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ABSTRACT: This paper analyses the relationship between road infrastructure improvements and investment in capital assets. Using aggregate data at a provincial level for 1977-2008, an equation for machinery and equipment investment is estimated applying Panel Corrected Standard Errors. The results indicate that the long-term elasticities of investment in relation to market potential, GDP and average years of schooling are 0.90, 0.75 and 0.80, respectively. Additionally, the long run impact of a road infrastructure investment policy is assessed. We find that the elasticities of investment in machinery and equipment, capital stock and GDP in relation to travel time are 1.18, 0.33 and 0.11, respectively.

JEL Codes: R4, R11
Keywords: Road infraestructure, Regional investment, Market potential, Travel time

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1. INTRODUCTION

Major investment plans have been undertaken in recent decades in Spain to improve and expand road infrastructures nationwide, part of them being financed by European funds. Consequently, today, Spain has the highest number of kilometres of motorways among European Union countries and it is well above the average in per capita and square kilometre terms. On this basis, one must ask what the effects of these investments have been on the Spanish economy.

The literature has analysed this subject from two perspectives: first, considering the effects on the location of economic activity and, second, in terms of its impact on economic growth. From the point of view of location of economic activity, the literature indicates that firms would prefer regions with a high quality road network, since this represents lower transport costs, greater productivity (due to the benefits arising from agglomeration economies) and more opportunities to access other markets (Graham, 2007; Holl, 2011). The public authorities can likewise use transport policy to influence the location decisions of firms and thus attract investments, create employment and increase the productivity of existing firms.

From the macroeconomic viewpoint, investments in public infrastructures have been analysed extensively, considering their effect on GDP or productivity. In this respect, the first results which identified a highly positive effect (starting with the work by Aschauer, 1989) were, subsequently, discussed and qualified (for a review, see Bom and Ligthart, 2014; and Straub, 2008; for Spain, see De la Fuente, 2010 and Boscá, et al 2011). At present, the literature maintains that infrastructures are important for economic growth, but warns that investment can lead to positive growth only for those projects that effectively reduce transport costs to the markets[1]. In other words, no positive effect can be expected from those projects that result in overinvestment in infrastructure (European Commission, 2014; IMF, 2014).

In this context, this paper contributes to the literature in several aspects. First, unlike the majority of works which consider GDP, productivity or the location of new plants or firms, this study analyses the impact of road infrastructures on the location of investments in capital assets. Despite the fact that investment is a relevant variable for economic growth, to the best of our knowledge only two studies have considered this variable (Brown et al, 2011 and Escribá and Murgui, 2008), approached through industrial or manufacturing investment. The impact of investment on economic activity depends on the type of capital asset in which it takes place. In our case, we focus on investment in machinery and equipment assets (including software, computers and mechanical and communications equipment), which are a key element for innovation and economic growth. Second, this paper proposes a novel methodology to assess the long run impact on the economy of a road infrastructure investment policy by allowing second round effects. This proposal defines a system of equations which captures the feedback effects among the variables of the model. Specifically, we define a system of four equations including market potential, machinery and equipment investment, total capital stock and GDP growth. After estimating the investment equation, we compute the impact of an improvement in the road network resulting in a 10% saving in travel time. On solving the system of equations simultaneously and dynamically, on average, the policy would result in a 12.18% increase in market potential, an 11.81% increase in machinery and equipment investment, 3.25% in total capital stock and 1.12% in GDP. Third, there is a rich database to carry out the empirical analysis. The time span – between 1977 and

[1] Melo et al (2013) provide a meta-analysis of the empirical evidence on the effect of transport infrastructure on economic output.

2008 – covers the period with the highest investment flow in capital assets in Spain. At the same time, the motorway network developed from a rather poor level of 1753 kilometres in 1977 to one of the highest in the EU: 13,518 kilometres in 2008. Moreover, the spatial disaggregation at provincial level allows taking advantage of using a broad panel data consisting of 46 cross sections and 32 years. Previous studies carried out for Spain do not cover all this period and, in some cases, the spatial disaggregation is lower. For example, Escribá and Murgui (2008) use a panel data consisting of 17 regions and the period 1964-2000; Cantos et al (2005) consider 17 regions and the period 1965-1995, while Nombela (2005) uses province-level data for the period 1980-2000, Holl (2004a) uses municipality-level microdata to assess the location of new manufacturing plants between 1980 and 1994 and Matas et al (2015) use microdata to estimate the impact of infrastructure investment on wages for three different points in time: 1995, 2002 and 2006.

The remainder of the paper is organized as follows. Section 2 discusses the related literature. Section 3 explains the main changes in the road network and describes the data and variables. Section 4 presents the model and the econometric methodology. Section 5 reports the results of the estimation and the analysis of the impact of a road infrastructure investment policy on the economy. The paper concludes with final remarks in section 6.

2. RELATED LITERATURE

From the initial studies of the location theory under the classical and neoclassical models to the most recent developments of New Economic Geography (NEG), transport costs have played a central role in the derivation of the fundamentals explaining the spatial distribution of economic activity.

At the beginning of the 20th century, the theory on the location of economic activity made headway with the works by Alfred Weber and the following generalizations and extensions raised by Leon Moses, Walter Isard, Melvin Greenhut, Edgar Hoover, among others. Under the assumptions of rational economic agents and perfect information, the optimal location is defined in terms of minimization of transport costs (McCann, 2001; Dawkins, 2003). Likewise, in the studies developed by Hotelling in 1929 and Palander in 1935, transport costs are a key component within the spatial competition approach.

Subsequently, starting with the work by Krugman (1991) and the emergence of NEG, special emphasis is again placed on transport costs to understand the dynamics of the location of economic activity and its effects on the unequal spatial distribution of production, employment and income (Puga, 2008).

As Redding (2009) explains, location decisions are determined by the tension between two forces: an agglomeration force which promotes the geographical concentration of economic activity, and a dispersion force which leads to a more equal distribution of the economic activity. The balance between these two forces is determined by transport costs. Variations in transport costs thus induce changes in the distribution of economic activity across a space.

Those forces attributed to the interaction of economic agents with the ability to cause an unequal development between regions are called second-nature forces. By contrast, first-nature forces are due to factors such as the natural resource endowment, climatic conditions and closeness to natural communication facilities. While NEG gives more importance to second-nature forces, the traditional location theory highlights the role of first-nature forces in determining the spatial distribution of economic activity (Ottaviano, 2008).

For these reasons, transport infrastructures play a key role in location models of economic activity, both from the perspective of traditional location theory and NEG. In this respect, investments in transport infrastructures could reduce transport costs to output and input markets and, furthermore, increase the number of potential markets that can be accessed. Combes et al, (2008), Ottaviano (2008) and Puga (2008) therefore maintain that the attraction of a location depends both on the relative size of its market and on the capacity and quality of its transport network to connect areas. Both dimensions can be captured by the market potential accessibility index proposed by Harris (1954), which could be interpreted as the volume of economic activity that is accessible from a region inversely weighted by the distance-related costs.

In this respect, the literature suggests a positive effect of market potential on the location of economic activity. In particular, Head and Mayer (2004) estimate a location model for Japanese firms located in several European countries during the period 1984-1995, and conclude that market potential played an important role in the location decisions of these firms. Moreover, Holl (2004a) finds that the improvements in Spanish road infrastructures between 1980 and 1994 (measured through market potential) influenced the location decisions of manufacturing plants. Using data for several years (1860, 1896, 1930, 1982, 2000), Combes, et al (2011) find that market potential was the main determinant in the spatial distribution of economic activity in France between 1860 and 1930 but it became less important with the fall in transport costs in the following decades.

Apart from transport infrastructures, the neoclassical theory also highlights other profit or cost-driving factors that determine the location of economic activity, such as agglomeration economies and labour market conditions (Arauzo-Carod, et al, 2010).

In this respect, agglomeration economies have been extensively documented in the literature as one of the most important determinants of production location decisions. These come from the cost reduction as economic activity is concentrated in a particular geographic area, helping the interaction between economic agents and generating greater productivity, investment and regional growth (Ciccone and Hall, 1996; Rosenthal and Strange, 2001).

Consequently, agglomeration economies are expected to be a factor attracting firms and investments toward regions. Indeed, Brown et al (2009), using state-level data for the United States between 1995 and 2006, find that agglomeration economies attract greater flows of industrial investment to regions. Escribá and Murgui (2011), using autonomous community level data, conclude that regional diversification (approximated by the Herfindahl index) and density of employment were determinant factors in the location of business investment in Spain between 1995 and 2007. Likewise, Smith and Florida (1994) for the United States; Guimaraes et al (2000) for Portugal; and Head and Mayer (2004) for Europe, conclude that agglomeration economies were crucial for the spatial distribution of foreign firms within their territories.

In addition, the empirical literature has found significant evidence of the relationship between labour market conditions and the spatial pattern of the location of economic activity. This analysis uses variables which capture the characteristics of human capital (such as average years of schooling, percentage of the population with a certain level of education) and labour costs (such as average wage per worker and unit labour costs).

A greater availability of human capital is related to higher productivity. It is therefore expected to be a factor attracting investments. In this respect, Combes et al (2011) provide evidence of the increasingly important role of human capital in the spatial economic structure of France. In a study on Spain for the period 1964-2000, Escribá and

Murgui (2008) conclude that human capital is one of the key factors determining investment flows toward new industrial centres. For Portugal, Holl (2004b) finds that the likelihood of a plant being set up in a municipality is significantly related to higher skills of the labour force in the region.

Finally, higher Unit Labour Costs (ULC) will have a negative impact on business location decisions (Coughlin and Segev, 2000; Davis and Schluter, 2005). Indeed, Davis and Schluter (2005) analyse the characteristics of the labour force which contribute to attracting new food plants in the United States between 1991 and 1997. Their results indicate that those counties with high wages in relation to their productivity attract less investment. Henderson and McNamara (2000) obtain similar results. Escribá and Murgui (2008) find that industrial wages were one of the factors determining changes in industrial investment location in Spanish regions between 1964 and 2000.

Consequently, according to location theory and empirical evidence, it can be said that transport costs ($transport_{it}$), agglomeration economies ($agglomeration_{it}$), human capital (HC_{it}) and labour costs ($labcost_{it}$) are determining factors in the location decisions of firms and, therefore, of investment flows toward regions ($investment_{it}$):

$$investment_{it} = f(transport_{it}, agglomeration_{it}, HC_{it}, labcost_{it}) \quad (1)$$

MODELLING LOCATION DECISIONS

The econometric modelling of location decisions starts with the approach used by Carlton (1979 and 1983), who analyses the determining factors of the location of new industrial firms in the metropolitan areas of the United States using a multinomial logit model.

Discrete choice models and discrete event models are the traditional econometric approaches in empirical studies on location decisions. However, as Arauzo-Carod et al (2010) explain, the selection of the methodology depends on the aim of the study and the availability of the data. Thus, with the passing of time and the greater availability of information, various approaches, specifications, aggregation levels and estimation methods have been applied, with the aim of studying the pattern of spatial distribution of production in different parts of the world.

In addition to the discrete choice and discrete event models applied, for example, by Carlton (1979 and 1983), Cieślik (2005), Holl (2004a, 2004b) and Smith and Florida (1994), other analyses have been undertaken using alternative models, such as Ordinary Least Squares and spatial techniques, including those by Escribá and Murgui (2008), Broadman and Sun (1997), Henderson and McNamara, (2000) and Brown et al (2009).

Moreover, the econometric methodology has been applied using different territorial units, for example countries (Head and Mayer, 2004), states (Brown et al, 2009), counties (Smith and Florida, 1994; Coughlin and Segev, 2000), "*concelhos*" or municipalities (Holl, 2004a; Guimaraes et al, 2000) and provinces (Broadman and Sun, 1997).

Notwithstanding the above, the literature recommends working with sufficiently small spatial units in order to capture the impact of transport investments because, in general, this impact is concentrated at a local level. Our spatial units of analysis are provinces (NUT-3 in the European classification). Unfortunately, investment is not observed at a lower level of spatial disaggregation. Yet, working with provinces guarantees that the variables used in the analysis are more reliable and of better quality than those defined at smaller spatial units.

3. EMPIRICAL ANALYSIS

The purpose of the empirical analysis is to assess the role played by road infrastructure investment in the location of investment in machinery and equipment assets in Spain. The analysis uses aggregate data at a provincial level between 1977 and 2008.

A firm's location choice entails making decisions on where, when and how much to invest. In turn, the type of investment depends on the nature of the economic activity to be carried out. As stated by the Fundación BBVA (2006), machinery and equipment investment is, in general, related to technology intensive and high-productivity sectors. In this regard, investments in such capital assets make the highest contribution to the increase in economic output. Therefore, this study has selected machinery and equipment investment as a way to approximate the potential for economic growth of the different Spanish provinces.

Since our objective is to evaluate the impact of improvements in the road sector, the Canary Islands, Balearic Islands, and the North African cities of Ceuta and Melilla are excluded from the analysis[2]. Our final sample was based on 46 provinces.

CHANGES IN THE ROAD NETWORK

In the late seventies, the quality of the road network in Spain was rather poor compared with European standards. High quality roads were limited to 1800 kilometres of motorways mostly located along the Mediterranean coast and in the Basque Country in the north. From 1983 onwards several road investment plans were implemented that transformed the Spanish motorway network into one of the highest quality in Europe. Essentially, the first investment plan consisted of upgrading the two-lane radial network connecting Madrid with other parts of Spain to motorways, except for those routes for which an alternative toll motorway existed. In later phases, investment decisions followed spatial cohesion arguments more than economic efficiency criteria. From 1993, investment was directed to the construction of motorways connecting the peripheral areas of Spain and it favoured sparsely populated regions with a low level of infrastructural stock.

[2] Additionally, we exclude the province of Guadalajara since data on investment for that province was unreliable. The exclusion of this province does not modify the estimated coefficients.

In order to show which provinces have benefited the most from the investment plans, Figure 1(a) plots the relationship between the reduction in travel time between 1980 and 2007 for each province and their initial travel time to other provinces (in 1980), whereas Figure 1(b) plots the relationship between the reduction in travel time and the GDP per capita in 1980. As can be observed, on the one hand, the most remote provinces in 1980 were those that experienced a greater reduction in travel time. On the other hand, infrastructure investment policy favoured those provinces with lower levels of GDP per capita in 1980[3]. This is the case with Almería, Málaga, Granada, Lugo, and Pontevedra. The richest but least favoured were Girona, Tarragona and Barcelona. Madrid stands out with a high GDP per capita in 1980 and notably favoured by the road infrastructure investment policy.

Figure 1(a) Reduction in travel time vs travel time

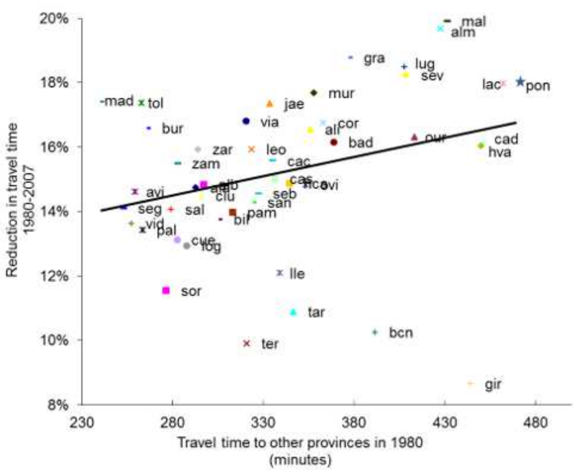
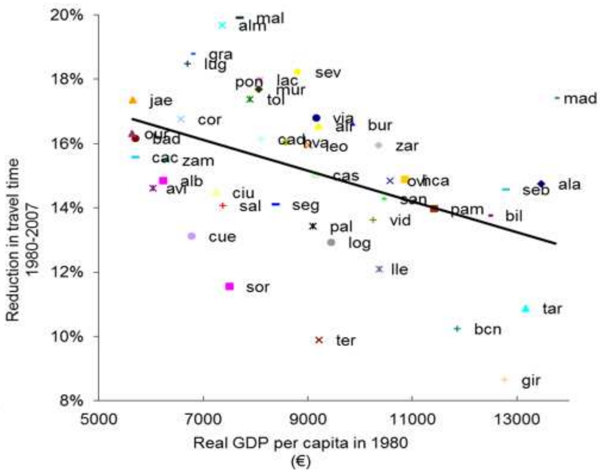


Figure 1(b) Reduction in travel time vs GDP per capita



On the whole, we can say that the development of the road network has not been associated with efficiency criteria, but with spatial cohesion arguments and the consolidation of a radial network focused on the country's capital –Madrid– (Bel, 2011).

[3] Matas, et al (2015) show that infrastructures investment policy consistently favoured low income regions from 1980 to 2011.

Also, it is important to note that the criteria used to improve the road network do not anticipate regional economic growth.

DATA

Machinery and equipment investment

As said above, our variable of interest is real gross investment in machinery and equipment[4]. This heading includes, among others, office machinery and computers; communication machinery and equipment; software; metal products; machinery and mechanical equipment; motor vehicles and other transport equipment. The database comes from Fundación BBVA-IVIE and it provides detailed information on the structure of the investment for each province. Although it is not possible to distinguish between private investment and public investment, the Fundación BBVA (2006) notes that the majority of this investment is carried out by the private sector[5]. Additionally, we cannot distinguish between investment in relocation, replacement or capital increase, so the results show the "net effects" of these investment decisions.

Market potential

The effects of road transport infrastructure on machinery and equipment investment are measured by using the concept of market potential, defined as follows:

$$pot_i = \sum_j \frac{GDP_j}{time_{ij}^{\alpha}}, \forall i \neq j \quad (2)$$

where:

- The economic mass of province j is approximated by real gross domestic product (GDP).

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[4] Machinery and equipment investment corresponds to the heading machinery and equipment (AN 1113) of the European System of Accounts which includes transport equipment (AN11131) and other machinery and equipment (AN11132).

[5] Public investment concentrated on construction assets between 1974 and 2002, while its machinery and equipment investment was, on average, less than 30%.

- Transport costs between provinces are approximated through actual travel time costs. The travel time matrix[6] ($time_{ij}$) is constructed according to the minimum time route observed between provincial capitals, taking into account the type of road, distance and speed. Since changes in road network between two consecutive years are quite small, we divide the sample period into five-year intervals and construct the time matrices for the central year of each of them. Then, we compute the market potential for each year in the interval using the corresponding time matrix for the central year. For instance, 1980 time data is used to compute market potential for 1977-1982. Nonetheless, in order to account for the most recent changes in the road network, we make an exception for the last years in the sample. Thus, we calculate the time matrices for 2005 and 2007 and use these matrices to compute market potential for the periods 2003-2005 and 2006-2008, respectively. To compute travel times we use the ArcGIS network analyst for the national road network in Spain.

- α is a distance-decay parameter. It reflects how the effect of market potential attenuates with distance from the source. It can be seen that if $\alpha=1$, the effect of region *j* on the market potential of *i* is inversely proportional to the transport costs between them. If $\alpha>1$, the speed of decay with the distance is more pronounced. Although its value is an empirical matter that depends on the activity considered and the nature and size of the transport costs, the literature frequently assumes that it is equal to one, including Gutiérrez (2001); Holl, (2011); Graham (2007); Combes, et al (2011). In this study, the distance-decay parameter is estimated together with the rest of the parameters of the investment equation.

Market potential presents several advantages compared with alternative measures of accessibility to markets by road. First, since its calculation does not depend on monetary

[6] Special thanks to Javier Gutiérrez from the Department of Human Geography of the Complutense University of Madrid for providing the time matrix.

units but rather on travel time, quality differences in the road network are better approximated. Moreover, the comparison of the stock of roads and motorways between provinces is more reliable. Another advantage is that since market potential is not bounded by the administrative limits it explicitly takes into account spatial externalities across neighbouring provinces and, in doing so, it reduces the potential for biased results in the econometric estimation (Combes, et al, 2008).

Agglomeration economies

Two variables are used to capture agglomeration economies. The first is regional GDP, as a proxy for the volume of economic activity in the region. The second is related to the economic diversification of the province. Both variables capture urbanization economies.

GDP has been used in several empirical studies as one of the most significant explanatory variables in location models of economic activity, such as Broadman and Sun (1997) and Cieślik (2005). By using GDP as an approximation to agglomeration economies and a measure of market potential as an approximation to accessibility, we distinguish between the effect of size (local demand) and accessibility (external demand) on the decision of investors. Higher GDP is expected to be positively related to higher investments for the provinces. The economic diversification is approximated through the inverse of the Herfindahl index, as follows:

$$diver_i = \frac{1}{Herf_i}\ ; \quad Herf_i = \sum_j \left(\frac{E_{ij}}{E_i}\right)^2$$

where $Herf_i$ is the Herfindahl index for the *i*-th province; E_{ij} is total employment in sector *j*, province *i*; E_i is total employment in province *i*. The data are obtained from the Spanish National Institute of Statistics (INE). We use the two-digit Spanish Economic Activity Classification System (CNAE).

Agglomeration economies are expected to be a factor attracting investment toward the provinces. With risk-averse investors, urbanization economies could capture the preference for regions with a diversified production structure, which reduces the negative effects of specific sectorial shocks. A diversified production structure moreover favours the exchange of complementary knowledge across different activities (Combes, et al 2011; Escribá and Murgui, 2011).

Human capital and labour costs

Human capital is approached through the average years of schooling of the working-age population. The data comes from the Valencian Institute of Economic Research (IVIE). The greater availability of human capital in a province is expected to have an investment attracting effect.

Finally, in order to capture the average labour cost per unit of output produced in the province, we calculate the unit labour costs (ULC), in real terms. ULC is defined as the ratio between labour costs per employee and apparent labour productivity (real GVA/employment), considering only the industry and services sectors. The data on labour costs, number of employees, real GVA and employment are obtained from the BBVA database. Since it is expected that high labour costs deter investment, ULC should have a negative effect on production location decisions.

Summary statistics on key variables are reported in Table 1. With the aim of showing the variables' evolution over time, Table 2 provides the average for each variable in different years.

Table 1 Summary statistics

Variables	Mean	Std. Dev.	Coefficient of variation	Minimum	Maximum
investment (thousands of €, 2000)	826435	1507830	1.82	48302	17200000
market potential	2354	972	0.41	867.12	6453
travel time (minutes)	311.39	143	0.46	27.61	737.56
GDP (millions of €, 2000)	11513	18966	1.65	756.76	159982
diversification	18.26	4.16	0.23	8.51	33.66
ULC (€, 2000)	0.45	0.21	0.46	0.08	1.01
average years of schooling	8.21	1.25	0.15	5.48	11.36

Table 2 Evolution of the variables 1980-2008

	Average						
Variables	1980	1985	1990	1995	2000	2005	2008
investment (thousands of €, 2000)	376107	380759	666649	620800	1190410	1508291	1879040
market potential	1454	1608	2186	2425	3066	3618	3988
travel time (minutes)	335.26	335.14	318.17	302.17	292.34	286.37	283.68
GDP (millions of €, 2000)	7436	8223	10632	11200	13899	16126	17592
diversification	15.88	18.25	18.11	19.34	19.40	19.54	19.46
ULC (€, 2000)	0.17	0.30	0.40	0.53	0.61	0.71	0.77
average years of schooling	6.73	7.26	7.89	8.53	9.12	9.81	9.95

The variables which showed higher growth over the 32-year period were machinery and equipment investment and ULC, with average annual growth rates above 5% in both cases. On the other hand, the highest variability was presented by investment and GDP.

The greater volatility of the machinery and equipment investment reflects the higher cyclical fluctuations that this variable experiences over time in relation to other macroeconomic variables. According to the data, all the provinces experienced considerable growth in machinery and equipment investment.

On another note, the high variability of real GDP reflects the heterogeneity among the provinces in relation to their size and economic weight in the country. The data show that, on different scales, all the provinces follow the same cyclical pattern with varying intensity, but with a clear tendency to increase, especially since 1995.

Referring to market potential, its average annual growth rate is 3.3%. According to Table 2, the highest growth in market potential occurs between 1985 and 1990, and between

1995 and 2000, which coincide with an equally significant growth of machinery and equipment investment.

Concerning the travel time data used in the calculation of market potential, Figure 1(a) shows that, on average, the most remote provinces in 1980 were those that experienced a greater reduction in travel time to other provinces between 1980 and 2007. The data also shows (Figure 1(b)) that infrastructure investment policy not only favoured the more distant provinces but also those with lower levels of GDP per capita in 1980.

Moreover, the ULC increased considerably between 1977 and 2008, although at a progressively lower rate. The economic diversification and the average years of schooling were the least volatile variables. According to the data, on average, the provinces tended slightly toward greater diversification of their economic activity. Meanwhile, the average years of schooling increased from 7 to 10 between 1980 and 2008.

4. MODEL

Based on the likelihood function value, a semi-logarithmic specification of equation (1) is chosen. Consequently, the machinery and equipment investment equation is defined as:

$$linvest_{it} = \delta + \beta_1 lpot_{it-1} + \beta_2 lGDP_{it-1} + \beta_3 ldiv_{it-1} + \beta_4 lULC_{it-1} + \beta_5 school_{it-1} + \gamma_i + \phi_t + \varepsilon_{it} \quad (3)$$

where subscript i refers to the province and t to the year. $linvest_{it}$ is the natural logarithm of the machinery and equipment investment. $lpot_{it-1}$ is the natural logarithm of the market potential. $lGDP_{it-1}$ is the natural logarithm of GDP. $ldiv_{it-1}$ is the natural logarithm of the diversification index. $lULC_{it-1}$is the natural logarithm of the ULC. $school_{it-1}$ is the average years of schooling. δ is the constant term. γ_i and ϕ_t are the provincial fixed effects and time effects, respectively. ε_{it} is the random disturbance term. And β_k (k=1,..,5) are the rest of the coefficients to be estimated.

By including time effects in the equation, we control for the common shocks which have affected all provinces over time, and therefore the economic cycle is captured. Moreover, when including provincial fixed effects, all those non-observable factors which do not vary over time but have an effect on investment location decisions are captured, for example the first-nature forces which include the geographic and climatic conditions of each province.

In equation (3) all the explanatory variables are lagged one period, since it is expected that the investments do not react contemporaneously to local factor changes, but with a certain lag[7]. In addition, using the lagged variables reduces the potential problems of endogeneity. In particular, since by definition investment is a component of GDP, regressing investment on GDP would generate a simultaneity problem between these two variables. Lagging the explanatory variable one period, however, helps to reduce such a problem.

Since increases in market potential, GDP, economic diversification and human capital attract more investment, the coefficients β_1, β_2, β_3 and β_5 are expected to be positive. Furthermore, given that the regions with higher labour costs per unit of product may deter investment, the coefficient β_4 is expected to be negative.

DISTANCE DECAY PARAMETER SELECTION

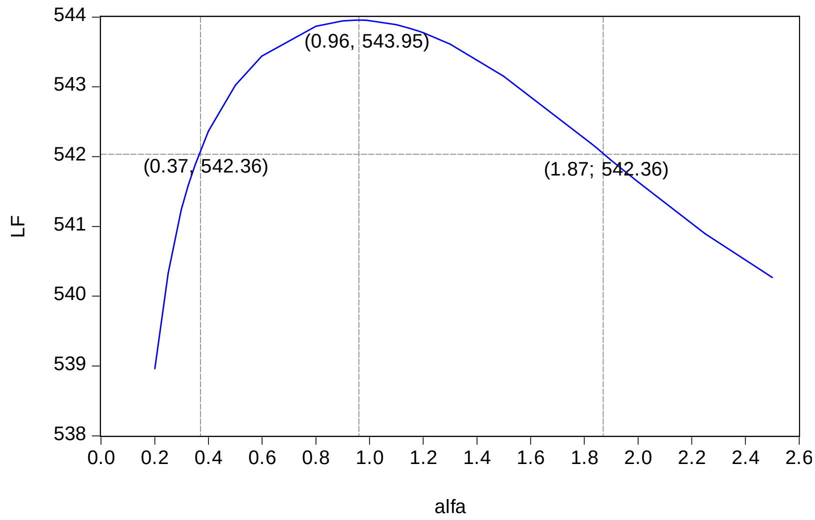
We estimate the value of the distance decay parameter, α, in the market potential formula (2) by selecting the value of α which maximizes the likelihood function (LF). Replacing (2) in (3), we obtain

[7] After testing different time lags, we found that a time lag of one period behaved best in terms of the model's adjustment capacity.

$$linvest_{it} = \delta + \beta_1 \ln \sum_j \frac{GDP_{jt-1}}{time_{ijt-1}^{\alpha}} + \beta_2 lGDP_{it-1} + \beta_3 ldiv_{it-1} + \beta_4 lULC_{it-1} + \beta_5 school_{it-1} + \gamma_i + \phi_t + \varepsilon_{it} \quad (4)$$

In this case, the maximum value for the LF is achieved when α=0.96. As Figure 2 shows the 95% confidence interval for α=0.96 is [0.37, 1.87]. Consequently, the standard hypothesis assumed in the literature of a unitary value for α is not rejected by the data.

Figure 2 The 95% confidence interval for α



5. RESULTS

Table 3 presents the estimation results for four different specifications of equation (3) by OLS and Panel Corrected Standard Errors (PCSE), which corrects for heteroskedasticity, contemporaneous correlation and serial correlation. The results show that the significance levels of the PCSE coefficients are lower than OLS coefficients, providing evidence that this correction should be applied. The coefficients of market potential, GDP and average years of schooling are very similar in all estimated equations, and they have the expected signs and are statistically significant at 1% level. This is not the case for the coefficients of economic diversification and ULC, which show a higher level of variability. It can be observed that when these two variables are excluded from the equation, the coefficients of the rest of explanatory variables remain almost unaffected (equations 7 and 8). In particular, this is true for our main variable of interest, the market potential variable[8].

Table 3 OLS and PCSE regression results

Dependent variable: $linvest_{it}$	OLS	PCSE	OLS	PCSE	OLS	PCSE	OLS	PCSE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
constant term	-3.00**	-1.63	-3.34**	-1.28	-2.78**	-1.62	-3.21**	-1.29
	(-2.24)	(-0.81)	(-2.52)	(-0.63)	(-2.06)	(-0.81)	(-2.40)	(-0.64)
$lpot_{it-1}$	1.11***	0.99***	1.13***	0.97***	0.99***	0.91***	1.01***	0.90***
	(6.35)	(3.82)	(6.46)	(3.73)	(5.74)	(3.65)	(5.83)	(3.56)
$lGDP_{it-1}$	0.71***	0.67***	0.71***	0.67***	0.83***	0.76***	0.84***	0.75***
	(8.00)	(4.63)	(7.99)	(4.55)	(9.82)	(5.29)	(9.91)	(5.15)
$school_{it-1}$	0.15***	0.09***	0.15***	0.10***	0.16***	0.09***	0.15***	0.10***
	(6.33)	(3.10)	(6.16)	(3.31)	(6.49)	(3.14)	(6.27)	(3.33)
$lULC_{it-1}$	-0.52***	-0.37**	-0.55***	-0.34*				
	(-3.87)	(-1.96)	(-4.13)	(-1.85)				
$ldiv_{it-1}$	-0.07*	0.07*			-0.09**	0.06*		
	(-1.82)	(1.80)			(-2.31)	(1.65)		
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Provincial fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.97	0.98	0.97	0.98	0.97	0.98	0.97	0.98
Sum of squared residuals	38.93	24.00	39.03	24.02	39.37	24.09	39.52	24.09
Standard error of regression	0.17	0.13	0.17	0.13	0.17	0.13	0.17	0.13
Provinces (N)	46	46	46	46	46	46	46	46
Years (T)	32	32	32	32	32	32	32	32
Number of observations	1426	1426	1426	1426	1426	1426	1426	1426

Note: t-value in parenthesis:. *, **, and *** indicate statistical significance at 10 percent, 5 percent and 1 percent, respectively.
PCSE Panel Corrected Standard Errors, correcting for AR(1) (common ρ)

According to the results presented in Table 3, our preferred equation for machinery and equipment investment is:

$$linvest_{it} = -1.29 + 0.90lpot_{it-1} + 0.75lGDP_{it-1} + 0.10school_{it-1} + \hat{\gamma}_i + \hat{\phi}_t \qquad (5)$$

Where $\hat{\gamma}_i$ and $\hat{\phi}_t$ are the estimated provincial and time effects, respectively; not reported here for reasons of space.

ROBUSTNESS CHECK

In order to verify the robustness of the results, equation (5) is reestimated controlling for potential endogeneity bias. To do so, a Dynamic Ordinary Least Squares (DOLS)

[8] An F-test is carried out to test whether all the coefficients of the time dummies are, jointly, equal to zero, with which the null hypothesis is rejected and it is concluded that the time effects are important in the model.

regression model is estimated (Kao and Chiang, 2000). DOLS is an approach used in the literature to correct endogeneity bias. It uses a parametric method which consists of including the future and past values (leads and lags) of the differenced explanatory variables on the right side of a cointegrated equation.

A problem of two-way causality could arise between the explanatory variables in the model – GDP, agglomeration economies, and infrastructure investment – and machinery and equipment investment. In other words, on the one hand, regions with favourable conditions in terms of economic resources, agglomeration economies and infrastructure endowments, are more attractive for investors. On the other hand, regions with greater economic dynamism (higher private investment and, therefore, machinery and equipment investment) attract labour and infrastructure investment and generate economic growth. Bi-directionality thus occurs between the dependent variable and the explanatory variables and, thereby, an endogeneity (or simultaneity) bias arises in the estimation by OLS. It should be asked to what extent this bias distorts the results of OLS in the model proposed.

With the aim of confirming the applicability of DOLS, we need to verify that the variables in equation (5) are non-stationary and cointegrated.

The plot of the series and the results of applying different panel unit root tests to the variables in levels and in first differences (appendix 2), make it possible to conclude that the variables: machinery and equipment investment, market potential, GDP and average years of schooling are integrated of order one. Additionally, from the application of the Kao residual cointegration test it can be concluded that there is sufficient empirical evidence to reject the null hypothesis of no cointegration at the usual levels of significance (see appendix 3).

Consequently, it can be stated that market potential, GDP and average years of schooling are valid variables to explain the behaviour of the machinery and equipment investment in the long term. Once the cointegration relationship has been confirmed, the long-term parameters can now be estimated efficiently by DOLS. The results are shown in Table 4. It can be observed that the estimated coefficients are very similar to those obtained by PCSE (column (8) Table 3). Therefore, the results suggest that the estimation by PCSE yields valid estimators for the long-term relationship between the dependent variable, machinery and equipment investment, and the regressors: market potential, GDP and average years of schooling. The fact that when using an estimation method that reduces the problem of endogeneity the estimated coefficients are not modified could be related to the criteria that guided the infrastructure investment decisions. As explained in section 3, as long as investment decisions do not anticipate future economic growth the problems of simultaneity bias are not severe.

Table 1 DOLS regression results

Dependent variable: $linvest_{it}$	
	DOLS(1,1)
constant term	-2.91
	(-1.33)
$lpot_{it-1}$	1.00***
	(3.72)
$lGDP_{it-1}$	0.84***
	(5.68)
$school_{it-1}$	0.11***
	(3.04)
Time effects	yes
Provincial fixed effects	yes
R^2	0.98
Sum of squared residuals	22.70
Standard error of regression	0.13
Provinces (N)	46
Years (T)	32
Number of observations	1334

Note: *t*-value in parenthesis:. *, **, and *** indicate statistical significance at 10 percent, 5 percent and 1 percent, respectively. DOLS (1,1) denotes one lead and one lag.

Thus, based on the principle of parsimony, equation (5) is chosen to represent the machinery and equipment investment equation. Since they are cointegrated processes, the coefficients can be interpreted in terms of long-term elasticities[9]. In particular, we estimate a long-term elasticity of the machinery and equipment investment in relation to market potential equal to 0.90. Moreover, the long-term elasticities in relation to GDP and to average years of schooling are, on average, 0.75 and 0.80, respectively.

THE IMPACT OF A ROAD INFRASTRUCTURE INVESTMENT POLICY

To assess the full long-run impact on the economy of a road infrastructure investment policy, we simulate the consequences of a reduction in travel time for all the links in the road network. The reduction in travel time will increase market potential, thus increasing

[9] The elasticity of the investment in relation to the average years of schooling is given by the product of the coefficient of this variable and the average of the series.

machinery and equipment investment, which, in turn, will lead to a larger capital stock and, consequently, to a GDP growth. Higher GDP leads to a new increase in the market potential that further increases GDP through a series of second round increments. It is therefore suggested that a system of equations should be defined which captures the feedback effect taking place between these variables. In this way, by solving the dynamic system simultaneously, it is possible to estimate the full long-run impact on the economy of an infrastructure investment policy. Each of the equations is defined and explained below.

Definition of the system of equations

<u>Market potential equation</u>

The market potential equation is defined in (2):

$$pot_i = \sum_j \frac{GDP_j}{time_{ij}}, \forall i \neq j \quad (2)$$

<u>Machinery and equipment investment equation</u>

The machinery and equipment investment equation is defined in (5):

$$linvest_{it} = -1.29 + 0.90lpot_{it-1} + 0.75lGDP_{it-1} + 0.10school_{it-1} + \hat{\gamma}_i + \hat{\phi}_t \quad (5)$$

As before, $\hat{\gamma}_i$ and $\hat{\phi}_t$ are the estimated provincial and time effects, respectively.

<u>Physical capital stock equation</u>

The capital stock equation is defined according to the accounting identity of perpetual inventory:

$$capital_{it} = capital_{it-1} - \delta capital_{it-1} + totalinv_{it}$$

where $capital_{it}$ and $totalinv_{it}$ are the total capital stock and the total gross investment, respectively; δ is the depreciation rate. Investment is divided into two components:

machinery and equipment investment, $invest_{it}$, and infrastructure investment, $infrainv_{it}$, (including housing and other constructions). Additionally, according to the literature[10] an average capital stock depreciation rate of 6% is assumed. So, the physical capital stock equation is given by:

$$capital_{it} = (1 - 0.06)capital_{it-1} + (invest_{it} + infrainv_{it})$$

<u>Aggregate production equation</u>

The Cobb-Douglas production function is widely used in the empirical literature to reflect a stable relationship between aggregate production and the stock of production factors (employment and capital) and the level of technical efficiency. Under perfect competition and constant returns to scale, the coefficient of labour, θ_L, should lie between 0.60 and 0.70 and the coefficient of capital between 0.30 and 0.40 (De la Fuente, 2010). Assuming that θ_L=0.65, the aggregate production equation is expressed as:

$$\ln(GDP_{it}) = 0.65\ln(employment_{it}) + 0.35\ln(capital_{it}) + \ln(A_{it})$$

where GDP_{it} is, as before, the GDP of the *i*-th province, period *t*; $employment_{it}$ is total employment; $capital_{it}$ is the physical capital stock; and A_{it} measures the technological progress.

Consequently, the system of equations is defined as:

$$\begin{cases} pot_i = \sum_j \frac{GDP_j}{time_{ij}} \\ linvest_{it} = -1.29 + 0.90lpot_{it-1} + 0.75lGDP_{it-1} + 0.10school_{it-1} + \hat{\gamma}_i + \hat{\phi}_t \\ capital_{it} = (1 - 0.06)capital_{it-1} + (invest_{it} + infrainv_{it} \\ \ln(GDP_{it}) = 0.65\ln(employment_{it}) + 0.35\ln(capital_{it}) + \ln(A_{it}) \end{cases}$$

[10] See, for example, De la Fuente and Doménech (2006).

The impact of a 10% reduction in travel time

In order to assess the impact of a road infrastructure investment policy, an improvement in the Spanish network of interurban main roads and motorways is assumed, leading to a 10% saving in travel time. To do so, a counterfactual analysis is carried out. The counterfactual consists in solving the system of equations, firstly, for the actual values of the transport policy (baseline scenario) and, secondly, for a 10% reduction in travel time between all links in the network. The impacts of such a policy are presented as the percentage change between the baseline and the counterfactual scenarios for all provinces. The results indicate that the 10% reduction in travel time generates an average total increase in market potential of 12.18%; machinery and equipment investment increases by an average of 11.81%; capital stock and GDP rise by an average of 3.25% and 1.12%, respectively.

It should be mentioned that our results are in line with other evidence for the Spanish economy that uses aggregate data. Nombela (2005), measuring the impact of transport infrastructures on the Spanish economy, finds that the GDP elasticity is 0.17. In order to reach this result, he estimates a Cobb-Douglas function using province-level panel data and approximates the transport infrastructures through the capital stock of transport infrastructures, according to data from the IVIE. He moreover finds that this elasticity is greater than that found when he uses autonomous community and national level data. He suggests that this is a reflection of the fact that the more connected the infrastructure and production variables, the greater the effect of the capital stock of infrastructure on GDP. He also indicates that the positive impact of transport infrastructures found in the studies for Spain is, to a large extent, due to main roads, in view of their importance within this sector.

Along the same lines Cantos et al (2005), estimating a production function for the private sector with a panel data for the Spanish autonomous communities, find an elasticity in relation to capital stock in road infrastructures of 0.088, which reflects their positive effect on the industry, services and agriculture sectors and the weight of these sectors within the private sector.

6. CONCLUSIONS

This paper analyses the relationship between road infrastructure investments and investment in capital assets, using aggregate data at a provincial level for the period 1977-2008. A function is specified in which the machinery and equipment investment depends on the market potential, GDP and human capital (approximated by average years of schooling). In particular, the variable of interest, market potential, is an accessibility index which allows market opportunities to be linked to the characteristics of the road network.

Our data shows that the most remote provinces and those with lower levels of GDP per capita at the beginning of the period experienced a greater reduction in travel time. Therefore, we suggest that the Spanish road infrastructure policy has not been associated with efficiency criteria, but with spatial cohesion arguments and the consolidation of a radial network focused on the country's capital.

The estimation of the equation with fixed time and provincial fixed effects is carried out controlling for heteroskedasticity, contemporaneous correlation and serial correlation. The results show that the long-term elasticities of the machinery and equipment investment in relation to market potential, GDP and average years of schooling are, on average, 0.90, 0.75 and 0.80, respectively.

In order to assess the full long-run impact of a road infrastructure investment policy, a system of equations is defined in which the different interactions between the variables is established. Starting from the system of equations, the elasticities of the machinery and equipment investment, capital stock and GDP are calculated in relation to travel time. The results are 1.18, 0.33 and 0.11, respectively.

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Appendix 1: Legend of the names of the provinces

Province	Label
Álava	ala
Albacete	alb
Alicante	ali
Almeria	alm
Avila	avi
Badajoz	bad
Barcelona	bcn
Bilbao	bil
Burgos	bur
Cáceres	cac
Cádiz	cad
Castellón	cas
Ciudad Real	ciu
Cordoba	cor
Cuenca	cue
Gerona	gir
Granada	gra
Huelva	hva
Huesca	hca
Jaén	jae
La Coruña	lac
León	leo
Lérida	lle
Logroño	log
Lugo	lug
Madrid	mad
Málaga	mal
Murcia	mur
Orense	our
Oviedo	ovi
Palencia	pal
Pamplona	pam
Pontevedra	pon
Salamanca	sal
San Sebastián	seb
Santander	san
Segovia	seg
Sevilla	sev
Soria	sor
Tarragona	tar
Teruel	ter
Toledo	tol
Valencia	via
Valladolid	vid
Zamora	zam
Zaragoza	zar

Appendix 2: Panel unit root tests and cointegration test

Unit root tests for the variables in levels

Tests	$linvest_{it}$	$lpot_{it-1}$	$lGDP_{it-1}$	$school_{it-1}$
Ho: Unit root				
Levin-Lin-Chu	1.418 (0.9219)	-1.2521 (0.1053)	0.0426 (0.5170)	3.0716 (0.9989)
Breitung	1.8490 (0.9678)	-1.5203 (0.0642)	-0.9985 (0.1590)	-2.8238 (0.0024)
Fisher Test: Inverse chi-squared P	68.3362 (0.9693)	52.9774 (0.9996)	73.9165 (0.9165)	95.3404 (0.3850)
Fisher Test: Inverse Normal Z	2.3967 (0.9917)	3.2689 (0.9995)	2.7402 (0.9969)	1.1659 (0.8782)
Fisher Test: Inverse Logit L*	2.1428 (0.9834)	3.2077 (0.9992)	2.7646 (0.9969)	1.1719 (0.8788)
Fisher Test: Modified inv. chi-squared Pm	-1.7445 (0.9595)	-2.8768 (0.9980)	-1.3331 (0.9088)	0.2463 (0.4027)
Pesaran Z[t-bar]	2.725 (0.997)	5.177 (1.000)	0.999 (0.841)	0.451 (0.674)
Ho: All panels are stationary				
Heteroscedastic Consistent Z-stat	8.9003 (0.0000)	9.3374 (0.0000)	10.2810 (0.0000)	7.6325 (0.0000)

Fisher-type unit-root test based on augmented Dickey-Fuller tests. Hadri LM test: LR variance: Quad. Spectral kernel Cross-sectional means removed except for Pesaran. 7 lags chosen. p-values in brackets.

Unit root tests for the variables in first differences

Tests	$linvest_{it}$	$lpot_{it-1}$	$lGDP_{it-1}$	$school_{it-1}$
Ho: All panels are stationary				
Heteroscedastic Consistent Z-stat	-5.4715 (1.0000)	-1.7393 0.9590	3.1073 (0.0009)	-4.2029 (1.0000)
Ho: Unit root				
Levin-Lin-Chu	-48.3795 (0.0000)	-34.7065 (0.0000)	-28.4384 (0.0000)	-37.4536 (0.0000)
Breitung	-28.5974 (0.0000)	-24.8384 (0.0000)	-21.4755 (0.0000)	-25.5392 (0.0000)
Fisher Test: Inverse chi-squared P	1952.73 (0.0000)	1174.78 (0.0000)	845.91 (0.0000)	1218.6114 (0.0000)
Fisher Test: Inverse Normal Z	-40.6711 (0.0000)	-30.5661 (0.0000)	-24.5270 (0.0000)	-30.7823 (0.0000)
Fisher Test: Inverse Logit L*	-79.5386 (0.0000)	-47.8510 (0.0000)	-34.4468 (0.0000)	-49.6359 (0.0000)
Fisher Test: Modified inv. chi-squared Pm	137.1749 (0.0000)	79.8237 (0.0000)	55.5787 (0.0000)	83.0549 (0.0000)
Pesaran Z[t-bar]	-30.887 (0.000)	-25.030 (0.000)	-19.638 (0.000)	-24.708 (0.000)

Fisher-type unit-root test based on augmented Dickey-Fuller tests. Hadri LM test: LR variance: Quad. Spectral kernel Cross-sectional means removed except for Pesaran. p-values in brackets.

Appendix 3: Cointegration test

Cointegration test

Kao Residual Cointegration Test		
Series: $linvest_{it}$, $lpot_{it}$, $lGDP_{it}$, $school_{it}$		
T = 32 (1977-2008), N = 46		
Null Hypothesis: No cointegration		
	t-Statistic	Prob.
ADF	-8.2525	0.0000
Residual variance	0.0228	
HAC variance	0.0133	

Trend assumption: No deterministic trend

Automatic lag length selection based on SIC with a max lag of 8

Newey-West automatic bandwidth selection and Bartlett kernel

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