High-Technology Employment and Transportation: Evidence from the European Regions

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(Received July 2014; in revised form April 2015)

High-technology employment and transportation: evidence from the European regions, Regional Studies. High-technology sectors are typically open to external inputs, resources and knowledge spillovers. This paper studies the impact of transportation, which is essential for providing external links to regional and global markets, on high-tech employment. It draws on a sample of 182 European regions for the period 2002–10. By implementing a dynamic panel-data estimator, it is found 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.

Regional Studies

Hoch-Technologie Beschäftigung Infrastruktur Verkehr

ALBALATE D. und FAGEDA X. Beschäftigungsniveau im Hochtechnologisektor und Verkehrswesen: Belege aus den europäischen Regionen, Regional Studies. Sektoren der Hochtechnologie sind normalerweise offen gegenüber externen Inputs, Ressourcen und Wissensübertragungen. In diesem Beitrag untersuchen wir die Auswirkungen des Verkehrswesens, das für die Bereitstellung von externen Verbindungen zu regionalen und globalen Märkten unverzichtbar ist, auf das Beschäftigungsniveau im Hightech-Sektor. Grundlage ist eine Stichprobe von 182 europäischen Regionen im Zeitraum von 2002 bis 2010. Durch Anwendung eines dynamischen Paneldaten-Schätzers stellen wir fest, dass die Dichte der Autobahnnetze und die Anzahl der Flugverbindungen das Beschäftigungswachstum fördern, wobei sich aber nur die Flugverbindungen einheitlich verhalten. Interessanterweise haben Netzfluggesellschaften größere Auswirkungen als Billigfluggesellschaften. Demgegenüber scheinen sich Hochgeschwindigkeits-Eisenbahnen nicht auf das Beschäftigungsniveau auszuwirken.

Regional Studies

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Albalate D. y Fageda X. Empleo de alta tecnología y transporte: evidencia de las regiones europeas, Regional Studies. Los sectores de alta tecnología suelen estar abiertos a aportaciones, recursos y difusión de conocimiento externos. En este artículo analizamos cuál es el impacto del transporte, que es fundamental para proporcionar enlaces externos a los mercados regionales y globales, en el nivel de empleo en el sector de alta tecnología. Nos basamos en una muestra de 182 regiones europeas para el periodo entre 2002 y 2010. Al aplicar un estimator dinámico de datos de panel, observamos que la densidad de las autopistas y el número de servicios aéreos fomentan el crecimiento de empleo, no obstante, este último es el único que permanece constante. Es interesante observar que las aerolíneas tradicionales tienen un impacto mayor que las aerolíneas de bajo coste. En cambio, el ferrocarril de alta velocidad no parece tener un gran efecto en el empleo.

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,1 receive considerable scholarly attention given their strong association with innovation, productivity and their role in promoting the international competitiveness of domestic economies (Heckler, 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, Klar (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 labour 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 centres (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 programmes 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 labour (Bresnahan et al., 2002; Acosta et al., 2011; Fallahi et al., 2014) and from university spillovers (Banias et al. 1993; Acosta et al., 2011) and so seek out neighbouring locations (Abramovsky et al., 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 research and development (R&D) makes a similar contribution. In fact, R&D intensity (the ratio of business–enterprise R&D to value added) and its application (through spillovers) promote skill upgrading (Hollander and Weel, 2002). Regional spillovers and initial clustering also benefit high-tech 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 kilometres 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 motorways and the number of flights offered) in determining high-tech employment growth in US metropolitan areas for the period 1988–99; 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
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 studies conducted at the country, regional and local levels are found. In general, most of these studies have focused on the aggregate impact of the stock of public capital on gross domestic product (GDP). Early examples of studies using production functions include ASCHAUER (1989), MUNNELL (1990), GARCÍA-MILÀ and McGuire (1992) and HOLTZ-EACKIN (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 JIWATTANKULPAISARN 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 US counties during the 1980s, reporting negative significance for manufacturing industries and positive coefficients for the financial, insurance and property (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 the 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 the present authors 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 the 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, the 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, the present paper does not include a variable for ports as the 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. HSR services and their impact on employment and firm location have, to date, generated little scholarly interest. Albalate and Bel (2012a, 2012b) 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 with 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, 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, one-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 Esteban-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 centres 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, the present authors 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 United States and Europe. Several studies of the United States 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. Blonigen 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 1970s. 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 the focus is the impact on employment in high-tech sectors, and so the analysis draws a distinction between the air services provided by network and low-cost airlines, respectively. This is done, 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.
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 labour 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).

Having said this, the business passengers who 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-tech 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 is especially high in long-haul flights that are operated with large aircraft and in Europe long-haul flights are dominated by network carriers.

Thus, one hypothesis tested in this 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.

DATA AND VARIABLES

The sample comprises the regions of the 27 countries making up the European Union, plus Norway and Switzerland. The data cover the period 2002–10, these dates being dictated by the availability of information for the variables included in the empirical analysis, above all that of the main variables, namely employment in high-tech sectors and transportation. These sectors are described in Table 1.

Information for all variables is at the regional (NUTS-II) level. Considered are all regions with more than 1 million inhabitants. The authors collected complete data for 182 regions, although the (few) missing values for some years means the panel is weakly unbalanced. The final sample includes data for 182 European regions, comprising a total of 1605 observations. Fig. 1 shows all regions included in the sample and the current level of high-tech employment as a percentage of total employment.

Table 2 provides a description of the variables used in the empirical analysis and the sources from which the corresponding data were collected. As explanatory variables of high-tech employment, the region’s population is included. The authors expect a positive sign for the coefficient associated with the variable of population. Also expected is a size effect, as data for the number of employees are provided in absolute values. Furthermore, larger urban agglomerations may be more

| Code | High-technology industries considered in the sample |
|------|-----------------------------------------------------|
| 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              |
| 64   | Post and telecommunications                         |
| 72   | Computer and related activities                     |
| 73   | Research and development                            |

Source: EUROSTAT indicators for high-tech industry and knowledge-intensive services. High-tech aggregation by NACE Rev. 1.1 (Nomenclature statistique des activités économiques dans la Communauté européenne).
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, also included as explanatory variables are 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 one accounts for the importance of the core city in relation to the rest of the region.

Also included are 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 hand, 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, a variable for the percentage of highly educated is also included. A positive sign for this coefficient is expected 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 a negative sign for the coefficient is expected 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.

Three transportation variables are considered to measure the endowment and quality of surface transportation infrastructure, as well as two variables that capture airline services in the region. For the surface transportation modes are included the density of motorways and the number of connections offered at HSR stations to control for inter-city accessibility. The length of metro (underground) lines also controls for the endowment of urban mass transportation. Generally expected is 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. The variables include transportation modes that 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 HSR and metro lines. In all, these variables measure the costs of input (cargo, knowledge and labour 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.
Table 2. Variables used in the empirical analysis

| Variables                        | Description                                                                 | Source                                                                 | Mean  | Standard deviation |
|----------------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------|-------|--------------------|
| Employment in high-technology    | Employment in technology and knowledge-intensive sectors (NACE Rev. 1.1)    | EUROSTAT                                                              | 1014.29 | 661.97             |
| sectors (thousands)              | (thousands)                                                                 |                                                                       |       |                    |
| Population                       | Number of inhabitants                                                       | Cambridge Econometrics (European Regional database publication)       | 2337472 | 1522512            |
| Density                          | Number of inhabitants per km²                                               | EUROSTAT                                                              | 413.09 | 952.81             |
| Weight_core_city                 | Ratio between the percentage of the population living in the core city and  | EUROSTAT                                                              | 0.45  | 0.28               |
|                                  | the total population living in the NUTS-II region                           |                                                                       |       |                    |
| Wage_high-technology             | Compensation paid to employees divided by the number of hours worked (€,  | EUROS TAT                                                              | 14.11 | 7.62               |
|                                  | millions/millions of hours)                                                 |                                                                       |       |                    |
| Education                        | Persons aged 25–64 and 20–24 years with upper secondary or tertiary education | EUROS TAT                                                              | 72.55 | 14.71              |
|                                  | attainment (%) age                                                          |                                                                       |       |                    |
| D_comunist                       | Dummy variable for those regions of countries formerly belonging to the     | Authors’ own data                                                      | 0.27  | 0.44               |
|                                  | Soviet Block                                                               |                                                                       |       |                    |
| Density_motorways                | Number of motorway-kilometres per 1000 km²                                 | EUROSTAT                                                              | 31.19 | 32.24              |
| Metro_lines                      | Kilometres of metro (underground) lines                                     | Authors’ own data using the World Metro Database and information       | 3.25  | 21.30              |
|                                  | obtained from Metro providers                                               |                                                                       |       |                    |
| HSR_lines                        | Number of high-speed rail (HSR) lines available with at least one HSR       | International Union of Railways and authors’ own data                 | 0.21  | 0.52               |
|                                  | station in the region (in which trains operate at speeds of ≥ 250 km/h)     |                                                                       |       |                    |
| Flights_network_airlines         | Number of flights at airports in the region operated by network airlines    | RDC Aviation                                                          | 16764 | 38166.22           |
|                                  | (airlines integrated in an international alliance – OneWorld, Star Alliance|                                                                       |       |                    |
|                                  | and SkyTeam)                                                                |                                                                       |       |                    |
| Flights_non_network_airlines     | Number of flights at airports in the region operated by non-network airlines| RDC Aviation                                                          | 11900.88 | 19256.27         |
For airline services, the number of flights offered by network and low-cost airlines is used. 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 channelled by an airline not involved in an international alliance is necessarily modest. Therefore, the 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, one can avoid the complex task of having to draw up a list of low-cost carriers without having access to comprehensive data on airline costs.

The authors expect a positive coefficient for the number of flights offered by network and low-cost airlines, although it is hypothesized 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 travellers 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 on long-haul flights operated with large aircraft, and in Europe long-haul flights are dominated by network carriers.

Note that the 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 channelled by a network carrier. Thus, the variable of the 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.

**ESTIMATION AND RESULTS**

Two major econometric issues in the 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.\(^5\)

For these reasons, the estimation is performed using different econometric techniques. The ordinary least squares (OLS) method for a cross-sectional dataset using 2010 only values (the most recent available) and using the whole sample assuming an AR(1) process in the error term.\(^6\)

The panel is short in time periods with respect to the number of regions and contains several explanatory variables without or with very low within variation compared with their between variation (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

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**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-technology                          | 7.58                           | 0.86                              | 0.11          |
| Education                                     | 14.48                          | 2.80                              | 0.19          |
| Density_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          |
of substantial differences between the random and the
fixed effects models, so that one cannot present the
results using the random effects model as the random
effects may be correlated with the explanatory variables.

Given these circumstances, and the interest in
addressing the possible endogeneity problem, a
dynamic model is considered as the preferred method,
as it seems reasonable to believe that employment at
period \( t-1 \) is a relevant variable for explaining employ-
ment at period \( t \). The estimation of a dynamic model
should also help one find instruments for the potentially
endogenous variables: lag of employment in high-tech
sectors, wages, and flights of network and low-cost air-
lines. Note that the lag of employment is endogenous by
definition, while wages and flights can be simulta-
neously determined with high-tech employment for
economic reasons; the level of employment may affect
labour 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
dynamic model is considered as the preferred method,
addressing the possible endogeneity problem, a

- Lagged levels are poor instruments for first-
- The system GMM, developed by Arellano and Bond
- Increases the efficiency of the estimation by adding the

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

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 poss-
able collinearity problems are reported in Table 6,
showing no concerns. Considering the possible critiques
to the GMM method of excessive number of instru-
mants – that can over-fit instrumented variables and biasing estimated coefficients – the instruments count
test robustness of results reducing it are reported
(see the last column in Table 5), as suggested by

| Variable | Levin, Lin and Chu test | Im, Pesaran and Shin test | ADF Fisher test | Phillips, Perron and Shin 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*** |
| Dx_communist | n.a. | n.a. | n.a. | n.a. |
| Density_motorways | -15.54*** | -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*** | -6.62*** |
| Flights_network_airlines | -44.00*** | -7.4e+14*** | -19.88*** | -20.30*** |
| 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. Statistical significance at 1% (***) and
10% (*).
The results reported in Table 5 confirm the 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 high-tech employment, which would indicate that

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

| Explanatory variables | Ordinary least squares (OLS) (cross-section using data for 2010) (1) | OLS with an AR(1) disturbance (2) | System generalized method of moments (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*** (0.0001) | 0.00035*** (0.00013) | 0.00065*** (0.00002) | 0.00066*** (0.00002) |
| Density | −0.03*** (0.01) | −0.03*** (0.03) | −0.04 (0.06) | −0.04 (0.07) |
| 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) |
| Dy_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 (H0: 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 |
| R² | 0.95 | 0.92 | – | – |
| Joint significance test (H0: No joint significance) | 148.53*** | 5981.222*** | 290626.322*** | 241673.377*** |
| Number of instruments | – | – | 116 | 97 |
| Wooldridge test (H0: No autocorrelation of order one) | – | – | 50.76*** | – |

Arefano–Bond test in first-differenced errors

H0: No autocorrelation of order one | – | – | −4.98*** | −4.93*** |
H0: No autocorrelation of order two | 4.39*** | 3.37*** |
H0: No autocorrelation of order three | −1.18 | −1.22 |
H0: No autocorrelation of order four | 0.56 | 0.58 |
Hansen test (H0: No over-identifying restrictions) | – | – | 96.31 | 86.42 |
Number of observations | 182 | 1605 | 1198 | 1198 |

Notes: Standard errors are given in parentheses (robust to heteroskedasticity). Statistical significance at 1% (***), 5% (**), and 10% (*).
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 the preferred GMM models.

The wages coefficient differs depending on the econometric technique used, but generally no statistical support for its influence on high-tech employment is found. 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, no unambiguous evidence is found 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.

It was also confirmed 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 the contribution, interesting results for the endowment of surface transport infrastructure are found. Only some limited evidence of a causal relationship between the density of motorways and employment in high-tech sectors is found. 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 the regression is conducted in a dynamic setting. The low variability of this variable over time could account for its lack of significance in the growth of employment.

The 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 (for a review, see Albalate and Bel, 2012b).

Regarding the length of the metro (underground) network, a positive and statistically significant coefficient in the cross-section regression, and a negative and non-statistically significant coefficient in the rest of regressions are found. Overall, the analysis suggests a negative (modest) dynamic impact that may point to high-tech employment being displaced from highly agglomerated urban areas and core cities. The interpretation is that this may happen to avoid inefficient surface mobility due to congestion.

In contrast, evidence is found 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. A statistically significant positive effect of the number of flights offered by low-cost airlines is just found in the panel regression using OLS with AR(1) disturbance. In this regard, the results of the analysis suggest a stronger effect of the flights offered by network airlines. Elasticities obtained from the estimations for network carriers are more than double those obtained for low-cost airlines in all regressions with panel data. Furthermore, it can be confirmed 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 the preferred regressions, while the coefficient for network airlines is positive and statistically significant in these regressions.

### DISCUSSION AND CONCLUSIONS

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, it is found that better accessibility provided by transport infrastructures to both medium-
and long-distance destinations contributes 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, the 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. The 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 the results on HSR 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 kilometres. 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, the authors believe the 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 centre cores; thus, the focus on wider regions (recall that the NUTS-II level is used) 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 seem to point to the direction that, precisely, high-tech industries avoid congested and highly dense core cities. The 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 centres of production even on nodes of the network.

The analysis confirms the importance of certain determinants identified in the previous literature. Thus, it is found 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 (ACOSTA et al., 2011; ACS et al., 2002; FINGLETON et al., 2004). As for wages, the literature typically reports a negative but non-significant effect on innovating industries (ACOSTA et al., 2011; ALMUS and NERLINGER, 1999; JENKINS et al., 2008). Other papers surprisingly report a positive and statistically significant effect (ACS et al. 2002). The results support the evidence on the non-significance of this variable to high-tech employment.

The results raise a number of points of methodological interest. Although fairly consistent results are reported for most of the 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, the 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, the authors are confident of the limited role identified for HSR in regional employment, though evidence for smaller areas centred in and around city cores has not been offered.

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 channelled across modes.

Acknowledgements – The authors are grateful to Nicolás López for his excellent research assistance, and to two anonymous reviewers for their very helpful comments.

Disclosure statement – No potential conflict of interest was reported by the authors.

Funding – This work was supported by the Spanish Government [project number ECO2012-38004] and by the Regional Government of Catalonia [project number SGR2014-325].
NOTES

1. This definition of high-tech industries is taken from the Technology, Innovation and Regional Economics Development Assessment of the Office of Technology at the US Congress, 9 September 1982.

2. 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 the 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 lower for low-cost airlines as they operate out of secondary airports located at some distance from the region’s main city. Finally, the authors do not expect to find substantial differences in the in-vehicle time between network and low-cost airlines.

3. 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 million 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.

4. Unfortunately, a variable for the density of railways that includes both conventional and high-speed rail lines could not be included. EUROSTAT data for this variable are very incomplete and its inclusion would have reduced substantially the number of regions that could have been considered in the regressions.

5. 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.

6. The Wooldridge test for autocorrelation was applied to panel data and indicated that there might be a problem of serial autocorrelation.

7. 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.

8. While ACS et al. (2002) 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.

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