The spatial effects of transport infrastructures on growth: analysis of the regional convergence in Spain

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Abstract

This article examines the direct and indirect effects of transport infrastructure on convergence and product for the Spanish provinces during 1980-2008. For this purpose, we estimate several models using spatial econometrics techniques. The evidence confirms the presence of absolute and conditional convergence with little impact of transport infrastructure. However, results suggest that transport infrastructure have a significant positive effect on regional output, with positive spillover effects; this result is quite peculiar because it is at odds with previous findings. We deduced some policy recommendations from these results and discussed in the light of the recent literature that has analyzed the Spanish case.

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1. Introduction

Economic growth and changes in regional disparities over time have traditionally concerned academics in the economic field. Several empirical and theoretical approaches have tried to contribute on the issue (Baumol, 1986; Barro and Sala-i-Martin, 2004). Likewise, international organizations have supported public infrastructure investment as an important mechanism for reducing gaps between lagging and leading regions. According to the World Bank Report (2009) the greater mobility of the production factors promoted by these policies, makes infrastructure investment to be a necessary element in any development strategy.

A particular attribute of the investment in transport infrastructure is to impact not only in the region where the investment is made, but in nearby areas (Ozbay et al., 2007; Yu et al., 2013). Spillover effects are mainly expected in the transport modes with network attributes, typically railways and roads (Del Bo and Florio, 2012; Gómez-Antonio and Garijo, 2012). A positive effect implies that a particular region is benefited from the better endowment of their neighbors, while a negative effect indicates that the region is worsened. In this case, the domestic factors migrate to regions where the infrastructure was improved.

Spain is a paradigmatic country with wide regional disparities. A massive allocation of resources in pursuit of the regional converge has enabled the country to expand its infrastructure capacity, to become the European Union (EU) member with the most extensive motorway network. Moreover, it has developed the most extensive high-speed railway network in Europe (Albalate et al., 2013). In this context, the process of convergence in Spain seems a relevant hypothesis to test.

While vast literature has examined the impact of infrastructure on regional convergence using cross-country regional data, few studies examine the impact of different modes of transport in a specific-country research. In particular, the literature focused in the Spanish case is limited and inconclusive.

The main contribution of this paper is to provide new evidence about the absolute and conditional convergence processes between Spanish provinces, from 1980 to 2008. We include the direct, indirect and total impacts of different modes of transport: network infrastructures (roads and railways) and single infrastructures (airports and ports). As mentioned, this disaggregation is a novelty with respect to previous studies that assessed the global impact of the public investment in transport infrastructure. Furthermore, we study the contribution of public transport capital investment to the gross regional product. The methodology is based on spatial econometric techniques, by applying a Spatial Durbin Model (SDM) which measures the effects on the region in which the investment is made and the spillover effects on neighboring regions (LeSage and Pace, 2009).

Our results suggest the existence of a common steady-state level for the Spanish provinces. This would indicate an automatic tendency to the equalization of income. Regarding transport infrastructure investment, the effect on economic growth seems to be poor. At the end, we discussed in the light of the recent literature that has analyzed the Spanish case.

The remainder of this study proceeds as follows. Section 2 provides a detailed description of the literature about the role of public capital on economic growth and convergence. It describes, as well, the main features of the Spanish institutional and political background. Section 3 explains the sources of data and the variables included in the analysis. Section 4 presents the empirical specification of the models and the econometric approach. Section 5 reports results, and finally, in section 6 we present our conclusions and a discussion of the policy implications.

2. Public investment in transport infrastructure

2.1. Literature review

The economic impact of infrastructures and the regional convergence have been studied through extensive literature. However, the impact of infrastructures over regional convergence has not been much explored.

Regarding the first issue, most of empirical studies estimated production functions to examine the impact of aggregate amounts of public capital on economic growth. Articles related to this stream are those of Aschauer (1989), Munnell (1990), Garcia-Milà and McGuire (1992) or Holtz-Eakin (1994). Some other studies conducted the analysis using cost functions (Nadiri and Mamuneas, 1994; Morrison and Schwartz, 1996) and, more recently, on the basis of the urban economics theory (Gómez-Antonio and Garijo, 2012; Gómez-Antonio and Fingleton, 2012). Except for a few cases, investment is considered without the disaggregation into types of infrastructure. The spatial unit of analysis varies from country-case to regional or local studies.

Later contributions on this aspect employed different theoretical frameworks to capture the spatial externalities of transport infrastructure (Cohen, 2010; Del Bo and Florio, 2012; Crescenzi and Rodríguez-Pose, 2012). In general, results suggest (not unanimously) there is a direct and positive impact. Regarding the magnitude of the effect, the new econometric techniques found that is smaller than in the pioneering work of Aschauer, although it is still debated.

For the specific case of Spain, several studies analyzed the impact of transport infrastructures on the regional and sectoral economic growth. Álvarez et al. (2006) reviewed different approaches (the ones used by Holtz-Eakin and Shwartz (1995) and Mas et al (1994)) for testing the existence of provincial and spatial spillovers. They reported positive direct effects while indirect effects were inconclusive. Baños et al (2013) showed the same findings studying the impact of better road accessibility on the private sector. Gomez-Antonio and Fingleton (2012) evidenced positive direct effects but negative spillovers from the change in capital stock over neighboring provinces. Likewise, Delgado and Álvarez (2007) and Moreno and López-Bazo (2007) demonstrated that transport infrastructure has a positive direct effect but it has a negative spillover effect for other provinces, the former analyzed particularly the high capacity roads endowment. The latter also found that returns to local public capital are higher than those of transport infrastructure in line with Gómez-Antonio and Garijo (2012). Finally, Fageda and Gonzalez-Aregall (2014) studied the influence of different modes of transport infrastructure over regional employment. They found significant negative spatial spillovers from modes with network characteristics.

There is much controversy in the literature about regional convergence. Several empirical and theoretical approaches tried to contribute on the issue (Barro and Sala-i-Martin, 2004). Neoclassical growth models stated that per capita growth rates tend to be inversely related to the starting level of per capita output (Ramsey, 1928; Solow, 1956; Cass, 1965; Koopmans, 1965). Empirically, evidence is not conclusive (Barro and Sala-i-Martin, 1991, 1992a, 1992b, 1995; Romer, 1986; Rebelo, 1991).

Focusing in the role of public infrastructure on convergence, empirical literature provides divergent results. Regarding cross-country analysis of European regions, evidence confirmed the existence of a convergence process with positive impact of infrastructures on economic growth, although different magnitude of their effect (Canaleta et al., 2002; Checherita et al., 2009). Previous cross-country empirical findings, from different geographical contexts, are also consistent with the reduction of the development gap among regions (Calderón and Chong, 2004). In country-specific articles, the evidence of infrastructures on regional convergence is not that clear (Costa-i-Font and Rodríguez-Oreggia, 2005; Pereira and Andraz, 2006).

Subsequent articles examined whether spatial interdependencies in infrastructure investment are a significant factor in explaining the effects on regional convergence. Studies of European regions (Florio, 2010; Del Bo et al., 2010) found evidence of a convergence process with positive and significant spatial spillovers. In Greek regions, Rodríguez-Pose et al. (2012) evidenced a positive impact of spatial spillovers on regional economic growth (particularly due to transport infrastructures), although no impact on reducing disparities.

2.2. Institutional background

A particular experience of redistributive policy through public infrastructure investment is the Regional Policy of the European Union (EU). The main instrument of the policy is the monetary assistance given through "Objective 1" of the Structural and Cohesion Funds (SCF). Regions with a per capita GDP below 75% of the EU average, meet the eligibility requirements to receive this transfer.

The program was set up in the mid-1970s with the aim of contributing to the improvement of socio-economic integration and cohesion, both among member states and among regions within the same country. Moreover, a decade later, on account of the growing concern about the great disparities among regions, the political authorities of the EU agreed to implement an in-depth reform of the SCF. Reform included an increase by 100% of the budget in real terms, with a further increase for the peripheral countries; Greece, Ireland, Portugal and Spain.

According to Puga (2002), the funds aimed at the regional policy were the fastest growing within the EU budget. Since then, public spending in infrastructure has been an important tool in fostering growth in the least developed regions. Particularly, in countries such as Portugal and Spain, about 70% of the total funds were intended for infrastructure projects (Lago-Peñas and Martínez-López, 2005).

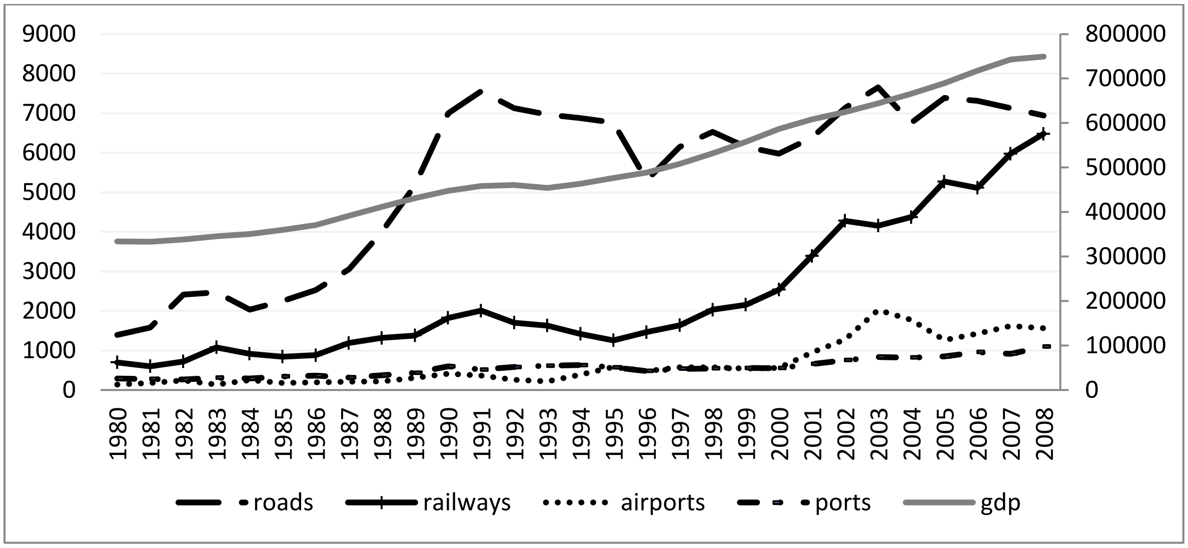
The specific objectives of the SCF reform program varied according to the mode of transportation that was involved. With regard to airports and ports, the investment was intended to reducing travel time and to improving quality and safety. In particular, for ports the expected outcome of the policy was to modernize infrastructure for handling the increase in container traffic. In the case of airports, it focused on dispersing the air traffic with the aim of reducing congestion, satisfying the increasing demand and improving the quality of the service. It is worth noting that the total investment in ports and airports was far behind the amount invested in roads or railways (General Regional Policy, 2000).

The main contribution of the Structural Funds in Spain was the construction of roads, while the Cohesion Funds were allocated mainly to railways. Lago-Peñas and Martínez-López (2005) stated that during the 1980s and 1990s Spain attained the highest percentage of public investment among the OECD countries.

2.2. The case of Spain

Spain is a country that has increased its transport infrastructure the most in recent years. For the period under study, Figure 1 shows the evolution of the transport investment at national level disaggregated into roads, railways, airports and ports. It includes the evolution of the GDP in the axis at the right. As can be seen, at the beginning of the 1980s, the transport investment policy implemented by the Government was targeted at increasing the capacity of the roads, in order to endow the country with high-capacity motorways. After that and until the end of the 1990s, the investment stressed the strengthening of the political centre, by constructing the 200-kilometre belt around Madrid and by increasing also the connections of the centre with the periphery (Albalate et al., 2012).

Figure 1. Evolution of transportation investment in Spain, 1980-2008 (thousands of constant euros, 2000)



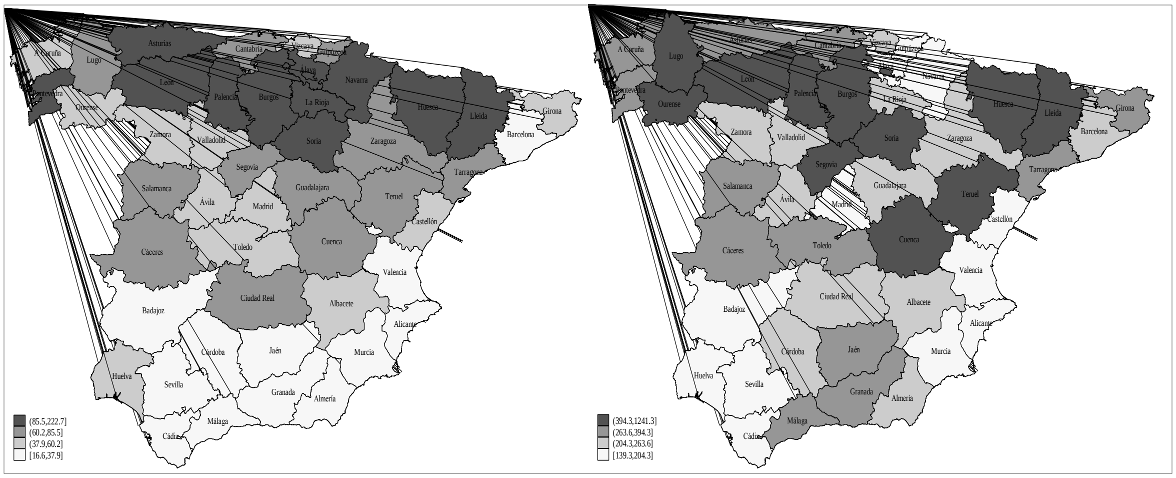
Source: Own elaboration based on data on *Instituto Valenciano de Investigaciones Económicas* (IVIE) and *Instituto Nacional de Estadística* (INE)

In recent decades, the transport investment policies have shifted their attention from roads to high-speed railways, based on the expansion of destinations and targeted almost exclusively at passenger transport.

The financing schemes for transport infrastructures have not been the same, high capacity network modes receive the largest share of Spanish investments in transport infrastructure while single transport facilities have received a lower allocation of resources (see Figure 1). However, airport investment in Spain has been much higher than investment levels along the European Union (EU) air markets.

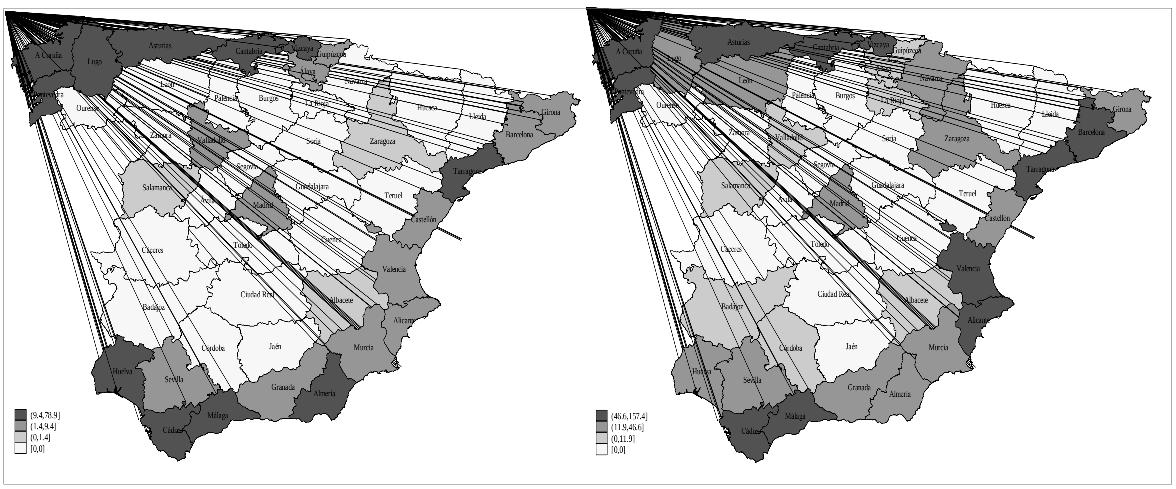
The regional allocation of network and single investment, at the beginning and the end of the period, is depicted by Figures 2 and 3. The figures show that investment in the network mode is allocated mostly in the North, although it has been increasing to the rest of the territory. Moreover, Single investment predominates along the Atlantic and Mediterranean coast, while at the end of the period shows some increase to other regions inside the country.

Figure 2. Distribution of network investment in 1980 (left) and 2008 (right) at NUTS-3



Source: Own elaboration based on IVIE

Figure 3. Distribution of single investment in 1980 (left) and 2008 (right) at NUTS-3



Source: Own calculations based onIVIE

The massive allocation of resources has enabled Spain to become the EU country with the most extensive motorway network and to develop the most extensive high-speed railway network in Europe, as well (Albalate et al., 2013). According to data provided by the International Transport Forum (cited in Albalate et al., 2013) over the period 2000-2009, airports investment achieved 1.5 times the investment in Germany, 1.9 times that of France and 4.8 times Italy’s investment. The context appears to be similar with regards to investment in ports. Data suggest that between 2000 and 2009, investment in Spain doubled the investment in Italy, and reached more than three times Germany’s budget and six times the investment in France.

3. Data and variables

In this section, we describe the data and variables used to assess the impact of transport infrastructures on regional convergence. For the purposes of this work we constructed a panel of Spanish regions with yearly data over the period 1980 – 2008. We consider each Spanish province, with the exception of the islands and the autonomous cities of Ceuta and Melilla. The reason why we have not considered them responds to differences in the endowment of transport infrastructures and the impossibility to capture their indirect effects.

We drew the source of information from the *Instituto Valenciano de Investigaciones Económicas* (Valencian Institute of Economic Research, IVIE), from the Spain's *Instituto Nacional de Estadísticas* (National Institute of Statistics, INE), and from the Cambridge Econometrics European database. The former provided data on investment and human capital value, the second one on gross domestic product (GDP) and population, while the latter about gross value added (GVA) and hours worked. The spatial unit of analysis is the EU regional level classification NUTS3 (Nomenclature des Unités Territoriales Statistiques), which are provinces in the case of Spain.

The main variable of interest is the regional growth rate ($\Delta GDP_{i,t+T}$) computed as the difference between the logarithm of the per capita GDP of province i in period $t+T$ and the logarithm of the per capita GDP of province i in period t. The main descriptive statistics of this variable, for each province and the whole period, are given in Table 1.

Table 1- Annual growth rate, descriptive statistics

Province	mean	min	Max	range	p25	p75	sd	cv
A Coruña	2.05	-1.98	7.82	9.80	0.78	3.20	2.16	1.05
Alacant	1.11	-2.98	6.42	9.41	-0.76	3.30	2.48	2.24
Albacete	2.17	-7.36	7.25	14.60	0.86	3.24	3.44	1.59
Almería	2.10	-3.27	10.34	13.61	-0.76	4.35	3.60	1.71
Araba	1.38	-8.08	4.96	13.04	0.40	3.39	2.82	2.04
Asturias	2.46	-2.76	5.80	8.55	1.31	3.92	1.85	0.75
Ávila	2.71	-8.09	8.64	16.73	1.70	4.83	3.74	1.38
Badajoz	2.82	-2.99	9.20	12.19	0.86	3.96	2.82	1.00
Barcelona	2.19	-2.48	6.50	8.98	0.56	3.59	2.50	1.14

Bizkaia	2.22	-1.49	7.01	8.50	0.11	3.46	2.21	1.00
Burgos	2.58	-4.07	9.51	13.58	1.60	3.77	2.83	1.10
Cádiz	3.90	-2.45	20.83	23.28	1.71	4.63	4.41	1.13
Cantabria	1.92	-3.78	7.36	11.14	0.22	3.47	2.73	1.42
Castelló	2.04	-4.84	10.26	15.10	0.51	3.07	2.86	1.40
Ciudad Real	1.78	-2.75	8.31	11.07	0.05	4.07	2.68	1.51
Cuenca	2.42	-3.94	9.16	13.10	1.14	3.66	2.59	1.07
Cáceres	2.67	-4.11	10.90	15.01	0.62	4.05	3.32	1.24
Córdoba	2.51	-8.19	8.58	16.77	1.98	4.07	3.77	1.50
Gipuzkoa	2.25	-5.13	6.82	11.95	0.36	4.43	2.75	1.22
Girona	1.55	-3.45	9.86	13.31	-0.96	3.46	2.87	1.85
Granada	2.60	-5.87	8.43	14.30	1.41	3.92	2.56	0.98
Guadalajara	1.61	-5.07	17.94	23.01	-1.29	2.02	5.17	3.21
Huelva	1.89	-6.16	10.26	16.42	-0.65	3.92	3.70	1.96
Huesca	2.49	-9.91	12.66	22.57	1.41	4.11	4.32	1.74
Jaén	2.80	-8.87	11.80	20.67	0.49	4.43	4.55	1.62
La Rioja	2.75	-6.15	15.94	22.09	1.29	3.80	3.55	1.29
León	2.88	-1.28	9.02	10.30	1.55	4.38	2.49	0.86
Lleida	1.94	-2.80	6.17	8.97	0.70	3.42	2.25	1.16
Lugo	2.26	-8.65	9.67	18.32	1.30	3.80	3.49	1.55
Madrid	2.31	-2.05	8.14	10.19	0.90	3.72	2.32	1.00
Murcia	1.74	-2.79	7.49	10.28	0.61	2.79	2.30	1.32
Málaga	1.59	-3.47	5.96	9.43	0.19	3.14	2.28	1.44
Navarra	2.13	-2.20	9.16	11.37	1.32	2.72	2.62	1.23
Orense	3.19	-4.77	10.66	15.43	1.87	4.22	2.88	0.90
Palencia	2.41	-9.58	13.87	23.45	-0.07	4.26	4.80	1.99
Pontevedra	1.93	-2.57	5.95	8.52	0.69	3.40	2.14	1.11
Salamanca	3.39	-6.31	8.08	14.39	1.63	5.54	3.14	0.93
Segovia	2.60	-5.33	11.75	17.08	0.66	4.50	3.61	1.39
Sevilla	2.42	-6.50	7.68	14.18	1.09	3.91	3.06	1.26
Soria	3.03	-6.88	10.75	17.63	0.84	5.03	3.75	1.24
Tarragona	1.48	-3.90	9.83	13.73	-0.92	3.62	3.08	2.08
Teruel	2.37	-19.37	14.10	33.46	0.10	5.03	5.88	2.48
Toledo	1.72	-9.13	12.18	21.31	0.24	2.83	3.97	2.31
València	2.27	-3.61	6.25	9.87	1.13	4.06	2.25	0.99
Valladolid	2.46	-6.79	6.66	13.45	1.43	4.62	2.76	1.12
Zamora	3.20	-10.49	13.21	23.70	2.17	5.02	4.18	1.31
Zaragoza	2.61	-2.58	7.74	10.32	1.74	3.83	2.39	0.92
Total	2.32	-19.37	20.83	40.20	0.71	3.91	3.25	1.40

Source: Own calculations based on INE

Among the explanatory variables, we introduced the logarithm of the initial level of *per capita* GDP (GDP_t) to capture the effects on economic growth of the region´s initial advantage, which may influence its responsiveness to public investment. In addition, we are interested in its coefficient in order to test the β-convergence.

Second, in order to assess the role of infrastructures, we considered the *per capita* regional and interregional public investment in infrastructures, disaggregated into network infrastructures (roads and railways) and single infrastructures (airports and ports). We incorporated as well the regional private investment. Furthermore, the effect of these variables over the neighboring regions was considered in order to capture the potential indirect effects related to infrastructures investment. Overall, we expected positive coefficients, since investment plays an important role in promoting growth. It is worth to note that investment variables were also included in logarithms. See Table 2 for the descriptive statistics of the investment variables.

Table 2- Disaggregation of investment, mean values (thousands of constant euros, 2000)

Province	Roads	Airports	Railways	Ports
A Coruña	134,158	9,369	31,985	37,373
Alacant	100,190	7,282	19,717	10,122
Albacete	176,444	1,286	49,046	0
Almeria	183,904	6,673	6,732	25,490
Araba	202,636	7,790	13,465	0
Asturias	214,640	2,725	44,240	32,546
Avila	226,627	0	29,624	0
Badajoz	151,603	447	12,721	0
Barcelona	72,483	19,741	52,776	12,734
Bizkaia	130,888	9,161	51,326	36,525
Burgos	221,841	0	27,105	0
Cadiz	214,217	0	13,817	0
Cantabria	87,532	3,324	16,199	42,826
Castello	239,837	2,665	25,485	29,108
Ciudad Real	171,152	0	54,478	26,835
Cuenca	150,654	0	79,390	0
Caceres	118,184	771	102,199	0
Cordoba	420,106	0	57,836	0
Gipuzkoa	147,746	1,374	38,648	18,437
Girona	169,041	4,377	29,703	7,105

Granada	157,565	2,539	9,708	5,311
Guadalajara	324,624	0	127,473	0
Huelva	158,222	0	7,502	36,697
Huesca	329,712	0	82,593	0
Jaen	157,707	0	10,487	0
La Rioja	150,333	3,096	8,267	0
Leon	259,508	3,313	65,202	0
Lleida	301,693	0	79,644	0
Lugo	295,950	0	15,795	13,274
Madrid	65,024	46,479	81,858	0
Murcia	117,001	23,395	28,487	14,445
Malaga	104,372	1,586	9,108	13,210
Navarra	185,506	2,317	12,632	0
Ourense	191,631	0	27,977	0
Palencia	254,156	0	48,495	0
Pontevedra	150,142	3,607	23,222	23,632
Salamanca	182,742	2,094	23,029	0
Segovia	311,842	0	137,331	0
Sevilla	88,484	8,981	39,380	5,790
Soria	375,221	0	121,316	0
Tarragona	177,467	4,113	95,675	43,710
Teruel	421,171	0	21,977	0
Toledo	197,459	39	49,775	0
Valencia	98,716	4,258	53,013	19,971
Valladolid	130,509	3,597	29,892	0
Zamora	286,881	0	9,288	0
Zaragoza	106,966	3,209	128,860	0
Total	193,925	4,034	44,776	9,684

Source: Own calculations based on IVIE

Literature recommends including some control variables in the estimation of regional product. Following Rodríguez-Pose et al. (2012), Calderón and Chong (2004) and Del Bo et al. (2010), we include the control variables in the model to account for regional differences in the equilibrium values of the stationary states, as indicated by the conditional β-convergence model. In particular, we use the following covariates:

- *Population density*. Population density is generally used in transport literature to denote regional agglomeration and congestion processes. Theory is not clear whether the sign of this coefficient should be positive or negative. A positive sign would indicate that the more densely populated regions attract most of the economic activity. However, when the density exceeds a certain level, its effect on economic growth can be negative, due to congestion.

- *Sectoral labor productivity.* The labor productivity for a particular sector (services, industry and agriculture) in a given province is defined as the real output (gross value added, GVA) divided by the total hours worked in the respective sector and province[1]. It represents the efficiency with which inputs are used in an economy to produce goods and services. The higher the productivity, the greater is the efficiency in the given sector. Thus, we expect the estimated coefficient of this variable to be positive.
- *Sectoral composition (Industrial and agricultural share).* We calculated the sectoral composition as the share of industrial and agricultural GVA to total regional GVA. The estimated coefficients of these variables are expected to be positive, although we consider that industrial regions are among of the main sources of GDP.
- *Per capita value of the human capital for the employed population.* This variable provides a measure of the educational level of the labor force in the region. It is measured in equivalent workers where the reference is a man younger than 20 years without education or with incomplete primary.

Regarding the distribution of the per capita GDP among the Spanish provinces, we find geographical inequalities along the territory. Figure 4 depicts the evolution, in four different years along the studied period: 1980, 1990, 2000, and 2008, from left to right, respectively. As can be seen, the richer regions are situated at the northeast of the country, whereas the poorer are at the southwest. This distribution pattern relatively maintains over the period. Figure 5 shows the distribution of the per capita GDP growth over 1990-1980, 2000-1990 and 2009-1999. In this case the distribution pattern is less clear, although it can be seen that the fastest growing areas are those with the lowest per capita GDP.

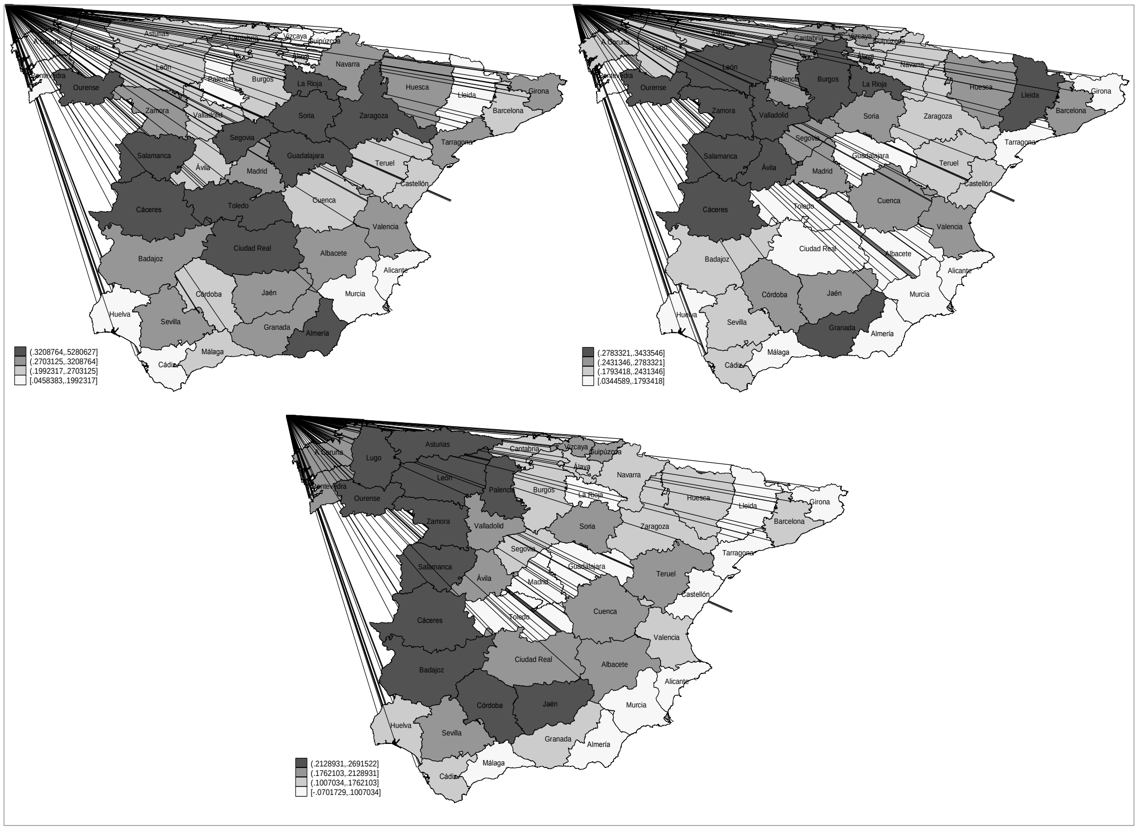
Figure 6 depicts a dispersion graph for the whole sample. The annual growth rate of *per capita* GDP is on the y-axis and the initial level of output in the x-axis. It can be seen a negative relationship between both variables, which gives an idea about the validity of the convergence hypothesis.

[1] Cambridge econometric provides the total hours worked at NUTS2 level.

Figure 4- Distribution of per capita GDP among regions, years 1980-1990-2000-2008

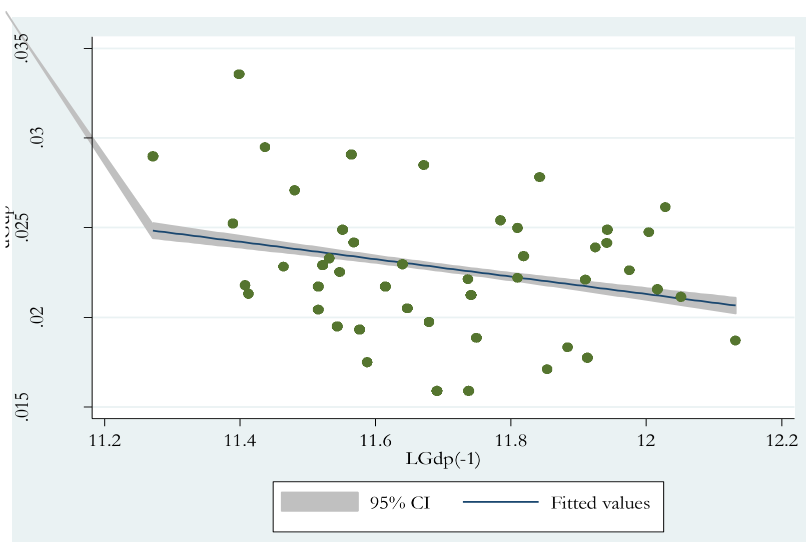
Source: Own elaboration based on INE

Figure 5- Distribution of per capita GDP growth among regions, periods (90-80) (00-90) (09-99)



Source: Own calculations based on INE

Figure 6- Relationship between the annual growth rate of *per capita* GDP and the initial level of output. All Sample.



Source: Own elaboration based on INE

4. The Empirical strategy

In this section we describe the methodology used to test the guiding hypotheses of the work. The hypothesis to validate is whether there has been a process of economic convergence among Spanish provinces during the period 1980-2008. A complementary hypothesis is the role of public investment in transport infrastructures. In particular, we are interested in assess whether public investment in transport infrastructures are significant in explaining regional convergence as well as significant contributors to regional GDP.

The process of economic convergence at country or regional level refers to an inversely relationship between the growth rate of per capita income and the starting level of per capita income. In particular, it is a situation where the gap in per capita output among regions tends to decrease over time.

Empirically, the most popular model of convergence is the "β-convergence model" developed in Barro and Sala-i-Martin (1992a) and Sala i Martin (1996). In this framework, the process in which the poor regions grow faster than the rich ones in the transition to the steady-state is measured by the coefficient β of the estimated regression. There is evidence of convergence if β is negative and statistically significant.

Overall, we conducted a panel data analysis to consider both the cross-section and time series dimensions of the processes. Additionally, the analysis includes a spatial panel data specification, in order to capture for potential externalities. We applied the Moran's I test as an indicator of the spatial autocorrelation. The index indicated the presence of significant spatial autocorrelation in the models, supporting the inclusion of spatial factors.

There are three main models proposed in the spatial econometrics literature. The Spatial Durbin Model (SDM) controls for endogenous spillovers including the spatially lagged dependent variable and for exogenous spillovers using spatial lags in the regressors. The Spatial Autoregressive Model (SAR) only includes a spatially lagged dependent variable, while the Spatial Error Model (SEM) contains a spatially correlated error component.

The different motivations for using spatial models can suggest than one may be more appropriate than other according to the context in which it applies (LeSage and Pace, 2009). The final selection of the models specification was driven by Wald tests and LR tests, the former shows that the SDM is to be adopted against SAR and the latter rejected the SEM.

The implication to our study is that the economic performance of a particular region depends, to some extent, of the value that the variable assumes in nearby areas, what justifies the inclusion of a spatially lagged dependent variable. Moreover, a change in an independent variable for a particular province potentially affects the economic activity in all other observations.

Indeed, there is some evidence that better transport infrastructures also affect in neighbor regions which permit the inclusion of spatially lagged explanatory variables (Cantos et al. 2005; Alvarez et al., 2006; Delgado and Álvarez , 2007; Moreno and Lopez-Bazo, 2007; Gomez-Antonio and Fingleton, 2009; Del Bo and Florio, 2012; Baños et al., 2013; Fageda and Gonzalez-Aregall, 2014). In addition, the SDM contains the other two models and has the attribute of giving unbiased estimates, even if the true economic process is SAR or SEM (Elhorst, 2010).

Regarding the empirical strategy itself, in a first stage we focused on testing the absolute convergence hypothesis. In this sense, we performed an absolute convergence estimation using the whole sample of 47 provinces, with the annual growth rate of *per capita* GDP as the endogenous variable and the initial level of *per capita* GDP (in logs) as the explanatory.

The specification of the SDM model, for the corresponding province *i* in year *t*, is as follows:

$$\Delta GDP_{it+1,t} = \alpha + \beta \ln(GDP_{it}) + W\gamma \ln(GDP_{it}) + \mu_i + \epsilon_{it} \qquad (1)$$

In a second stage, we examined the role of transport infrastructures on regional growth. We applied a similar procedure to the case of the absolute convergence, in this case we added up the disaggregation of transport infrastructures (see equation 2).

$$\Delta GDP_{it+1,t} = \alpha + \beta \ln(GDP_{it}) + \gamma_1 ln(Network_{it}) + \gamma_2 \ln(Single_{it}) + W\gamma_3 ln(Network_{it}) + W\gamma_4 \ln(Single_{it}) + \mu_i + \epsilon_{it} \qquad (2)$$

Finally, we tested the impact of transport infrastructures on *per capita* GDP[2].

$$GDP_{it} = \alpha + \beta_1 ln(Network_{it-1}) + \beta_2 \ln(Single_{it-1}) + \beta_3 PopDensity_{it} + \beta_4 Lproductivity\_a_{it} + \beta_5 Lproductivity\_i_{it} + \beta_6 Lproductivity\_s_{it} + \beta_7 Share\_a_{it} + +\beta_8 Share_{i_{it}} + \beta_9\, Valuehk_{it} + \beta_{10} WGDP_{it} + \beta_{11} Wln(Network_{it}) + \beta_{12} W \ln(Single_{it}) + \mu_i + \epsilon_{it} \quad (3)$$

In the three equations above, μ_i are individual fixed effects and W (N×N) are the spatial weights matrices which summarizes the arrangements of the N spatial units in the sample. In general, the literature does not recommend the random effects model for this type of estimates (Elhorst, 2012b). In addition, the fixed effects model allows control of omitted variables that correlate with the dependent variables and are invariant over time. In this respect, the fixed effects model only captures the variation within the data.

Each element of W is called the spatial weight, w_{ij}. The spatial weights capture the neighborhood, being different from zero when the regions i and j are considered neighbors. By convention, no region can be a neighbor of itself, so the main diagonal of W has all its elements equal to zero ($w_{ii} = 0$).

The spatial weights matrix occupies a central position in spatial econometrics as it defines the set of neighbors for each location. A weakness that has been attributed to spatial econometric models is that the election of the weights matrix will influence the rest of the analysis (Elhorst, 2010). In the econometric practice, the contact matrix is constructed using different criteria. These criteria range from the use of the geographical position to the use of flows that capture social interactions and other sources of socio-economic information. The geographical criteria have the advantage of being exogenous to the model, since the election of neighbors does not responds to variables considered in the analysis, as suggested by Anselin (1988, 2001).

[2] In a preliminary version, a dynamic panel data analysis was included, by performing the first-difference GMM technique on economic growth. These results were not much in line with literature and presented several interpretation problems. A possible explanation might be that, even though the GMM estimator has the advantage of eliminating any problem of endogeneity; it also has the disadvantage of not allowing incorporating heterogeneity between regions when it is not captured by the explanatory variables.

Once selected the space weights, it is usual to work with any transformation to improve the statistical properties of the estimators and contrasts. The most commonly used is the row standardization.

We estimated a SDM with three different specifications of the distance matrix: standardized contiguity matrix, standardized inverse matrix of the squared distance and the five nearer neighbors matrix. First, we considered a row standardized contiguity matrix (W_contiguity) with elements $w_{ij} \neq 0$ when two provinces share a common border and $w_{ij} = 0$ in other case. This matrix assumes that interregional effects are present only between bordering provinces. In a second place, we compute a row standardized inverse matrix of squared distance (W_distance) based on the geographical situation of the provincial capitals. The assumption behind this specification is that all regions contribute to spatial spillovers according to the distance between each other and penalizing heavily the higher distances. In order to check for the robustness of the results, we finally constructed a row standardized five nearer neighbors matrix (W_nearestn), in which the elements $w_{ij} \neq 0$ are the five closest provinces. In this case, we relax the assumptions made for the first matrix, including more elements in the interactional space.

When analyzing the results, the total effect can be decomposed into a direct and an indirect effect. The direct effect captures the effect on the region itself to a unit change in the explanatory variable. This change will be unique in each region. The indirect effect is the one associated to the spatial spillovers.

Overall, the expected signs of the spatially lagged variables are unclear. In relation to the network investment, the expected direction of the spillovers is a priori undetermined. A positive effect may be explained to the better connectivity of improved roads and railways beyond the place where the investment was allocated. It may be negative, as well, due to the attraction that better infrastructures made to the productive factors from other regions.

For the case of single investment, the provinces situated closer to well-endowed regions can benefit from easier access to a wider range of goods belonging from distant markets, while the provinces with large ports and/or airports can also attract productive factors from regions with poor activity.

5. Results

The empirical analysis is exposed in three sub-sections. Sub-section 5.1 presents our empirical results regarding the absolute β-convergence process taking annual growth rates. In Sub-section 5.2 we allow for the possibility of multiple steady states and try to verify the conditional β-convergence hypothesis, taking into account different components of public investment in transport infrastructures. Our main concern in this section is to examine the contribution of regional public transport endowment on the Spanish province´s rates of growth and test to what extent investment in transport infrastructures is influencing the convergence process. Finally, Sub-section 5.3 assesses the impact of infrastructure investment on regional GDP.

It is worth to note that the spatial autocorrelation coefficient (*rho*) is significant in all specifications, which evidences that Spanish provinces are spatially interconnected. Additionally, we computed the Hausman test in all specifications to select between fixed and random effects. In all cases the fixed effects model is more suitable for our spatial panel models.

5.1. Absolute β-convergence

Table 3 reports the results of the absolute convergence estimation of the bias-corrected SDM model[3] using the contiguity, the distance and the nearest neighbor weights matrices, respectively. We can find that the signs and significance levels are consistent between the three specifications, although the coefficient differs. Looking at our variable of interest, the empirical evidence suggests the presence of an absolute convergence process among the Spanish provinces along the period. The β-coefficient, that is, the estimated parameter of the initial level of per capita GDP is negative and statistically significant in all specifications. Due to similar levels of technology, factor mobility and regulations this process is more likely among homogeneous regions, as is the case of provinces of the same country. Results are in line with Del Bo et al (2010) for European regions at NUTS 2 level.

[3] We applied the maximum likelihood (ML) estimator to fit the spatial panel data models, as suggested by Anselin (1988). The ML estimation is based on the assumption of normal error terms, and it is implemented in the *xsmle* stata command.

In order to have a preliminary idea of the spatial interactions, Table 3 also notes that the annual growth rate of *per capita* GDP in a province is negatively correlated to the initial level of *per capita* GDP in the neighboring areas. The sign and magnitude of the spatial spillover effects are provided by Table 4.

Table 3. Estimation results of Absolute Convergence (bias-corrected fixed effects)

VARIABLES	W_contiguity	W_distance	W_nearestn
Gdp	-8.339	-8.903	-8.778
	(1.286)***	(1.310)***	(1.271)***
W*Gdp	8.120	8.663	8.631
	(1.331)***	(1.355)***	(1.313)***
rho	0.411	0.450	0.596
	(0.030)***	(0.031)***	(0.030)***
sigma2_e	8.723	8.714	8.175
	(0.351)***	(0.350)***	(0.328)***
Spatial specific effects	YES	YES	YES
Observations	1,269	1,269	1,269
R-squared	0.016	0.017	0.018
Log-likelihood	-3,202.55	-3,198.97	-3,161.12

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Absolute Convergence, the direct and indirect effects of the explanatory variable

VARIABLES		W_contiguity	W_distance	W_nearestn
Gdp	Direct effect	-7.828	-8.459	-8.501
		(1.015)***	(1.048)***	(1.038)***
	Indirect effect	7.502	8.079	8.212
		(1.272)***	(1.329)***	(1.501)***
	Total effect	-0.326	-0.381	-0.288
		(0.740)	(0.781)	(1.039)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As Table 4 shows, the total effect of the independent variable is not significant. The indirect effect of the initial level of *per capita* GDP is positive and statistically significant, which means that it does not only contribute to the dependent variable directly but also indirectly through spatial spillovers. Indeed, the contribution of a particular region to the growth rate of the neighboring areas is positive, whereas the impact on the own growth rate of the per capita GDP is negative. Likewise, the findings are in line with the β-convergence hypothesis.

5.2. Conditional β-convergence

Moving on to the analysis of the conditional convergence, tables 5 and 6 display the estimation results of equation (2) which includes variables of transport infrastructure investment.

Table 5. Estimation results of Conditional Convergence (bias-corrected fixed effects)

VARIABLES	W_contiguity	W_distance	W_nearestn
Gdp	-8.9450	-9.2353	-9.2955
	(1.305)***	(1.320)***	(1.285)***
Single	0.0104	0.0001	0.0068
	(0.037)	(0.037)	(0.036)
Network	0.3933	0.3597	0.3708
	(0.201)*	(0.201)*	(0.204)*
W*Gdp	8.2552	8.6313	9.2217
	(1.454)***	(1.483)***	(1.513)***
W*Single	-0.1489	-0.1323	-0.1897
	(0.076)*	(0.080)*	(0.098)*
W*Network	0.0343	0.0248	-0.1477
	(0.291)	(0.307)	(0.338)
rho	0.4161	0.4439	0.5927
	(0.030)***	(0.031)***	(0.033)***
sigma2_e	8.6641	8.6697	8.1246
	(0.349)***	(0.348)***	(0.326)***
Spatial specific effects	YES	YES	YES
Observations	1,269	1,269	1,269
R-squared	0.019	0.021	0.021
Log-likelihood	-3197.73	-3195.03	-3156.89

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Evidence still demonstrates the presence of a β-convergence process, even with the introduction of investment variables in the model. In this case, the estimated β-coefficients are slightly higher in absolute terms, that could reflect transport infrastructure contribute to the acceleration of the process of convergence.

In all cases, network infrastructures have an impact of greater magnitude than single infrastructure. This can be attributed to the fact that investment in networks represents a large proportion of the total investment in the transport sector.

The estimation suggests the presence of a significant positive association between *per capita* network investment and regional growth. In contrast, the coefficients reported for the *per capita* single investment are not significant in any case.

The accurate interactions among provinces are provided in Table 6. With concerns to the *per capita* GDP, the results remain unchanged to the first estimation. The inclusion of transport variables has slightly increased the magnitudes of the impact.

Regarding the transport infrastructure, our empirical evidence suggests that the impact to regional economic growth is poor. For the case of networks, the direct contribution to the dependent variable is positive and significant at the 10% level (at 5% for the contiguity matrix), whereas the indirect contribution is not significant. Likewise, the estimated coefficient of the total effect is positive and statistically significant only at the 10% level for the contiguity weight matrix.

The argument that transport infrastructure allow for greater economic benefits than just the direct effect on the particular region is based on its specific attributes previously explained. This is mainly expected for the case of network infrastructures (roads and railways). Our weak result may be explained by the great expansion of Spanish high-speed railways in the period, designed almost exclusively for passenger transport with little support for freight transport. The limited increase of freight rail transport seems to have weakened the capacity of the transport infrastructure in promoting regional equality (Puga, 2002; Albalate et al., 2013; Fageda and Gonzalez-Aregall, 2014).

For the case of single infrastructure, the estimated coefficients are negative in all cases. The direct impact of single investment on regional growth is not statistically significant. In contrast, the spatial interactions reflect a significant influence of single investment to the economic growth of neighboring areas. Overall, the total effect is not significant regardless of the weight matrix used.

Our results are in line with those obtained by Del Bo et al (2010) about the impact of infrastructures on European regional convergence, particularly transport infrastructure. In contrast, Rodríguez-Pose et al (2012) pointed out an unclear contribution of public investment to narrow de development gap across Greek prefectures. The spillover effects show a disagreement with the literature, both articles found positive and significant indirect effects of transport infrastructures in the process.

Table 6. Conditional Convergence, the direct and indirect effects of the explanatory variables

VARIABLES		W_contiguity	W_distance	W_nearestn
Gdp	Direct effect	-8.4550	-8.8176	-8.9978
		(1.040)***	(1.065)***	(1.054)***
	Indirect effect	7.2543	7.7071	8.8101
		(1.473)***	(1.598)***	(2.110)***
	Total effect	-1.2007	-1.1105	-0.1877
		(1.180)	(1.341)	(1.902)
Single	Direct effect	-0.0013	-0.0083	-0.0048
		(0.044)	(0.044)	(0.043)
	Indirect effect	-0.2067	-0.1981	-0.3987
		(0.124)*	(0.141)	(0.242)*
	Total effect	-0.2080	-0.2064	-0.4036
		(0.150)	(0.167)	(0.266)
Network	Direct effect	0.4288	0.3906	0.3892
		(0.215)**	(0.216)*	(0.218)*
	Indirect effect	0.3468	0.3469	0.2050
		(0.410)	(0.461)	(0.673)
	Total effect	0.7756	0.7375	0.5942
		(0.473)	(0.524)	(0.720)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.3. Transport infrastructure and *per capita* GDP

This sub-section reflects our findings of the impact of transport infrastructure on regional *per capita* GDP, including the set of control variables previously described (equation 3). Results are revealed in tables 7 and 8.

Focusing first on the main results of the estimations (see Table 7) the different components of transport infrastructure present positive and highly significant parameters, as expected.

Observing our control variables, it can be seen that the regional sectoral shares and the value of the human capital play an important role in promoting growth, in line with theory. In addition, population density is negatively related to the dependent variable, which possibly refers to a congestion process, as mentioned above.

By contrast, the negative coefficients of the agricultural labor productivity are not consistent with expectations. A possible explanation might be that areas specialized in services and industrial regions are the major contributors to the GDP. It is worth noting that the agriculture coefficients are not significant.

Considering the impact of transport infrastructure (see table 8) we find positive and highly significant total, direct and indirect effects of network and single investment on regional GDP. These means that public investment on transport infrastructure not only contribute to the regional output directly, but indirectly through spatial interactions.

Although both are positive, there are some differences in the impact of the modes of transport. The magnitude is greater for the case of the network infrastructure, which are roads and railways. Airports and ports, the infrastructures that form the single mode show a slightly smaller coefficient. In all cases, the indirect effect is greater than de direct effect.

The findings related to total and direct effects are in line with the literature. However, with regards to the indirect effects results are not consistent with previous articles. In particular, Fageda and Gonzalez-Aregall (2014) found negative spatial spillovers of ports and not significant spillovers of airports, in an analysis that focuses on industrial employment.

Table 7. Estimation results of the impacts on *per capita* GDP (bias-corrected fixed effects)

VARIABLES	W_contiguity	W_distance	W_nearestn
Single(-1)	0.0032	0.0026	0.0028
	(0.001)***	(0.001)***	(0.001)***
Network(-1)	0.0192	0.0169	0.0150
	(0.004)***	(0.004)***	(0.004)***
PopDensity	-0.5313	-0.5233	-0.5568
	(0.030)***	(0.029)***	(0.029)***
Lproductivity_a	-0.0031	-0.0031	-0.0036
	(0.002)	(0.002)	(0.002)*
Lproductivity_i	0.0067	0.0057	0.0047
	(0.002)***	(0.002)***	(0.002)***
Lproductivity_s	0.0201	0.0197	0.0193

	(0.004)***	(0.004)***	(0.004)***
Share_a	0.0044	0.0057	0.0046
	(0.001)***	(0.001)***	(0.001)***
Share_i	0.0044	0.0056	0.0053
	(0.001)***	(0.001)***	(0.001)***
Valuehk	0.0444	0.0143	0.0017
	(0.015)***	(0.015)	(0.014)
W*Single(-1)	0.0030	0.0084	0.0058
	(0.001)**	(0.001)***	(0.002)***
W*Network(-1)	0.0055	0.0094	0.0036
	(0.005)	(0.005)*	(0.006)
Rho	0.8940	0.9065	0.9507
	(0.012)***	(0.012)***	(0.009)***
sigma2_e	0.0027	0.0026	0.0025
	(0.000)***	(0.000)***	(0.000)***
Spatial specific effects	YES	YES	YES
Observations	1,222	1,222	1,222
R-squared	0.3286	0.224	0.027
Log-likelihood	1688.69	1748.19	1815.05

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Impacts on per capita GDP, the direct and indirect effects of the transport infrastructure explanatory variables

VARIABLES		W_contiguity	W_distance	W_nearestn
Single(-1)	Direct effect	0.0068	0.0087	0.0072
		(0.001)***	(0.001)***	(0.001)***
	Indirect effect	0.0512	0.1078	0.1675
		(0.013)***	(0.017)***	(0.041)***
	Total effect	0.0579	0.1165	0.1747
		(0.014)***	(0.018)***	(0.042)***
Network(-1)	Direct effect	0.0334	0.0313	0.0248
		(0.005)***	(0.005)***	(0.005)***
	Indirect effect	0.1993	0.2487	0.3537
		(0.039)***	(0.047)***	(0.100)***
	Total effect	0.2326	0.2800	0.3785
		(0.043)***	(0.050)***	(0.103)***

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

In this article we use spatial econometric techniques to analyze the β-convergence process both of the absolute and conditional type, and the role of transport infrastructures on regional *per capita* GDP. Considering data from 1980 to 2008, we have found strong evidence of absolute convergence occurring across Spanish provinces.

This result holds also when we move on to consider conditional convergence, and take explicitly account of the role of infrastructure. However, we found little impact of investment in transport infrastructure. The most direct influential role was exerted by the network mode. The direct impact of the single mode was not proved and can be related to an overcapacity phenomenon given in Spain (excess of supply of transport infrastructure). With regards to the spillover effects, we found negative impact of the single infrastructure and not significant effect of networks.

Finally, we found positive and highly significant total, direct and indirect effects of network and single investment on regional *per capita* GDP. This is an interesting result; in particular the positive sign of the spatial spillovers is not in line with previous literature on the issue.

Our findings also contribute to the debate on the distribution of public resources. Regional policies in the EU, and particularly in Spain, have been widely promoted by successive governments, using infrastructure investment as the main tool in fostering equality. However, the large investment in transport infrastructure does not seem to have contributed much to the reduction of regional disparities. In this context, the policy implication that derives directly from the results is that it seems unnecessary to allocate such amount of resources to this specific policy in pursuit of regional convergence. Considerations of efficiency and demand should be taken into account, in order to achieve the best allocation of public resources and maximize the contribution of investment in infrastructure on economic growth.

Regarding the limitations and suggestions for future research, a possible omission of this study is that it overlooks the role played by political and institutional factors. We have seen that political decisions play an important role in determining the allocation of public resources across the country. Thus, it could be interesting to study this issue in detail, including more specific control variables.

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