HIGH-TECH EMPLOYMENT AND TRANSPORTATION: EVIDENCE FROM THE EUROPEAN REGIONS

AUTHORS

Daniel Albalate (albalate@ub.edu).
Dep. of Economic Policy, University of Barcelona (Spain)

Xavier Fageda* (xfageda@ub.edu).
Dep. of Economic Policy, University of Barcelona (Spain)

Contact address (both authors)
Department of Economic Policy (University of Barcelona)
Av. Diagonal, 690
08034 Barcelona (Spain)
Tel: +34 934039721
FAX: +34 934024573

*Corresponding author: Xavier Fageda

Abstract:

High technology sectors are typically open to external inputs, resources, and knowledge spillovers. We study the impact of transportation, which is essential for providing external links to regional and global markets, on high- tech employment. We draw on a sample of 182 European regions for the period 2002-2010. By implementing a dynamic panel-data estimator, we find that the density of motorways and the number of air services promote employment growth, yet only the latter remains consistent. Interestingly, network carriers have a greater impact than low cost carriers. In contrast, high-speed rail does not seem to impact on employment.

Keywords: High technology; Employment; Infrastructure; Transportation

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1. Introduction

High technology activities, i.e., those involving the creation of new products and innovative processes through the systematic application of scientific and technical knowledge,[i] receive considerable scholarly attention given their strong association with innovation, productivity and their role in promoting the international competitiveness of domestic economies (HECKER, 2005). Additionally, interest in this sector arises from its close association with well-paid jobs (reflecting the high proportion of scientists, engineers and specialized technicians that it engages) and its ability to stimulate sustainable economic growth. In this regard, ECHEVERRI-CARROLL and AYALA (2008) measure the high-tech wage premium and show that it can be attributed to the workers' higher productivity and the advantages derived from spillovers rather than to the self-selection of the highly educated population.

Given their known and potential economic contribution, many governments worldwide have sought to attract high-tech manufacturing and knowledge-intensive services to their territories in recent decades. For example, KLAK (1989) argues that areas with a cluster of high-tech industries have more balanced occupational structures and KASK and SIEBER (2002) show that, while far from being uniform in their performance, high-tech industries typically outperform non high-tech manufacturing industries in output per hour and in unit labor costs. Additionally, they conclude that output per hour is likely to grow faster and unit costs to decline more rapidly in high-tech manufacturing industries.

Interest in high-tech clusters has been further promoted by such success stories as those of Silicon Valley, Singapore and Taiwan, which have captured the attention of the world as "teeming" technology centers (MAZZUCATO, 2013), while playing a major role in generating policies worldwide to support the “social structure of innovation” (FLORIDA and KENNEY, 1988) and the development of high-tech “ecosystems” (BAHRAMI and EVANS, 2000).

Many governments have implemented public programs to foster the location and development of these industries, shaping the determinants of their creation and location. For example, research shows that the high-tech sector benefits from a ready supply of educated labor (BRESNAHAN et al., 2002; ACOSTA et al., 2011; FALLAH et al., 2014) and from university spillovers (BANIA et al. 1993; ACOSTA et al., 2009) and so seek out neighboring locations (ABRAMOVSKY, 2007; ACS et al., 1999; AUDRETSCH et al., 2005). Moreover, AUDRETSCH and LEHMANN (2005) report that universities in regions with greater knowledge capacity and higher knowledge output also generate a larger number of technology start-ups. ACS et al. (2002) find some evidence of these spillovers on high-tech employment and confirm that, in addition to university, industrial R&D makes a similar contribution. In fact, R&D intensity (ratio business-enterprise R&D to value added) and its application (through spillovers) promote skill upgrading (HOLLANDERS and TER WEEL, 2002). Regional spillovers and initial clustering also benefit high technology firm formation (HARHOFF, 1999; FINGLETON ET AL., 2004).

The literature to date has paid little attention to the importance of transportation in fostering high-tech activities. Only a few papers include transport variables as controls in their empirical analyses. FINGLETON (1992), for example, used the number of kilometers of motorway in each county, and whether that county had access to a domestic or international airport, to explain the location decisions of high-tech firms in Great Britain in 1984. His coefficients were only statistically significant in an initial regression model that included all regional areas, presenting a positive correlation with motorway endowment (although this disappeared when the London area was omitted) and a negative relationship with international airport access. More recently, JENKINS et al. (2008) have considered the role of certain transport infrastructure and services (number of freeways and the number of flights offered) in determining high-tech employment growth in US metropolitan areas for the period 1988-1999; however, none appeared to have a statistically significant impact.

This paper contributes to the literature by refining this analysis and by focusing more specifically on the role of transportation and not simply including different modes as environment controls. To do this we evaluate the extent to which different modes of transportation help promote regional high-tech employment across Europe. Our underlying hypothesis is that transportation brings together critical resources and inputs in the innovation process in accessible places. Its role in promoting communication is therefore essential for all processes based on shared knowledge and collective learning, given the need for institutional, organizational and technical proximity (BRESCHI and MALERBA, 2001). For instance, SAXENIAN and HSU (2001) describe how knowledge skills can be transferred across large distances and how they can contribute to the reciprocal industrial upgrading of geographically distant regions. Indeed, high-tech activities also build up strong extra-regional relationships so as to meet their input and output requirements (BRITTON, 2004). In this respect, high-tech clusters need to be open to external spillovers, given that the evidence shows that the foreign stock of knowledge has a positive impact on industry net sales (CHYI et al., 2012).

Transportation is therefore essential as external links to high-tech clusters provide access to knowledge, skills, contacts, capital and information about new technological opportunities and new markets (BRESCHI and MALERBA, 2001). This is particularly true of cutting-edge knowledge, which as it is tacit in nature and difficult to transmit, gives transportation a key role in promoting face-to-face interaction and ensuring effective communication (FELDMAN, 2000). Interestingly, the advances in information technologies do not seem to have reduced the need for face-to-face interactions. Indeed, electronic and face-to-face contacts may be complementary rather than substitutes (GASPAR and GLAESER, 1998), and they are not necessarily equivalents. STORPER and VENABLES (2004) have formalized the idea that face-to-face contacts have unique advantages as a means of communication, coordination and motivation.

Drawing on the preceding discussion, this paper therefore considers the essential role played by fast, medium-distance transportation facilities (roads and high speed rail) and long-distance transport services (air services provided by network and low cost carriers) in their contribution to high-tech employment.

The rest of this paper is organized as follows. First, we review the related literature on the relationship between transportation, on the one hand, and employment and economic growth, on the other. Second, we describe our data and variables and, third, we present our empirical strategy and the main results obtained. The article finishes with a discussion of our results and a presentation of our conclusions.

2. Transport infrastructure and employment – a literature review

Several empirical studies have used production functions to examine the impact of infrastructure on economic growth. The geographical unit of analysis has been quite diverse and so we find studies conducted at the country, regional and local levels. In general, most of these studies have focused on the aggregate impact of the stock of public capital on GDP. Early examples of studies using production functions include ASCHAUER (1989), MUNNELL (1990), GARCIA-MILÀ and MCGUIRE (1992) and HOLTZ-EAKIN (1994). Given that roads represent a high proportion of the total stock of public capital, studies using production functions typically distinguish between roads and other infrastructure. While it is generally accepted that public capital (above all that related with roads) has positive effects, the magnitude of these effects is unclear.

In contrast to the extensive literature examining the link between public capital and output, few studies focus on the impact of transport infrastructure on regional employment and those that do generally concentrate their attention on one specific mode of transportation.

Road infrastructure, for example, has merited little attention with regard to its contribution to employment, though JIWATTANAKULPAISARN et al. (2009), CLARK and MURPHY (1996) and DURANTON and TURNER (2012) are obvious exceptions. JIWATTANAKULPAISARN et al. (2009), in an analysis of the US state of North Carolina, in which they employ various econometric techniques, report that investment in highways does not have a strong impact on private sector employment. Similarly, CLARK and MURPHY (1996) fail to find a consistent statistical significance of highway expenditure on employment growth in the US counties during the 1980s, reporting negative significance for manufacturing industries and positive coefficients for the financial, insurance and real estate commercial sectors. Interestingly, CLARK and MURPHY (1996) find more consistent evidence of the positive and significant role of highway density in less densely populated areas, an effect that disappeared in more congested regions. Finally, DURANTON and TURNER (2012) estimate a structural model to investigate the effects of interstate highways on the growth of employment in US metropolitan areas and find a robust, statistically significant impact.

HOLL (2004) also examines the relationship between roads and employment. Drawing on micro-level data for Spanish regions, she reports the significant impact of roads on the location of new manufacturing establishments, although her results imply that the benefits from road improvements concentrate around new infrastructure. Similarly, MATAS et al. (2013) find evident of relevant effects of road transportation on wages for Spanish regions. Finally, AKYELKEN (2013) find significant interactions between road transport and education in explaining employment across Turkish regions.

Here we undertake an empirical analysis applied to European regions with more than 1 million inhabitants (for details see the next section). Most of Europe's largest urban areas have been well supplied with a dense highway network for many years and this fact may influence our estimated impacts of motorway density on high-tech employment. However, it should not be forgotten that roads are the dominant mode of transportation for short- and medium-haul trips in Europe for both goods and passenger traffic. Thus, our hypothesis is that motorway density has a positive effect on regional high-tech employment but its statistical significance is *a priori* uncertain.

In the case of ports a number of studies have been carried out, most notably, by BOTTASSO et al. (2013) and FERRARI et al. (2010), both of which report that port throughput has a positive impact on employment in European and Italian regions, respectively. Here, however, we do not include a variable for ports as our focus is on high-tech employment and ports specialize in moving goods with a low added value to weight ratio. By contrast, firms operating in high-tech sectors need to transport both employees and goods with a high added value to weight ratio.

High-speed rail (HSR) services and their impact on employment and firm location have, to date, generated little scholarly interest. ALBALATE and BEL (2012a, b) offer an overview of international experiences and of the latest research on HSR operations, but conclude that their economic impacts are limited, if not negligible, when oriented solely to passenger traffic. Given the scale of investment required in promoting HSR services, only high-density routes providing large time savings respect to other modes justify the fiscal effort. Moreover, the level of investment is rarely offset by the associated social benefits. There is some evidence that the first HSR operations opened in Japan boosted employment rates in the cities served but this was achieved at the expense of jobs in medium-sized and small cities, pointing to the disruption created by HSR operations at the regional level (GIVONI, 2006). Likewise, PUGA (2002) stresses that enhanced accessibility works both ways so that firms located in more developed regions enjoy better access for supplying distant, poorer regions. This potentially undermines the industrialization prospects of these less developed regions.

ESTEBAN (1998) concludes that HSR operations do not appear to attract advanced services companies, the latter failing to show any great propensity to locate in areas near railway stations. Similarly, MANNONE (1995 and 1997) studied the effects of HSR services on firm location in several French cities between 1984 and 1991 and found that only four firms from a total of 663 identified them as being a key determinant in their choice of location. Yet, a third did claim they had taken this factor into consideration. However, all in all, it is consistently found in other cities and countries, that HSR neither accelerates industrial concentration nor promotes administrative or economic decentralization (MARTÍ-HENNEBERG, 2000). Thus, the impact of HSR on location, if it can be said to exist, seems to be limited to the urban core and the area around the station, while its regional distributive effects are slight.

There is some evidence of a hierarchical relocation of firms from towns to cities and MARTÍN (1998) considers that a location near a HSR station is only important for companies that seek to conduct business with others located in urban centers on the HSR line. PRESTON and WALL (2008) conclude that the economic benefits of HSR are difficult to detect being ‘swamped’ by external factors, but that they may be more sizeable in more central locations. High-tech industries though are rarely located in urban cores near HSR stations.

Based on the findings of previous analyses of the economic impact of HSR, we do not expect to find any significant effects of this infrastructure on high-tech employment rates.

More attention has been dedicated to links between air transportation and employment. Various studies have undertaken empirical analyses of the causal relationship between employment and different indicators of air traffic using samples of urban areas in the US and Europe. Several studies of the US case find evidence of a notable impact of air services on the economic performance of urban areas. Thus, BRUECKNER (2003) reports a significant causal link between air traffic and employment in service-related industries, though not in goods-related industries. GREEN (2007) finds that having a hub is a stronger predictor of employment and population growth than total traffic. BLONINGEN and CRISTEA (2012) provide evidence of a direct significant effect of passenger traffic on population, income and employment (especially in the wholesale and retail industries), in a study that takes advantage of the shock on air traffic attributable to the liberalization of the sector at the end of the seventies. Finally, BILOTKACH (2013) finds that the number of non-stop destinations has a stronger impact on total employment and the number of business establishments in US urban areas than do other measures of air traffic such as the number of flights or the total number of passengers.

In Europe, BEL and FAGEDA (2008) find that the supply of direct intercontinental flights is a major determinant of the location choices for large firms' headquarters in European cities and PERCOCO (2010) reports evidence of direct significant effects and positive spatial spillovers of air traffic on employment for the Italian regions.

Here our focus is the impact on employment in high-tech sectors, and so our analysis draws a distinction between the air services provided by network and low-cost airlines, respectively. We do this, first, because network airlines have increasingly concentrated their flights at a small number of airports out of which they operate their hub-and-spoke routes. By adopting this strategy network airlines can offer higher flight frequencies and a higher number of non-stop destinations (BRUECKNER, 2004; FLORES-FILLOL, 2009). Second, in Europe only those hub airports dominated by network airlines are able to offer a significant number of non-stop flights to intercontinental destinations, and low-cost airlines are unable to replicate their business models in this long-haul segment (FRANCIS ET AL., 2007)

Yet, low-cost carriers have been able to exploit their cost advantages on point-to-point, short-haul routes by implementing a model based on the intensive utilization of aircraft and crews, lower labor costs, lower airport charges and a simpler management model (e.g., one plane type, a single-fare class, no free on-board frills, etc.). In this regard, the downward pricing pressure that low-cost airlines exert on the routes they operate is well documented (e.g., DRESNER et al., 1996; MORRISON, 2001; OLIVEIRA and HUSE, 2009).

Thus, airlines that operate hub-and-spoke networks are able to offer higher frequencies than airlines operating point-to-point routes, albeit at higher fares. As such, the services of network carriers are likely to be more highly valued by business passengers, while the services of low-cost carriers should be more highly valued by leisure passengers. Note that business passengers are generally less fare sensitive than leisure passengers, but they are more demanding with regard to the quality of services in relation to such features as the flight schedule, frequency of flights, availability of lounge facilities and frequent flyer bonuses (BUTTON et al., 1999).[ii] Having said this, the business passengers that are most sensitive to schedules should be the highest wage earners, and these are usually those employed in high-tech sectors.

Air services are also relevant for the movement of goods with high added value in relation to their weight as it is the case of high technology manufactures. While some flights are exclusively used for air cargo, it is usual that commercial flights for passengers also carry goods. This may explain the strong correlation between the two dimensions of air traffic, passengers and cargo, in European airports. In this regard, note that the amount of cargo transported in commercial flights for passengers are especially high in long-haul flights that are operated with big aircrafts and in Europe long-haul flights are dominated by network carriers.

Thus, one hypothesis we test in our empirical analysis is that the number of flights offered by network airlines has a stronger impact on high-tech employment than the number of flights offered by low-cost airlines.

3. Data and variables

Our sample comprises the regions of the 27 countries making up the European Union plus Norway and Switzerland. Our data cover the period 2002-2010, these dates being dictated by the availability of information for the variables included in the empirical analysis, above all that of our main variables, namely, employment in high-tech sectors and transportation. These sectors are described in table 1.

<<Insert table 1 about here>>

Information for all variables is at the regional (NUTS II) level.[iii] We consider all regions with more than 1 million inhabitants. We have been able to collect complete data for 182 regions, although the (few) missing values for some years means our panel is weakly unbalanced. Our final sample includes data for 182 European regions, comprising a total of 1605 observations. Figure 1 shows all regions included in our sample and the current level of high technology employment as a percentage of total employment.

<<Insert Figure 1 about here>>

Table 2 provides a description of the variables used in the empirical analysis and the sources from which we have collected the corresponding data. As explanatory variables of high-tech employment, we include the region's population. We expect a positive sign for the coefficient associated with the variable of population. We expect a size effect, as data for the number of employees are provided in absolute values. Furthermore, larger urban agglomerations may be more attractive for firms operating in high-tech sectors as the availability of specialized service providers and the opportunities for knowledge spillovers with other firms should be higher. However, these agglomeration economies can be countered with inefficiencies associated with congestion. Hence, we also include as explanatory variables the region's density of population and the weight of the population of the urban area in relation to the total population in the region. With this last variable we account for the importance of the core city in relation to the rest of the region.

<<Insert table 2 about here>>

We also include the wages paid to employees in high-tech sectors. Here, the expected sign associated with this variable is unclear: on the one hand, higher salaries imply higher costs for firms; on the other, higher salaries may be an indicator of the higher productivity of employees (as discussed above). However, most studies report a negative relationship between wages and employment. In this regard, we also include a variable for the percentage of highly educated. We expect a positive sign for this coefficient as high-tech sectors demand skilled employees and the literature describes the key role played by university and education spillovers in promoting high-tech sectors.

The empirical model also includes a dummy variable for regions of countries that formerly were part of the Soviet block. This is the first time this variable has been used in such analyses, but we expect a negative sign for the coefficient to reflect the lag in high-tech industries with respect to the more traditional market-oriented regions and the manufacturing specialization of what used to be planned economies.

We consider three transportation variables to measure the endowment and quality of surface transportation infrastructure and two variables that capture airline services in the region. For the surface transportation modes we include the density of motorways and the number of connections offered at high-speed rail stations to control for inter-city accessibility.[iv] The length of metro (underground) lines also controls for the endowment of urban mass transportation. We generally expect a positive sign for the coefficients associated with these variables because firms located in regions with better infrastructure and transport accessibility can take advantage of lower transportation and communication costs and enjoy, at the same time, the internal and external links required by high-tech activities. Our variables include transportation modes than can lower transport costs for cargo and communication costs for passengers, as is the case of motorways and airline services, and just for passengers in the case of high-speed rail and metro lines. In all, these variables measure the costs of input (cargo, knowledge and labor supply) and output mobility for high-tech sectors and their accessibility to potential markets. Note, however, that severe congestion in urban cores may hinder high-tech industry location and the existence of large urban transit systems or high population density can also capture these inefficiencies in mobility.

For airline services, we use the number of flights offered by network and low-cost airlines. Network airlines are understood to be those carriers that belong to an international alliance (i.e., Oneworld, Star Alliance, and SkyTeam). Today, the amount of connecting traffic that can be channeled by an airline not involved in an international alliance is necessarily modest. Therefore, our approach distinguishes between airlines that exploit connecting traffic as an essential part of their business (i.e., network airlines) and airlines that focus their business on point-to-point routes (i.e., low-cost airlines). By adopting this criterion, we are able to avoid the complex task of having to draw up a list of low-cost carriers without having access to comprehensive data on airline costs.

We expect a positive coefficient for the number of flights offered by network and low-cost airlines, although we hypothesize that this positive effect will be stronger for the variable that captures the number of network airline flights.

The services of network airlines should be more convenient for business passengers while the services of low-cost airlines should be preferred for leisure passengers in terms of cheap fares. As discussed above, the former usually offer higher flight frequencies at higher fares; furthermore, the flight schedules of network airlines are more likely to meet the needs of business travelers since they offer flights at peak hours from the largest airports in the region. At the same time, certain characteristics of low-cost carriers (including, strict baggage restrictions and limited seat space) could make them less attractive for business passengers, while their route configurations provide more links to tourist destinations. Furthermore, air services are relevant for the movement of goods with high added value in relation to their weight. As explained above, the amount of cargo transported in commercial flights for passengers is especially high in long-haul flights that are operated with large aircraft and in Europe long-haul flights are dominated by network carriers.

Note that our analysis is focused on airline services instead of airport connectivity. In this regard, hub airports may be approximated by two common characteristics; a large size and a high proportion of traffic channeled by a network carrier. Thus, the variable of number of flights offered by network airlines is already capturing the better connectivity of hub airports

Table 3 shows the variance decomposition of the continuous variables used in the empirical analysis in two orthogonal components: the within-component (variability within each region) and the between-component (variability between each region). It can be seen that the variability across regions is higher than the variability within each region for all variables. The within variation is particularly low in relation to the between variation for the variables of population, density of population and density of motorways, while the dummy variable for those regions that formed part of the Soviet block is obviously time-invariant.

<<Insert table 3 about here>>

4. Estimation and results

Two major econometric issues in our regressions have to be dealt with. First, the error term may present a problem of temporal autocorrelation and, second, some of the explanatory variables, such as wages or number of flights, may be determined simultaneously with the dependent variable.[v]

For these reasons, we perform the estimation using different econometric techniques. We use the ordinary least squares (OLS) method for a cross-sectional dataset using

2010 only values (the most recent available) and the whole sample assuming an AR(1) process in the error term. [vi]

Our panel is short in time periods respect to the number of regions and contains several explanatory variables without or with very low within variation compared to their between variation (See table 3). Hence, the fixed effects estimation would be imprecise and the prediction of the conditional mean would not be possible (CAMERON and TRIVEDI, 2005). Additionally, the Hausman test points to the existence of substantial differences between the random and the fixed effects models, so that we cannot present the results using the random effects model as the random effects may be correlated with the explanatory variables.

Given these circumstances, and our interest to address the possible endogeneity problem we consider as our preferred method a dynamic model, as it seems reasonable to believe that employment at period t-1 is a relevant variable for explaining employment at period t. The estimation of a dynamic model should also help us find instruments for the potentially endogenous variables: lag of employment in high technology sectors, wages and flights of network and low-cost airlines. Note that the lag of employment is endogenous by definition, while wages and flights can be simultaneously determined with high-tech employment for economic reasons; the level of employment may affect labor prices and regions with high-tech employment may demand more flights.

In a dynamic setting, an immediate problem to emerge is the correlation between the fixed effects in the error term and the lagged dependent variable. The difference GMM estimator, developed by ARELLANO and BOND (1991), first-differences all the variables in the model and instruments the differentiated variables that are not strictly exogenous with all their available lags in levels. A problem with the original Arellano-

Bond estimator is that lagged levels are poor instruments for first-differences if the variables are close to a random walk (which is the case when the data show high persistence). The system GMM, developed by ARELLANO and BOVER (1995) and BLUNDELL and BOND (1998), increases the efficiency of the estimation by adding the original equation in levels to the estimation. In this equation, variables in levels are instrumented with lags of their own first-differences. The Arellano-Bond test for autocorrelation shows the existence of AR (2) autocorrelation so that we need to include the two-period-lagged dependent variable (in addition to the one-period-lagged) on the right-hand-side of the regression (CAMERON and TRIVEDI, 2005). Additionally, we need to restrict the instrument set for the potentially endogenous explanatory variables (lags of high-tech employment, wages, network and low-cost airline flights) to three lags and longer.

In the regressions that use OLS, the standard errors are robust to heteroscedasticity, while in the dynamic regression the resulting standard-error estimates are consistent in the presence of any pattern of heteroscedasticity and autocorrelation within panels. Finally, we include year dummies to control for the common trend in all regions in the dataset.

Before conducting the panel data analysis, panel unit root tests are required to make sure all series are stationary. Table 4 reports the results of several tests that confirm that the variables used in the empirical analysis are stationary.

<<Insert table 4 about here>>

Our results are displayed in Table 5. Note that the system GMM includes two lags of the dependent variable as explanatory variables. In this regard, both lags of the dependent variable are highly significant. Hence, our preferred regression is that which uses system GMM. Moreover, this technique has the added advantage of providing instruments for the potentially endogenous explanatory variables.

<<Insert table 5 about here>>

<<Insert table 6 about here>>

The overall explanatory power of the model is very high and the Hansen test confirms the suitability of the instruments in the system GMM regression. The high overall explanatory power of the model may be explained by the size effect that captures the variable of population. Variance inflation factors measuring possible collinearity problems are reported in Table 6, showing no concerns. Considering the possible critiques to the GMM method of excessive number of instruments - that can overfit instrumented variables and biasing estimated coefficients - we report the instruments count and test robustness of results reducing it (See last column in Table 5) as suggested by ROODMAN (2009).

The results reported in Table 5 confirm our expectations for the population variable. The coefficient associated with this variable is positive and statistically significant regardless of the econometric technique used. Employment in high-tech sectors is higher in more populated regions but density and weight of the core city could affect in an opposite direction on high-tech employment, what would indicate that congestion and inefficiencies derived from heavily dense urban areas might hinder high-tech establishments. However, note that their coefficients are only statistically significant in the OLS models and not in our preferred GMM models.

The wages coefficient differs depending on the econometric technique used, but generally we do not find statistical support for its influence on High-tech employment. It is positive and statistically significant in the OLS panel regression with AR(1) disturbance, while it is not statistically significant in the rest of the models. Overall, therefore, we do not find unambiguous evidence that wages are a determinant of employment in high-tech sectors in a given direction. In contrast, the level of education is a strong predictor of employment in these sectors, which is consistent with the literature on education spillovers. Indeed, the coefficient associated with the variable of education is positive and statistically significant regardless of the econometric technique used.

We also confirm that employment in high-tech sectors is lower in regions of countries that formed part of the Soviet block. As expected, the coefficient associated with this variable is negative and statistically significant regardless of the econometric technique used.

More directly related to our contribution, we find interesting results for the endowment of surface transport infrastructure. We find only some limited evidence of a causal relationship between the density of motorways and employment in high-tech sectors. The coefficient associated with this variable is only positive and statistically significant in the OLS regressions, while it is not statistically significant in the system GMM regressions. Hence, regions with a greater density of motorways have greater numbers of employees in high-tech sectors, but this positive effect is not statistically significant when we conduct the regression in a dynamic setting. The low variability of this variable over time could account for its lack of significance in the growth of employment.

Our results clearly show that high-speed train access does not have a positive effect on high-tech employment. The coefficient associated with this variable is generally negative but never statistically significant regardless of the econometric model used.

This finding is consistent with the literature examining the lack of economic impact of most HSR lines in Europe on firm productivity, location and employment (See a review in ALBALATE and BEL, 2012b).

Regarding the length of the metro (underground) network, we find a positive and statistically significant coefficient in the cross-section regression, and a negative and not statistically significant coefficient in the rest of regressions. Overall, our analysis suggests a negative (modest) dynamic impact that may be point that high-tech employment is displaced from highly agglomerated urban areas and core cities. Our interpretation is that this may happen to avoid inefficient surface mobility due to congestion.

In contrast, we find evidence that the number of flights offered by network airlines in the region's airports has a positive effect on employment in high-tech sectors in that region. The coefficient associated with this variable is positive and statistically significant regardless of the econometric technique used. We just find a statistically significant positive effect of the number of flights offered by low-cost airlines in the panel regression using OLS with AR(1) disturbance. In this regard, the results of our analysis suggest a stronger effect of the flights offered by network airlines. Elasticities obtained from the estimations for network carriers are more than double of those obtained for low-cost airlines in all regressions with panel data. Furthermore, we confirm that the coefficients of the network and low-cost airline variables are statistically different in all regressions with panel data. More importantly the coefficient associated with the flights of low-cost airlines is negative but not statistically significant in the system GMM regressions, which are our preferred regressions, while the coefficient for network airlines is positive and statistically significant in these regressions.

5. Discussion and concluding remarks

Understanding the determinants and drivers of high-tech employment is crucial for achieving efficient policy designs that can foster growth in these sectors. In spite of the vast literature examining high-tech activities, the role of transportation has surprisingly been neglected, being treated only marginally in a few studies. Nonetheless, high-tech activities require sizeable, effective and efficient external regional and global links in order to meet their need for inputs of capital, information, knowledge and resources. Indeed, the firms that operate in these sectors typically adopt both active and passive roles as contributors and receivers of innovation and creativity, respectively.

This study has provided evidence of the importance of transport infrastructure and services for these industries. In particular, we find that better accessibility provided by transport infrastructures to both medium-distance and long-distance destinations contribute to growth in high-tech employment. This applies to some extent to motorway endowment, but more especially to air transportation. Furthermore, by distinguishing between network and low cost carriers, our analysis has highlighted the heterogeneity of impacts depending on the supplier of these long-distance mobility services. As such, this paper also contributes to the literature on the economic impact of air transportation by reporting different employment effects according to airline type for an industry that has very specific mobility requirements associated with the connections established between distant innovation poles and a large number of destinations. Airlines differ to the extent that low cost carriers typically focus their business on single, dense and highly specific routes which, in many cases, link tourist destinations with densely populated nodes, while network carriers tend to offer more integrated services that include connecting flights at hub airports serving a larger set of destinations, which, moreover, may be located at considerably greater distances. Our findings show that all flights might impact on high-tech industries but that network carriers satisfy their connectivity needs better and, as a result, they have a greater impact on high tech employment.

A similar interpretation can be made of our results on high-speed rail access. This mode of transportation is quite rigid and offers few connecting destinations, and so does not meet the needs of high-tech industries. Usually, HSR connects large poles to medium-sized cities at medium distances and so services are only competitive on routes between 150 and 700 km. Moreover, this mode of transportation cannot offer any advantage in the movement of goods in most of the countries considered due to their passenger oriented design.

Overall, we believe our results show that high-tech activities benefit from flexible and open modes of transportation that act as both local and global external links. As studies of HSR's geographical and economic impacts tend to show, it is essentially an infrastructure that serves urban city center cores; thus, our focus on wider regions (recall we use the NUTS II level) might hide or dilute any positive effects HSR potentially has in and around the city core. In this regard, results on the negative effect of local transit systems captured by the length of the metro (underground) network seems to point on the direction that, precisely, high-tech industries avoid congested and highly dense core cities. Our result supports the claims of PUGA (2002) that transport technologies that exhibit increasing returns to scale (as is the case of HSR) are unlikely to promote new centers of production even on nodes of the network.

Our analysis confirms the importance of certain determinants identified in the previous literature. Thus, we find that high-tech employment is positively associated with highly populated and educated regions, which account for agglomeration economies and knowledge spillovers, just as other empirical studies have consistently found (See ACOSTA et al. 2009; ACZ et al. 2002; FINGLETON et al., 2004).[vii] As for wages, the literature typically reports a negative but non-significant effect on innovating industries (ACOSTA et al. 2009; ALMUS and NERLINGER, 1999; JENKINS, LEIGHT and JAYNES). Other papers surprisingly report a positive and statistically significant effect (See ACZ et al. 2002).[viii] Our results support the evidence on the non-significance of this variable to high-tech employment. Here, we have been able to contribute a new determinant to the literature by finding a robust relationship between ex-communist economies and high-tech employment.

Our results raise a number of points of methodological interest. Although we report fairly consistent results for most of our regressors across estimation methods (especially in the cases of the role of population, education, communist past and network airline flights), other variables present some differences, even losing and gaining statistical significance. Specifically, the role of motorway density, population density, the weight of the core city, wage and the number of flights offered by low cost carriers differ depending on the estimation technique used. In the case of roads, the differences might reflect the different questions addressed by these models, given that the dynamic model captures employment growth better while roads remain stable over time allowing for little variation. Despite this, our results perhaps should be seen as initial evidence that needs to be treated with caution. Having said that, the robustness of the importance of network carrier flights seems clear as a source for fostering employment in high-tech sectors, being markedly superior to the impact of low cost carriers. In a similar vein, we are confident of the limited role identified for high-speed rail in regional employment, though we have not offered evidence for smaller areas centered in and around city cores.

To conclude, this study has described the impact on employment of various transportation modes and identified the need for further discussion on the role played in this by transport infrastructure. However, more research is required to understand the mechanisms via which these impacts are channeled across modes.

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Endnotes

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[i] We take this definition of high technology industries from the *Technology, Innovation and Regional Economics Development Assessment of the Office of Technology* at the US Congress, September 9, 1982.

[ii] Consumer decisions with regard to transportation are generally based on the generalized cost of the trip, which includes both monetary and time costs. One of the main components of the time costs is that of schedule delay, which is the difference between the desired and actual time of departure. The schedule delay cost is negatively correlated with flight frequency. An additional time cost is the time required to access the infrastructure, which in some cases can be higher for low-cost airlines as they operate out of secondary airports located at some distance from the region's main city. Finally, we do not expect to find substantial differences in the in-vehicle time between network and low-cost airlines.

[iii] The NUTS classification (Nomenclature of Territorial Units for Statistics) is a hierarchical statistical system used by Eurostat for dividing up the economic territory of the European Union. According to the Statistical classification of Eurostat, the population of the NUTS II areas should range between 800,000 and 3,000,000 inhabitants. In practice, the statistical territorial units are defined in terms of the existing administrative units in the Member States and do not necessarily fulfill these population limits.

[iv] Unfortunately, we are unable to include a variable for the density of railways that includes both conventional and high-speed rail lines. Eurostat data for this variable are very incomplete and its inclusion would have reduced substantially the number of regions we could have considered in the regressions.

[v] The variables for motorway density and the number of high-speed train lines should not be endogenous. Their infrastructure is associated with high investment levels and it shows a strong inertia over time. In this regard, investment in this infrastructure entails a complex decision-making process that includes technical, economic and political elements. As such, it is difficult to argue that these variables are correlated with the error term.

[vi] We apply the Wooldridge test for autocorrelation in panel data which indicates that we may have a problem of serial autocorrelation.

[vii] Fingleton et al. (2004) only report an association with human capital and education, and find only an insignificant relationship between employment in computer services and population size.

[viii] Note, that while Acz et al. (2012) find a positive and statistically significant effect of wages on employment, they acknowledge that this is a surprise. They argue that higher wages and employment might be a legacy of faster growth in previous years, a phenomenon not included in their short panel.

TABLES

Table 1. High technology industries considered in the sample.

Code	High technology manufacture
24.4	Manufacture of pharmaceuticals, medicinal chemicals, and botanical products
30	Manufacture of office machinery and computers
32	Manufacture of radio, television and communications equipment and apparatus
33	Manufacture of medical, precision and optical instruments, watches and clocks
35.3	Manufacture of aircraft and spacecraft
Code	High technology knowledge-intensive services
64	Post and Telecommunications
72	Computer and related activities
73	Research and Development

Source: Eurostat indicators of high-tech industry and knowledge-intensive services. High-tech aggregation by NACE Rev. 1.1

Table 2. Variables used in the empirical analysis

Variables	Description	Source	Mean	Standard Deviation
Employment in high-technology sectors	Employment in technology and knowledge-intensive sectors (NACE Rev.1.1). Thousands	Eurostat	1014.29	661.97
Population	Number of inhabitants	Cambridge Econometrics (European Regional database publication)	2337472	1522512
Density	Number of inhabitants per Squared-Km	Eurostat	413.09	952.81
Weight_core_city	Ratio between the Percentage of population living in the core city and the total population living in the NUTS II region	Eurostat	0.45	0.28
$Wage^{high\text{-}technology}$	Compensation paid to employees divided by number of hours worked (millions Euros/millions hours)	Eurostat	14.11	7.62
Education	Persons aged 25-64 and 20-24 with upper secondary or tertiary education attainment. (% age)	Eurostat	72.55	14.71
$D^{ex\_communist}$	Dummy variable for those regions of countries formerly belonging to the Soviet block	Authors' own data	0.27	0.44
Density_motorways	Number of motorway kilometers per 1000 km2	Eurostat	31.19	32.24
Metro_lines	Km of metro (underground) lines	Own data using the World Metro Database and information obtained from Metro providers	3.25	21.30
HSR_lines	Number of HSR lines available with at least one HSR station in the region (in which trains operate at speeds of ≥ 250 km/h.	International Union of Railways and authors' own data	0.21	0.52
Flights_network_airlines	Number of flights at airports in the region operated by network airlines (airlines integrated in an international alliance - Oneworld, Star Alliance, and SkyTeam).	RDC aviation	16764	38166.22
Flights_non_network_airlines	Number of flights at airports in the region operated by non-network airlines	RDC aviation	11900.88	19256.27

Table 3. Variance decomposition of the variables used in the empirical analysis

Variable	Variability across regions (1)	Variability within each region (2)	Ratio (2)/(1)
Employment in high-technology sectors	657.16	57.87	0.09
Population	1522600	115246.9	0.07
Density	954.57	28.04	0.03
Weight_core_city	0.28	0.03	0.11
$Wage^{high\text{-}technology}$	7.58	0.86	0.11
Education	14.48	2.80	0.19
$D^{ex\_communist}$	0.44	0	0
Density_motorways	32.32	2.24	0.07
Metro_lines	9.62	19.01	1.97
HSR_lines	0.33	0.16	0.48
Flights_network_airlines	37698.58	5878.96	0.16
Flights_non_network_airlines	18190	6189	0.34

Table 4. Unit root tests for the variables used in the empirical analysis

Variable	Levin, Lin and Chu test	Im, Pesaran and Shin Test	ADF Fisher test	Phillips, Perron, Fisher test
Employment in high-technology sectors	-25.95***	-10.65***	-9.61***	-10.62***
Population	-206.25***	-157.91***	-4.07***	-4.13***
Density	-206.25***	-157.94***	-4.07***	-4.13***
Weight_core_city	-11.59***	-9.99***	-9.69***	-9.37***
$Wage^{high-technology}$	-25.48***	-24.74***	-24.74***	-26.51***
Education	-26.43***	-16.01***	-22.17***	-24.40***
$D^{ex\_communist}$	N.A.	N.A.	N.A.	N.A.
Density_motorways	-12.54***	-2.2e+14***	N.A.	-18.04***
Metro_lines	-35.28***	-6.91***	-9.41***	-16.76***
HSR_lines	-2.52***	-3.30***	-7.27***	-9.62***
Flights_network_airlines	-44.00***	-7.4e+14***	-19.88***	-20.39***
Flights_non_network_airlines	-35.28***	-14.43***	-22.75***	-23.78***

Note: The null hypothesis in all tests is that the variable follows a unit process

Table 5. Results of estimates of the high-technology employment equation

	Dependent variable: employment in high-technology sectors			
Explanatory variables	OLS (cross-section using data for 2010) (1)	OLS with an AR 1 disturbance (2)	System GMM – Standard errors robust to autocorrelation within panels (3)	System GMM – Standard errors robust to autocorrelation within panels (4)
Lag_ one (employment in high-technology sectors)	-	-	1.33*** (0.15)	1.33*** (0.15)
Lag_ two (employment in high-technology sectors)			-0.47*** (0.15)	-0.49*** (0.15)
Population	0.00039*** (0.00001)	0.00035*** (0.000013)	0.00005*** (0.00002)	0.00006*** (0.00002)
Density	-0.03** (0.01)	-0.03*** (0.003)	-0.004 (0.006)	-0.004 (0.007)
Weight_core_city	-28.99 (37.45)	-73.12*** (19.07)	-12.69 (25.45)	-6.08 (29.44)
$Wage^{high-technology}$	1.14 (1.12)	1.03*** (0.44)	0.56 (0.82)	0.62 (0.84)
Education	5.34*** (1.36)	2.62*** (0.58)	0.62*** (0.21)	0.63*** (0.23)
$D^{ex\_communist}$	-97.26*** (31.59)	-66.90*** (5.06)	-14.30** (7.01)	-15.32** (8.03)
Density_motorways	0.83*** (0.29)	0.98*** (0.06)	0.15 (0.09)	0.13 (0.11)
HSR_lines	-23.74 (29.92)	7.17 (8.41)	-1.42 (3.63)	-2.84 (3.90)
Metro_lines	0.85** (0.36)	-0.004 (0.10)	-0.18 (0.13)	-0.20 (0.14)
Flights_network_airlines	0.001** (0.0004)	0.002*** (0.00019)	0.00038** (0.00015)	0.00043** (0.00016)
Flights_non_network_airlines	0.001 (0.0008)	0.001*** (0.00024)	-0.00016 (0.00019)	-0.00087 (0.00020)
Intercept	-333.96*** (11.37)	-58.61*** (69.32)	-58.15*** (20.07)	-60.57*** (23.18)
Year dummies	NO	YES	YES	YES
Test differences in coefficients (Ho: Flights_network_airlines - Flights_non_network_airlines = 0)	0.0001	5.20***	2.82*	4.08**
Elasticity obtained for the variable of Flights_network_airlines	0.015**	0.040***	0.0066***	0.0074***
Elasticity obtained for the variable of Flights_non_network_airlines	0.012	0.017***	-0.0020	-0.0010

R^2	0.95	0.92	-	-
Joint significance test (Ho: No joint significance)	148.53***	5981.22***	290626.32***	241673.37***
Number of instruments	-	-	116	97
Wooldridge test (Ho: No autocorrelation of order one)	-	50.76***	-	-
Arellano-Bond test in first-differenced errors				
Ho: No autocorrelation of order one			-4.98***	-4.93***
Ho: No autocorrelation of order two			3.39***	3.37***
Ho: No autocorrelation of order three			-1.18	-1.22
Ho: No autocorrelation of order four			0.56	0.58
Hansen test (Ho: No overidentifying Restrictions)		-	96.31	86.42
Number of observations	182	1605	1198	1198

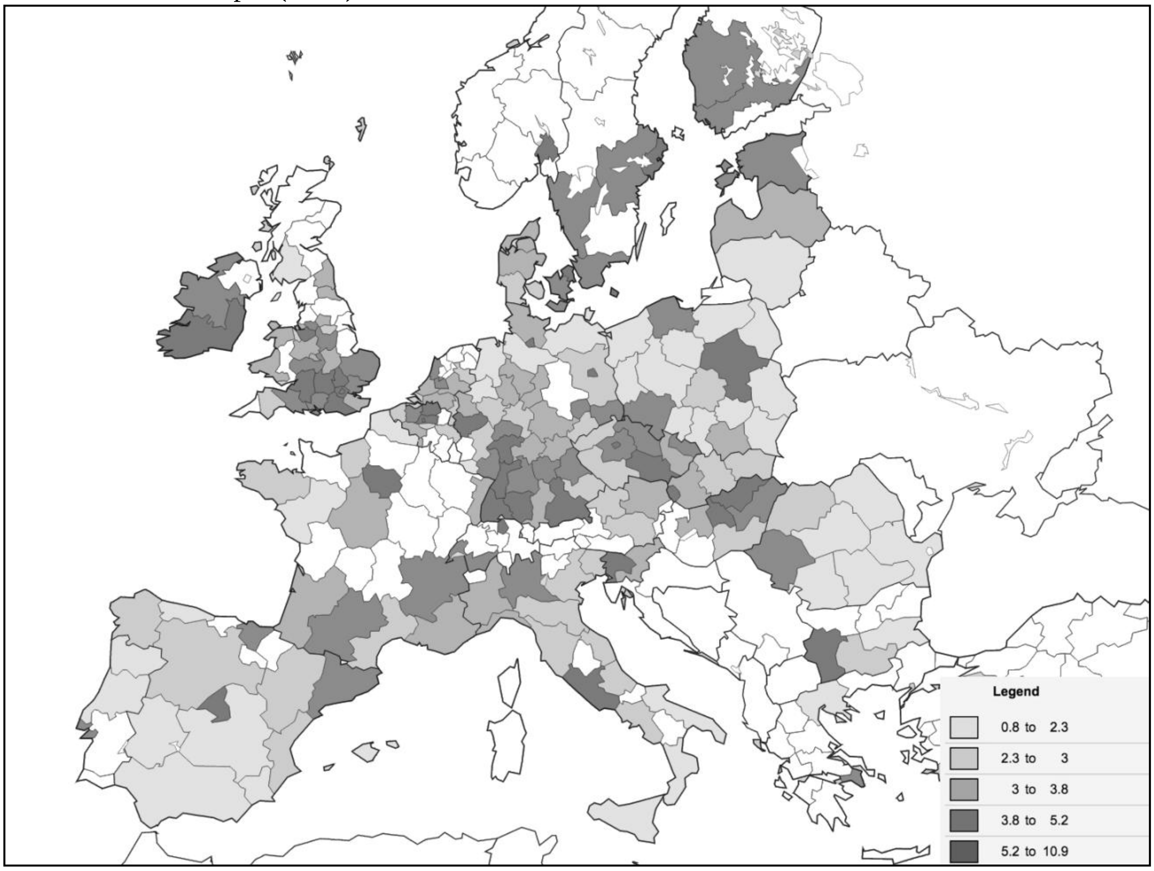
Note 1: Standard errors in parentheses (robust to heteroscedasticity)
Note 2: Statistical significance at 1% (***), 5% (**), 10% (*)

Table 6. Variance Inflation factors

Explanatory variables	Variance inflation factors
Population	2.29
$Wage^{high-technology}$	1.05
Education	1.54
$D^{ex\_communist}$	1.73
Density_motorways	1.42
HSR_lines	1.64
Metro_lines	1.31
Density	1.58
Weight_population_urban_area	1.46
Flights_network_airlines	2.72
Flights_non_network_airlines	2.08

Figures

Figure 1. High Tech Employment as a percentage of total employment in the NUTS II regions included in our sample (2013)



Source: Eurostat.