regions worldwide or as the geographic dispersion of co-patenting activities of inventors in the region with inventors in other regions abroad. We estimate the impact of the entry of a LCC on the level of interregional integration of a region. The entry of a LCC determines an increase of 1 unit of the inverse Herfindal index of the cited regions - interpretable as the number of regions effectively cited by one region. We adopt an unbalanced panel of 3,733 innovative companies in Germany between 1992 and 2009, for a total of 14,518 observations, and study their innovative productivity. We find that firms located in regions where the airline liberalization induced a higher level of interregional knowledge integration increased significantly their innovative productivity.

The remaining is organized as follows. The next section discusses theoretically the relationship between interregional integration and innovative productivity and revise existing empirical studies. Section 3 provides a brief description of the European airline liberalization process and its implications. Section 4 addresses in detail the data used. Section 5 shows descriptive statistics on the main variables of interest. Section 6 presents the empirical model and section 7 the consequent results. Finally, the last two sections conclude and discuss limitations and suggestions for future research.

2. Innovative productivity and interregional knowledge integration

The core research question of this paper is: which is the impact of interregional integration of a region on the innovative productivity of local firms? A first series of studies have analyzed the relationship between firms' performance and characteristics of the region or cluster where firms are located (for a review: Cruz and Teixeira, 2009). Firms located in regions endowed with a certain critical mass of firms and institutions performing innovative activities are expected to benefit from agglomeration economies: 1. broader access to specialized labor, 2. access to specialized suppliers and collaborators, 3. access to localized knowledge spillovers (Marshall, 1891). Baptista and Swann (1998) found that firms located in regions with a higher concentration of labor in their own sector are more innovative. Similar studies have also found that geographic proximity is effective given a certain level of technological similarity which enables knowledge spillovers to be captured by recipient firms (Autant-Bernard, 2001).

Other studies have explored the extent to which knowledge diffuses at longer distances and across countries (Coe and Helpman, 1995; Bottazzi and Peri, 2003; Keller, 2004). Some authors have questioned the relative importance of local knowledge search and exploitation, against the access to knowledge external to the region. Boschma (2005) distinguishes five dimensions of proximity (cognitive, organizational, social, institutional, geographical) and claims that while too much distance along these dimensions might impede communication and collaborations, too much proximity might deter innovation due to technological lock-in and lack of sources of novelty. Specifically, Bathelt et al. (2004) pointed out that the combination of "internal learning processes - local buzz -" and "communication channels" with other external environments - "pipelines" - is required to maintain and increase innovative performance.

In line with these contributions, we expect interregional knowledge integration to have a positive impact on innovative performance for several, non-exclusive, reasons. First, the inflow of new knowledge developed in another context might constitute a novel input to the knowledge production function of firms located within a region (Coe and Helpman, 1995). These knowledge externalities potentially overcome diminishing returns to exploitation of knowledge internal to the firm and the region. Second, innovation requires recombination of different technologies and approaches; different sources of knowledge might result to be complementary (Cassiman and Veugelers, 2006; Cohen and Levinthal, 1990). Firm level analyses have demonstrated that internal R&D strategies and search for external knowledge at broad international level are complementary strategies (Cassiman and Veugelers, 2006). Finally, higher knowledge integration to other regions worldwide might allow the timely identification of technological opportunities and of potential areas of specialization in order to develop competitive advantages and invest in high productivity sectors as compared to competitors (McCann and Ortega-Argilés, 2013). Accordingly, we formulate the hypothesis that *firms* *located in regions with a higher level of interregional knowledge integration have a higher innovative productivity*.

Important previous studies found results coherent with this hypothesis (Breschi and Lenzi, 2012; Crescenzi, 2014; Eisingerich et al., 2010; Frenz and Ietto-Gillies, 2009; Lecocq et al., 2012). Many of these focused on the innovative performance of multinational companies and found a positive correlation between the presence of the firm in different regional contexts and their innovative performance. Phene et al. (2006) suggest that the type of external knowledge combinations, in terms of technology and geographical distant knowledge, determines the likelihood of breakthrough innovation. Breschi and Lenzi (2012) find that the coexistence of dense internal collaborations within a city and a certain number of external connections, measured through co-inventor network indicators, is positively associated to patenting productivity.

In this paper we place the phenomenon in the broader context of the increasing interregional integration. Among several possible drivers of this phenomenon we focus on the reduction of transportation costs which is likely to affect the possibility of regions to access external contexts. Exploiting the exogenous shock to the transportation costs provided by the European airline liberalization, we try also to address explicitly the endogeneity issue which is likely to affect the relationship under study. First, firms and regions showing the ability to reach and connect different sources of knowledge might also be endowed with other unobserved characteristics, such as better infrastructures, organizational and managerial skills, likely to affect performance. Second, reverse causality can affect the results if the most innovative regions and firms are more able in a second place to reach distant knowledge and to developed technologies with a broader geographic scope.

3. The European airline liberalization

To the extent that geographic proximity can be complementary to other forms of proximity to geographically distant environments (Eisingerich et al., 2010), the attractiveness of specific locations might increase and agglomeration economies might strengthen (Sonn and Storper, 2008). However, there is general consensus on the fact that progress in the information technology and the reduction of transportation costs are expected to allow for an easier access to distant knowledge and to possibly reduce the relative importance of geographic proximity per se (Tranos, 2013). We explicitly take into account the latter of these two factors as a driver of the capacity of a region to access external environments.

Simply considering the level of connectivity of a region, for example in terms of airports proximity or number of flights, might be subject to similar concerns to those previously discussed: the level of investments in transportation infrastructures and transportation cost from and towards a certain region can be themselves a function of the innovativeness and the attractiveness of the region. Especially for this reason, we exploit the airline liberalization in Europe as a source of an exogenous shock to the transportation costs.

Before this regulation change, European aviation markets were mainly regulated by bilateral agreements and dominated by monopolistic markets. The airline liberalization was a deregulation process started in 1986 and accomplished in 1992 with the Third Aviation Liberalization Package (Calder and Laker, 2002). However, the effective implementation of the deregulation was considerably delayed in many countries and, even afterwards, the entry of new airlines in several European airports was constrained by the lack of available slots or the resistance of local administrators. Calder (2002) summarizes the process: "Europe's skies... have officially been open since 1997. But leading airports remain effectively closed to newcomers because of the shortage of available slots. … And in parts of Europe, obstructive governments act... to constrict the freedom of the skies". As a consequence, the effects of the liberalization propagated gradually in European regions for reasons mostly independent from the strategic planning of new entrants and from time variant characteristics of the regions. Most importantly to our purpose, the consequences of airline liberalization likely diffused independently from time specific shocks to the demand of flight connections in a region.

In each airport the effects of liberalizations materialized with the entry of new airlines operating at substantially lower prices and towards destinations previously not reachable with direct connections: low cost carriers (LCCs). More generally the entry of a LCC determined the shift from monopolistic markets to competitive markets. LCCs prices have been from one half to eight times lower than the average of previous traditional carrier prices. Traditional flag carriers reacted to the higher competition by also reducing prices, offering, for temporary periods, prices at the level of those of LCCs and entering new markets. Therefore prices decreased substantially while the number of direct destinations and the frequency of connections increased.

Overall, generalized travel costs decreased towards most of the main destinations. While enthusiastic, the following words by Calder (2002) provide a feeling about the perceived strength of the impact of LCCs' entry on connectivity: "Thanks to low-cost airlines, second home ownership abroad has rocketed. Lifestyles have been transformed, and long-distance relationships formed, thanks to a newly affordable Europe." We hypothesize that the airline liberalization had a considerable positive impact on the interregional integration of European regions and we consider the entry of a LCC a potential instrument of our variables of interest.

4. Data

In order to test our hypothesis we combine data from different sources. First of all, we use the Mannheim Innovation Panel (MIP) as a source of information on innovative firms in Germany. The MIP combines survey information on innovation activities of German firms from 1992 to 2009 and constitute a representative sample of innovative firms in Germany. Firms participating in the survey report on several indicators related to their economic and innovation activities. Among these we focus primarily on their innovative productivity as dependent variable, defined as the amount of innovative sales per employee. Innovative sales are defined as the amount of sales that respondents consider to be consequent to the sale of new innovative products.

Considering firms observed for at least 2 periods and with a positive amount of innovative sales for at least one period, we obtained an unbalanced panel of 3,733 firms for a total of 14,518 observations within the period just mentioned. We assigned firms based on the postal code of their addresses to regions in Germany at the level 3 of the Nomenclature of territorial units for statistics (NUTS3 level of the NUTS classification). While the total of NUTS3 regions in Germany is 428, only 403 are represented because not all regions host innovative firms in our sample.

Region and firm patents based indicators have been obtained combining information from the European Patent Office (EPO) Worldwide Patent Statistical Database 2013 (PATSTAT) and the REGPAT 2013 Database provided by the Organization for Economic Co-operation and Development (OECD). REGPAT 2013 contains information on EPO patents and the geographic location of inventors and applicants at the level of NUTS3 regions. Finally, information regarding the entry of LCC in airports relevant for German regions was obtained by the Official Airline Guide (OAG) database on historical flight status. The data have been used to obtain yearly information on European airports relevant for German regions and on the airlines operating in these airports. Whenever possible, we categorized airlines as LCC or traditional airlines based on categorization proposed by the literature in transportation economics (e.g. Dobruszkes, 2006). Few airlines not found in this literature have been categorized based on complementary search on the internet and, specifically, airlines web sites.

Furthermore, airports in Germany and close to the German boarders had to be assigned to the region that reasonably had access to them, based on their relative distance. Therefore both airports and NUTS3 regions have been localized according to their longitude and latitude (considering for NUTS3 regions their geographic center). For each region and airport pair we estimated their average travel time distance through query in the Google API geocoding database. Finally, for each region we kept only airports at a maximum of 3 hours driving distance since this is approximately the minimum travel time at which all regions considered can reach at least one airport. As alternatives, airports at a maximum of 2 and 1 and a half hour have been considered, matching regions with no accessible airports in this travel time with their closest airport. Table 1 reports the list of variables considered in the analyses, their description and descriptive statistics.

--- Insert Table 1 about here ---

Among the variables reported, the main variables of interest are the indicators of interregional knowledge integration which we measure through indicators of the geographic dispersion of the knowledge sources of technologies developed within a region. As indicator of dispersion we adopt the inverse Herfindahl index *(invH)*. *Region citations invH* corresponds to the inverse Herfindahl index of the distribution of citations from patents belonging to a NUTS3 German region across other worldwide regions at the NUTS2 level. *Region copatents invH* corresponds to the inverse Herfindahl index of the distribution of co-patenting activities of NUTS3 German region inventors with inventors across other worldwide regions at the NUTS2 level abroad. The inverse Herfindahl index is defined by:

$$invH = \frac{1}{H} = \frac{1}{\sum_{i=1}^{N} s_i^2}$$

Where H is the Herfindahl index, i that goes from 1 to N are the regions cited (or where at least one coinventor is located) and s is the share of citations to (or co-patenting activities with inventors in) the region i, in a given year. Here, the inverse Herfindahl index is a measure of the geographic dispersion of the citations (or co-patenting activities), which has a direct intuitive interpretation as the effective number of regions cited (or involved in co-patenting activities). In other words, backward citations (co-patenting activities) of a region are distributed across other regions in such a way that they are as concentrated as they would be if they were divided evenly across a number of regions corresponding to the value of the variable *Region citations invH* (*Region copatents invH*). Note that these variables are constructed for German regions at the NUTS3 region level and, as such, have to be understood as a characteristic of the region where firms are located.

5. Descriptive statistics

Interregional knowledge integration indicators

We report descriptive graphs relative to our variables of interest. The graphs reported in Figure 1 show the effective number of regions cited by inventors in German regions - *Region citations invH* – (Figure 1 graph a) and the effective number of regions involved in co-patenting activities

- *Region copatents invH* - (Figure 1 graph b). Both measures have increased significantly over the period considered. Interestingly, Breschi and Lenzi (2012) have found a similar trend for the indicator of geographic distance connection of US cities. This evidence indicates an increasing average interregional integration of regions with other regions worldwide.

--- Insert Figure 1 about here ---

In addition we show in figure Figure 2 the trend of citations abroad, citations to other German regions and citations to the same NUTS2. Similarly, in Figure 3, we show the trend of co-patenting activities abroad, co-patenting activities with other German regions and co-patenting activities in the same NUTS2. It is interesting to note that the number of citations abroad is consistently higher than the number of citations within Germany and within the same region. The number of citations abroad is also sharply increasing over time, although proportionally to the increase in the total number of citations. Similarly, the total number of co-patenting activities abroad increased from an average of 4 in 1992 to approximately 20 in 2009. However this increase is proportional to the increase of co-patenting activities in general and, in this case, co-patenting activities within the region and in Germany remain largely prevalent.

--- Insert Figure 2 about here ---

--- Insert Figure 3 about here ---

Entry of LCC

The graph reported in Figure 4 shows the entry pattern of LCCs in German regions. Each line corresponds respectively to the share of regions with access to at least one airport with a LCC operating in 3 hours driving, 2 hours driving (or closest airport) and 1 and a half hour (or closest airport). Importantly to note, the first entries are registered in 1997 and the number of regions with access to LCC flights sharply increase in a period of approximately 5 years. Between 2003 and 2004, irrespectively of the three different criteria of matching regions with airports, the totality of regions in Germany had access to at least one airport with LCCs operating at a reasonable travel distance.

--- Insert Figure 4 about here ---

The effect of LCCs entry on interregional integration

In the following graphs (Figure 5 and Figure 6) we present a graphical semi-parametric analysis to explore the effect of LCC entry on interregional integration. We estimate the relative averages of *Region citations invH* and *Region copatents invH* at different periods before, after and at the moment of LCC entry (time 0) having controlled for region fixed effects and year fixed effects. Averages are plotted in reference to the average in period minus 1, one year before the LCC entry.

The analyses allow to observe that the averages of these indicators, especially *Region citations invH*, once controlling for year and region fixed effects, are approximately constant up to the year of LCC entry and significantly increase after three years from the LCC entry. While this indicates that the effect of the LCC entry is not sharp at the moment of entry, it is consistent with a gradual penetration of LCCs in the airport and other airports destinations. Furthermore, observed citations and co-patenting activities are the results of innovation activities performed likely in the previous few years, such that is natural to expect a delay in the observable consequences of the LCCs entry. Most importantly, the lack of a pre-trend - an increase of the indicators previous to the entry - provides descriptive support to the exogeneity of the entry decision that does not seem to be anticipated by a demand shock. The pre-entry period for the *Region copatents invH* is not clearly constant but does not present an increase in the last periods before the entry.

--- Insert Figure 5 about here ---

--- Insert Figure 6 about here ---

6. Model

We adopt a two stages IV model. In the first stage equation we estimate the *Region citations invH* (or alternatively the *Region copatents invH*) as a function of firms fixed effects, year fixed effects and the set of firm and region controls. We use a linear model with fixed effects and robust errors to estimate this equation. Accordingly to the analyses presented above, the LCC entry is considered with a lag of 3 years in order to optimize the power of the estimation.

$$RegIntegration_{rt} = \gamma_0 + \gamma_1 LccEntry_{rt-3} + \gamma_2 FirmCtrls_{irt}$$

$$+ \gamma_3 RegCtrls_{rt} + \gamma_4 FirmFE_i + \gamma_5 YearFE_t + \epsilon_{irt}$$

Second stage equation dependent variable is the innovative productivity. Given the characteristics of this variable, non-negative and with potential zero-inflation, we adopt a Quasi Maximum Likelihood Estimation (QMLE) method with fixed effects. Errors are bootstrapped to take into account the non-normality of the residuals in the two-steps IV estimation. The QMLE method has desirable properties for the analyses under studies, such as consistency of the estimates independently from the variance functional form and robustness to zero-inflation

(Wooldridge, 1997, 2002). Firms and region controls are considered accordingly with the first stage regression. The models specification includes firms fixed effects and year fixed effects.

$$InnProd_{irt} = \exp(\beta_0 + \beta_1 RegIntegration_{rt} + \beta_2 FirmCtrls_{irt} + \beta_3 RegCtrls_{irt} + \beta_4 FirmFE_{ir} + \beta_5 YearFE_t) + \varepsilon_{irt}$$

Year fixed effects control for any shock to productivity over time, common to all firms in Germany. Firm fixed effects control for time invariant characteristics of the firms. Note that these two levels of fixed effects control for several potentially omitted variables such as policy changes at country level, diffusion of ICT technologies, geographic position, sector specific characteristics, etc. as far as these are not correlated with the ideosyncratic error term, firm-year specific. Also, region fixed effects would be quasi-perfectly collinear with respect to firm fixed effects: controlling for firms fixed effects automatically implies that also region time invariant characteristics are controlled for, with the exception of few firms that appeared over time in different regions (6%). Removing these firms does not change the results.

The two stages IV model is designed in order to control for additional potential sources of endogeneity. Several of unobservable variables correlated with interregional knowledge integration and affecting innovative productivity might be time variant so that controlling for fixed effects at the relative level of analysis might not solve the problem. Also, reverse causality is not solved by fixed effects estimation. Taking into account lagged independent variables might partially address this issue. Nonetheless, innovative performance based on patent indicators are already measured with delays determined by the patent application process, and this raises concerns on the right timing to consider. Finally, the indicators used to measure knowledge flows, especially patent based indicators, are subject to considerable measurement errors leading to downward bias of the estimations (Alcacer and Gittelman, 2006; Breschi and Lissoni, 2005; Criscuolo and Verspagen, 2008; Jaffe et al., 2000).

Our two stages IV model estimation strategy is based on the assumption that the entry of LCCs is uncorrelated with the ideosyncratic error term, firm-year specific: this is, it is not directly correlated with firms' innovative productivity having controlled for firm and region controls and, in particular, year and firm-region specific characteristics. In other words, our estimation strategy is valid as far as the entry of LCC is uncorrelated with year-firm specific factors and if it affects innovative productivity solely through the higher intrregional integration of regions. Our confidence in these assumptions is based on the modalities of the European airline liberalization as described in the previous pargraph. However, we discuss potential challenges in the last session of the paper.

7. Results

In the following we present results for the analyses relative to the variable of *Region citations invH.* Table 2 presents results for the productivity equation without instrumenting the variable of interest. Table 3 presents the first stage of the two steps IV estimation, while Table 4 presents results for the second stage equation where *Region citations invH* is replaced by the its predicted value from the first stage equation. In both tables controls are included gradually from Model 2 to Model 4. Model 1 does not include controls. Model 2 includes controls at the firm level. Few observations drop due to missing values in the firms control variables. We control for the logarithm of the number of employees of the firm, the logarithm (plus 1) of the R&D expenditure per employee, the logarithm (plus 1) of the exports per employee and the patent stock of the firm, which is calculated with a discount rate of 15%. In Model 3, region level controls are considered: the total amount of R&D expenditure, the exports, the number of employees and the total number of patents in the region (as aggregated value of all firms located within the region). Finally Model 4 includes additional controls at the firm level to control whether the firm is involved directly in R&D cooperation activities in Germany or abroad.

Beyond being standard controls, the firm level controls limit the concern that the effect of the LCC entry on innovative productivity of firms can be mediated by factors else than the level of interregional integration. A reduction of the generalized transportation costs might determine a higher growth of the firm (number of employees), free resources that could be dedicated to innovation (R&D expenditure), ease export with an effect on the incentives to innovate and on knowledge acquisition from customers abroad (Salomon and Shaver, 2005), or it can directly affect patenting activities of the company (patent stock). Similarly, the reduction of transportation costs might have an impact at region level on the total amount of employees, R&D performed, export and inventions (patents), also consequently to the entry (or the exit) of new firms in the region. These variables can have a spillover effect on the innovative productivity of the company. Finally, R&D cooperation in Germany and abroad are included to provide a test indicating whether the effect of interregional integration is fully mediated by direct R&D collaborations of the firm itself.

--- Insert Table 2 about here ---

From Table 2 we observe the results when the variable of interest is treated as exogenous. Interregional integration, as measured by the *Region citations invH* variable, has a positive effect on innovative productivity and the result is robust to the inclusion of the listed controls. The magnitude of the coefficient is not high, indicating that one additional region effectively cited by a region increase by about 2% innovative productivity of firms. However, this already corresponds to an effect of 16% higher innovative productivity for a standard deviation of the variable. Controls have the sign that might be expected especially regarding R&D expenditure per employee, export per employee and patent stock. These variables affect positively the innovative productivity of firms. On the contrary, innovative productivity decreases with the number of employees. Among region control variables it is interesting to note that the amount of R&D performed in the region affect the outcome variable, although the variable is only weakly significant. This result is consistent with the expectation of knowledge spillovers of R&D activities of co-localized firms. Other region characteristics do not show a significant impact. Finally, R&D cooperation abroad positively affects innovative productivity but the inclusion of the variable does not affect the result on the variable of interest.

--- Insert Table 3 about here ---

The first stage results (Table 3) show that the *Region citations invH* is strongly affected by the entry of a LCC. The indicator increases approximately of 1 unit and the F-test on the omitted instrument has a value higher than 30, largely beyond the indicative threshold of strong instruments. It is interesting to note that firm level variables have no significant impact on the *Region citations invH* variable. On the contrary region level variables affect the indicator, as it might be expected.

--- Insert Table 4 about here ---

The second stage results (Table 4) report again a significant effect of *Region citations invH* on innovative productivity, importantly, robust across different specifications. The estimation coefficient increases considerably, passing from 0.02 to about 0.35. This coefficient would imply, after correction for the logarithm approximation, an effect of about a 40% higher innovative productivity per unit increase of *Region citations invH.* This sharp increase is typical, to some extent, of IV estimators: in this sense, it might be due to the lower efficiency of the two steps IV estimation method and to a considerable measurement error of the endogenous variable, as mentioned in section 2. Also, it cannot be excluded that unobserved variables determine a downward bias of the estimation if interregional integration is treated as exogenous. First, a higher number of citations towards other regions might be pushed by a negative shock to the marginal productivity of internal knowledge exploitation, such that the search and use of external novel inputs might be simultaneous to a lower innovation performance. Second, an increase of the number of citations towards other regions might be driven by the emergence of new firms and regions operating in similar sectors, as such representing a sign of a higher external competition from other regions negatively affecting innovative sales. Indeed, it is important to note that the coefficient resulting from the QMLE model in Table 2 and the coefficient from the two step IV estimation in Table 4 are significantly different, revealing, under our assumptions, endogeneity of the variable of interest.

--- Insert Table 5 about here ---

Table 5 reports the main models, considering the entire list of controls, of the analyses using the variable *Region copatents invH* as indicator of interregional integration. Model 1 reports results for the QMLE model on the innovative productivity where *Region copatents invH* is treated as exogenous. Model 2 reports the first stage analysis on the same variable. Model 3 shows the second stage equations. Results are significant and equivalent to those obtained with the citations based indicator. However the instrument does not pass the threshold of 10 of the F-test and the instrument cannot be considered strong in this case.

8. Conclusions

Geography of innovation is gradually evolving under the increasing level of connectivity among regions, driven by communication technologies improvement, reduction of transportation costs as well as political barriers (Chessa et al., 2013; Tranos, 2013). Firms, regions and policy makers have invested increasingly in the search of distant knowledge and in order to be connected with different locations. Overall interregional integration has been increasing. However, only recently scholars have started to explore the dynamics and effects of the phenomenon.

In this paper we exploit the airline liberalization in Germany and find that the entry of new operators (LCC) in the airports accessible to a region affects its interregional knowledge integration, measured as the geographic dispersion of the knowledge sources of inventions developed in the region and of its co-patenting activities. In a sample of 3,733 innovative firms in Germany between 1992 and 2009, for a total of 14,518 observations, we find that companies located in regions with a higher degree of interregional integration have higher innovative productivity. The effect is robust and increases in magnitude when the indicators of interregional integration are instrumented with the entry in the region of a LCC.

This evidence supports policies oriented to improve interregional integration and have implication for the location and investment decision of companies. To the extent that the access to distant knowledge is important for firm and region innovative productivity, location in a smaller but well integrated region might result convenient compared to location in a relatively bigger geographical cluster with lower level of interregional integration. Further research is needed to confirm these results and to disentangle different mechanisms underlying the relationships here observed. Some limitations of the analyses presented and considerations for future research are discussed in the following and last paragraph.

9. Limitations and future research

In the analyses above we found a strong effect of the level of interregional integration of a region and the innovative productivity of firms located in the region. This result is robust to several controls and most importantly it is confirmed in analyses where the level of interregional integration is instrumented with the exogenous shock given by the European airline liberalization. However, we list three main concerns.

First, the LCC entry is likely not the only factor affecting interregional integration in the period analyzed. Importantly, Information and Communication Technologies (ICT) diffuse in the same period. In this respect, year fixed effects and region fixed effects are expected to control for any factor affecting interregional integration over time and across regions, as far as this is not correlated with the entry of LCCs in a specific airport in a specific year. Since the timing of entry of LCCs in different airports have been mainly determined by exogenous factors or by time invariant characteristics of a region, we consider unlikely that LCC entry is correlated with region-year specific characteristics determining the level of interregional integration, including the diffusion of ICT technologies. However we intend to explicitly include in future development of this research indicators of ICT diffusion.

Second, the reduction of generalized transportation costs determined by the entry of a LCC might affect innovative productivity via factors else than a higher level of interregional knowledge integration. We tried to limit this concern showing the robustness of the results to the inclusion of several variables at the firm and region level. However, additional more specific mechanisms can be taken into account, such as the entry of multinational companies in the region and the access to skilled labor from abroad. In future research we intend to consider these and similar factors as additional controls.

Third, the scope of our results is limited by the lack of firm level indicators equivalent to the indicators of interregional integration. These indicators cannot be computed based on patents data in our sample, given that most of the firms do not patent or patent very seldom over time. To our knowledge, the firm and region level have not been jointly tested so far. However it would be important to study to which extent it is correct to conceptualize interregional knowledge integration as a property of the region; alternatively, the effect encountered might emerge as an average effect of firms actually investing in the access to distant knowledge.

Finally, we intend to explore in future research the heterogeneity of the effects here identified across different sectors, firms and regions.

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Figures and Table

Table 1: Variables description

Variable	Description	Mean	Std.Dev	Min	Max
Dependent variable:					
Innovative productivity	Innovative sales per employee	0.0334221	0.2318288	0	22.08855
Interregional Integration:					
Region Citations invH	Inverse Herfindal Index of the distribution of citations of a NUTS3 german region across worldwide NUTS2 regions (excluding self inventor citations)	14.31764	8.333502	0	40.33333
Region copatents invH	Inverse Herfindal Index of the distribution of copatenting activities of a NUTS3 german region across worldwide NUTS2 regions abroad	10.8801	11.21936	1	63.77087
Firm controls:					
N of employees	Number of employees	890.8101	7230.576	1	282758
R&D_employee	R&D expenditure per employee	0.0067321	0.0180511	0	0.4974076
Export_employee	Export per employee	0.093235	0.1890346	0	7.999145
Patent stock	Firm patents stock (discounted at the 15% discount rate)	4.749419	55.86117	0	3698.046
Region Controls:					
Region R&D	Aggregated value of firms R&D expenditure of the region (based on MIP data)	318.0797	1905.673	0	39720.49
Region N of employees	Total number of employees in the region	3190.854	16923.03	0	305108.8
Region export	Aggregated value of firms export of the region (based on MIP data)	25648.51	87240.04	0	953992
Region patents	Number of patents of the region (based on REGPAT)	107.1853	307.8417	0	2629
Firm R and D collaboration:					
R&D coop in DE	Each year equal 1 if the focal firm have engaged in R&D collaborations within Germany in the first subsequent period where the information is available	0.2261331	0.4183407	0	1
R&D coop abroad	Each year equal 1 if the focal firm have engaged in R&D collaborations with firms or institutions abroad in the first subsequent period where the information is available	0.1208155	0.325924	0	1
Instrument:					
LCC entry	Equal 1 if a low cost carrier is operating in an airport close to the region (max. 3 hours driving)	0.5705331	0.4950171	0	1

Figure 1: Citations and co-patenting activities inverse Herfindahl index 1992-2009

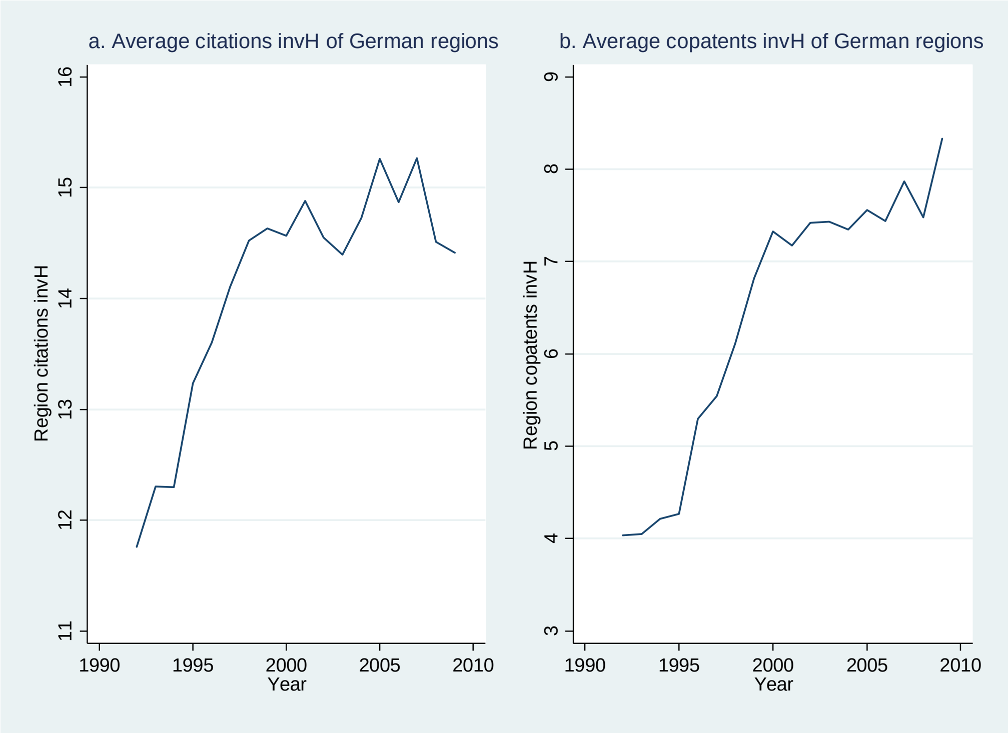

Figure 2: Average number of citation of German regions to other regions

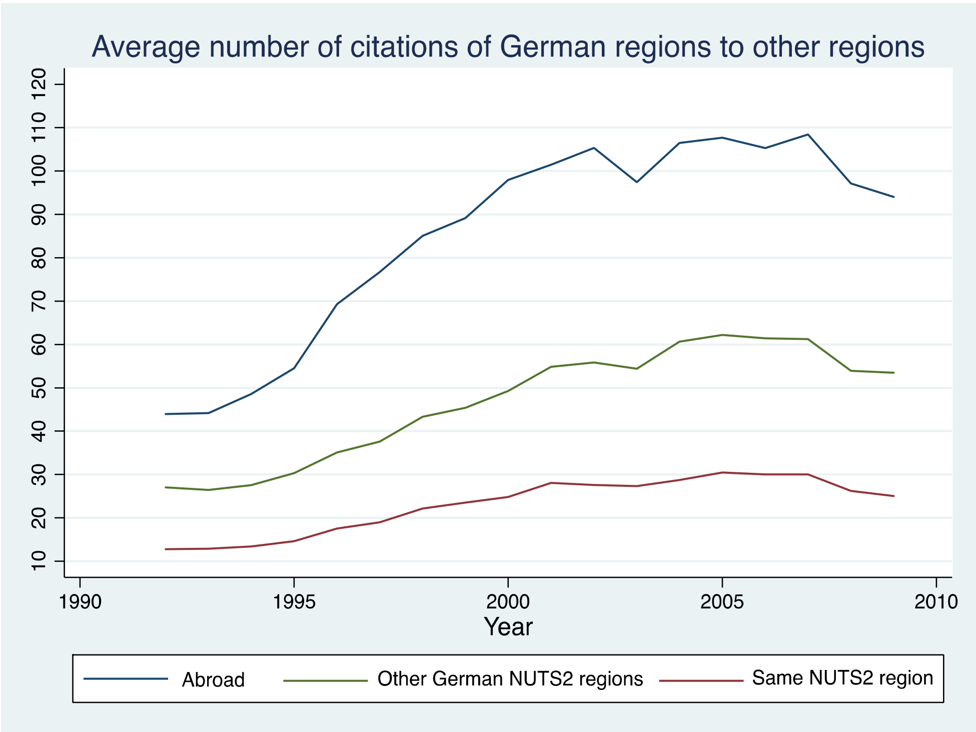

Figure 3: Average number of German regions co-patents with other regions

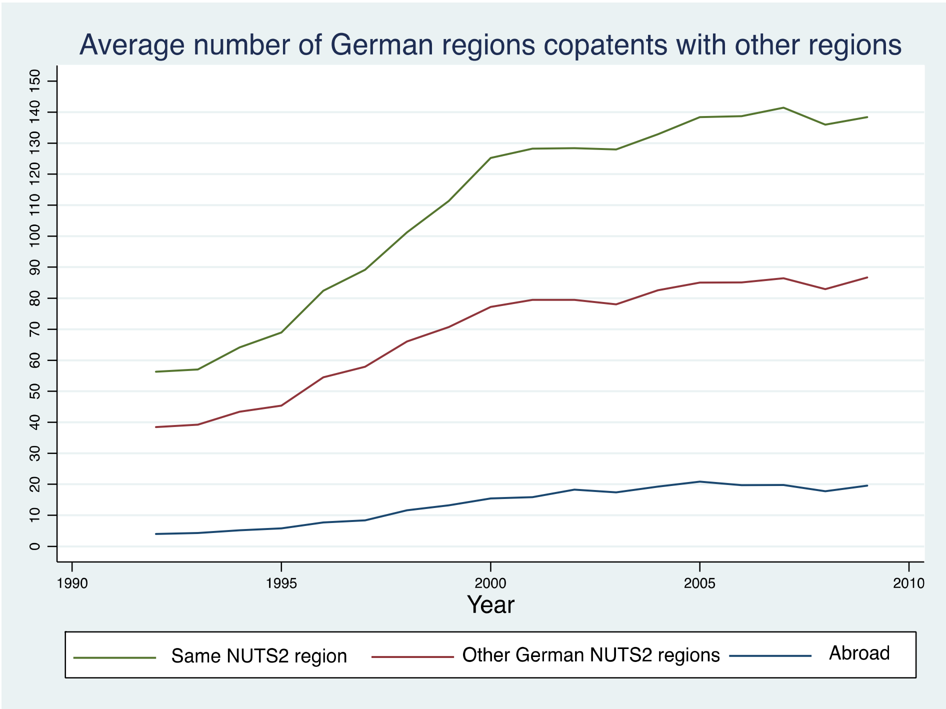

Figure 4: LCC entry in German regions

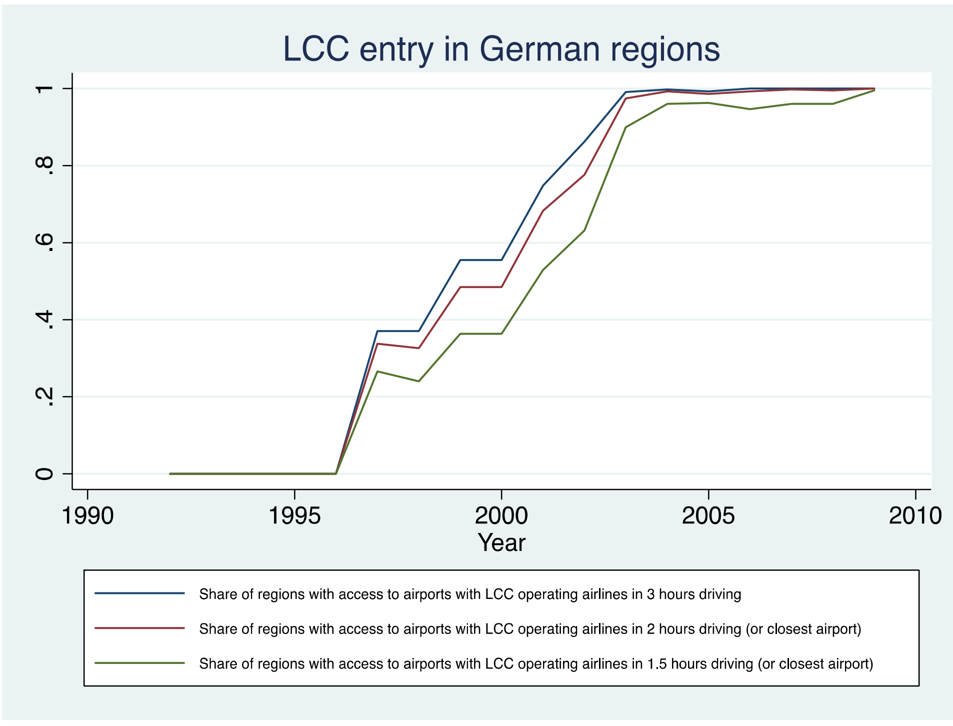

Figure 5: Effect of LCC entry on regions citations invH

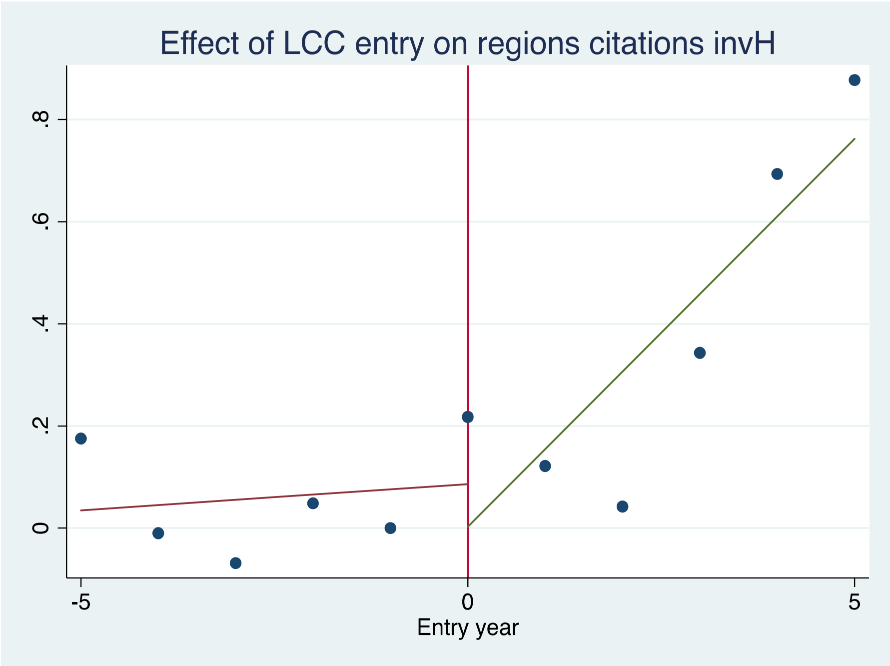

Figure 6: Effect of LCC entry on regions co-patents invH

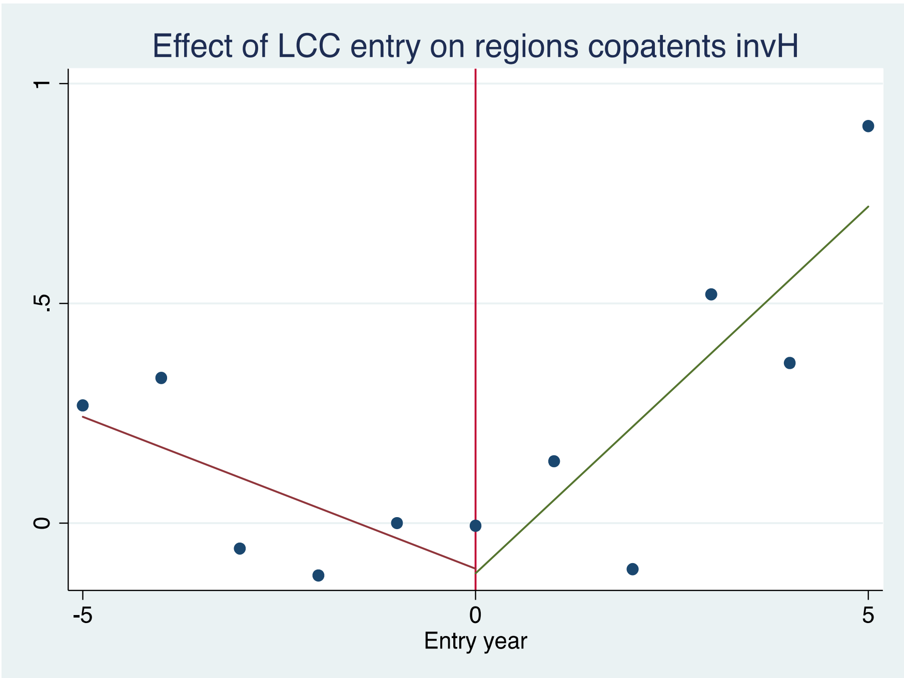

Table 2: QMLE model on innovative productivity - Region citations invH

	Model 1	Model 2	Model 3	Model 4
Region citations invH	0.020**	0.019**	0.017**	0.018**
	(0.008)	(0.008)	(0.007)	(0.007)
N employees (log)		-0.128	-0.157**	-0.158**
		(0.079)	(0.079)	(0.078)
R&D_employee (log)		6.741**	6.534**	6.057**
		(3.017)	(2.894)	(2.463)
Export_employee (log)		0.177**	0.165***	0.168***
		(0.071)	(0.055)	(0.052)
Patents stock		0.002***	0.002***	0.002***
		(0.001)	(0.001)	(0.001)
R&D coop in DE				-0.280
				(0.183)
R&D coop abroad				0.320*
				(0.174)
Region R&D			0.055*	0.054*
			(0.031)	(0.031)
Region export			-0.001	-0.001
			(0.039)	(0.039)
Region N employees			0.027	0.029
			(0.052)	(0.052)
Region patents			-0.001	-0.001
			(0.001)	(0.001)
Year dummies	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	14,518	14,504	14,504	14,504
Number of firms	3,733	3,731	3,731	3,731
Chi-squared test	159.4	219.5	225.7	238.0

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: First stage regression results on Region citations invH

	Model 1	Model 2	Model 3	Model 4
LCC entry (lag 3 years)	1.085***	1.082***	1.055***	1.057***
	(0.189)	(0.188)	(0.186)	(0.186)
N employees (log)		-0.046	-0.096	-0.101
		(0.134)	(0.134)	(0.134)
R&D_employee (log)		0.599	-1.246	-1.351
		(2.413)	(2.430)	(2.437)
Export_employee (log)		0.066	0.055	0.054
		(0.056)	(0.055)	(0.055)
Patents stock		-0.002	-0.003	-0.003
		(0.002)	(0.002)	(0.002)
R&D coop in DE				0.095
				(0.182)
R&D coop abroad				0.056
				(0.232)
Region R&D			0.296***	0.295***
			(0.049)	(0.049)
Region export			0.092**	0.093**
			(0.042)	(0.042)
Region N employees			-0.029	-0.030
			(0.078)	(0.078)
Region patents			0.001**	0.001**
			(0.001)	(0.001)
Year dummies	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Constant	10.812***	10.868***	10.122***	10.121***
	(0.190)	(0.695)	(0.854)	(0.854)
Observations	14,518	14,509	14,509	14,509
Number of firms	3,733	3,731	3,731	3,731
F-test on ommitted instrument	33.13	33.18	32.12	32.28
Chi-squared test	42.39	34.57	30.63	28.60

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

Table 4: Second stage regression (QMLE) results - Region citations invH

	Model 1	Model 2	Model 3	Model 4
Region citations invH	0.302***	0.338***	0.352***	0.343***
	(0.104)	(0.105)	(0.105)	(0.116)
N employees (log)		-0.119	-0.131*	-0.131
		(0.077)	(0.076)	(0.081)
R&D_employee (log)		6.456***	6.862***	6.462**
		(2.369)	(2.297)	(2.605)
Export_employee (log)		0.161**	0.151***	0.155**
		(0.065)	(0.058)	(0.065)
Patents stock		0.002***	0.003***	0.003***
		(0.001)	(0.001)	(0.001)
R&D coop in DE				-0.297
				(0.204)
R&D coop abroad				0.285*
				(0.161)
Region R&D			-0.044	-0.041
			(0.038)	(0.047)
Region export			-0.034	-0.033
			(0.041)	(0.043)
Region N employees			0.040	0.042
			(0.052)	(0.050)
Region patents			-0.001*	-0.001*
			(0.001)	(0.001)
Year dummies	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	14,518	14,504	14,504	14,504
Number of firms	3,733	3,731	3,731	3,731
Chi-squared test	196.1	433.8	548.3	415.9

Boostrap standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Regression results on innovative productivity - Region co-patents invH

	Model 1	Two stages IV model Model 2	Model 3
	QMLE	First stage	Second stage
Region copatents abroad invH	0.022***		0.749***
	(0.007)		(0.217)
LCC entry (lag 3 years)		0.483**	
		(0.193)	
N employees (log)	-0.154**	-0.324*	0.077
	(0.076)	(0.166)	(0.090)
R&D_employee (log)	6.141**	-2.437	7.825***
	(2.495)	(3.326)	(2.349)
Export_employee (log)	0.168***	-0.084	0.236***
	(0.052)	(0.064)	(0.059)
Patents stock	0.002***	0.001	0.002
	(0.001)	(0.002)	(0.001)
R&D coop in DE	-0.268	-0.236	-0.088
	(0.187)	(0.162)	(0.149)
R&D coop abroad	0.299*	0.174	0.174
	(0.172)	(0.207)	(0.164)
Region R&D	0.061*	0.043	0.028
	(0.031)	(0.052)	(0.028)
Region export	0.003	-0.137***	0.102**
	(0.039)	(0.046)	(0.048)
Region N employees	0.015	0.476***	-0.325***
	(0.052)	(0.084)	(0.116)
Region patents	-0.001*	0.011***	-0.009***
	(0.001)	(0.001)	(0.003)
Year dummies	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Observations	14,504	14,504	14,504
Number of firms	3,731	3,731	3,731
F-test on ommitted instrument	-	*6.26*	-
F-test	-	53.81	-
Chi-squared test	242.6	-	544.1

Model 1, 2: Robust standard errors in parentheses; Model 3: Boostrap standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1