High capacity road networks and economic development

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Resumen

La alta capacidad de redes de carreteras constituye un elemento esencial de la estructura territorial y generan efectos económicos importantes. Sin embargo, han sido tema de muy poca investigación, debido principalmente a la escasez de datos de este tipo de capital con respecto al tiempo y alcance geográfico. El presente artículo esta basado en una estimación de este componente del capital público en regiones españolas en el periodo de 1970 a 1998, realizado por los autores para evaluar el impacto del sector económico de dicha infraestructura. Los resultados muestran un efecto significativo y positivo en la economía del sector privado, donde el sector agrícola e industrial en España han sido los más beneficiados gracias al desarrollo de este tipo de infraestructura. La investigación se enfoca en el efecto del desbordamiento ocasionado por la red de infraestructura. La evidencia obtenida, apoya la hipótesis de que la alta capacidad de capital de carretera en regiones adyacentes y regiones con características sociales y económicas similares, también tiene un efecto en el capital regional privado.

Palabras clave: redes de carreteras, estructura territorial, infraestructura, desarrollo económico

Abstract

High capacity road networks constitute an essential element of territorial structure and generate important economic effects. However, they have been subject to very little research, mainly due to the lack of data of this type of capital with respect to time and geographical scope. This article is based on an estimate of this component of public capital in Spanish regions from 1970 to 1998, performed by the authors, to evaluate the economic sector impact of such infrastructure. Results show a positive and significant effect on the private sector of the economy, in which the agriculture and industrial sectors have most benefited from this type of infrastructure development in Spain. The research focuses on the spillover effects derived from network infrastructure. The evidence obtained supports the hypothesis that high capacity road capital in adjacent regions and regions with similar social and economic features also has an effect on regional private capital.

Key words: road networks, territorial structure, infrastructure, economic development

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Introduction

One of the public policy decisions that has the greatest economic and social repercussions is that of investing in transport infrastructure, both for its territorial structure effect as well as its capacity to reduce costs and increase economic production capacity. The interest in analyzing the economic effects of such investments has increased considerably in recent years. The greater part of research has highlighted that it is vital to achieving balanced economic development. Despite these encouraging results, evidence also shows that economic effects may not be those initially expected. In an attempt to accurately define the effects, this study incorporates the spillover effect, in other words, the possibility of one region benefiting from an investment in infrastructure located in another region. Another important feature of the analysis is the differentiation of investment components, thus enabling us to determine whether or not they all have the same effect on private production. The progress gained in these areas is of particular interest, as it allows us to understand the results obtained by studies in the field and provide relevant proof to guide public investment decisions.

Of all Public Administration investment components, one which has generated the greatest economic interest has been that of high capacity networks (motorways, dual lane highways). This is mainly justified as being one of the most important investments in the country and because the locating of its expected effects has relevant territorial repercussions. This relevance is reflected by the large number of studies endeavoring to quantify its effects on private production (Cohen and Morrison, 2002, Pereira et al., 2004). The majority have focused on the U.S., being one of the economies with the greatest levels of development in this type of infrastructure and comprehensive databases. A frequent result of these studies shows that high capacity roads may favor the development of certain areas, whilst in others result in changes in the location of economic activity, thus questioning the feasibility of the investment as a tool for stimulating growth in less developed areas. Some of the studies carried out claim that only areas close to large cities with high levels of economic activity benefit from investment in infrastructure (Chandra and Thompson, 2000). Furthermore, studies show that these types of high capacity networks produce benefits in the areas in which they are located and facilitate mobility between different territories, thus generating positive and negative effects in other regions, which makes it more difficult to obtain conclusive results on the influence of this type of infrastructure.

The diversity of productive structures and degrees of maturity of transport systems justifies the need for further evidence on the impact of this investment in countries other than the United States. Such is the case of the Spanish economy, in which the implementing of the *Plan Estratégico de Infraestructuras* *y Transportes* PEIT has provided an enormous boost to development of a High Capacity Network in Spain, reaching European levels in a very short period of time. The study of this type of infrastructure has been limited in Spain, due to a lack of specific estimates in Spanish regions. Development of the high capacity network, although initiated in the seventies, was not extended to the majority of Spanish provinces until the nineties. This delay in expansion is partly due to the unbalanced development of infrastructure work between other countries and Spain[3]. In this respect, implementing of the PEIT, in addition to being an extraordinary investment initiative involving a significant recent increase in infrastructure, has resulted in more studies, although they are still mainly focused on comparing different types of transport (Cantos *et al*., 2002).

This research study endeavors to provide an in-depth look at the relationship between the high capacity network in Spanish regions and regional economic activity in different sectors. It analyses the differential effect on different production sectors: agriculture, industry, energy, construction and services. The study therefore attempts to determine the existence of negative and positive spillover, thus allowing a better understanding of the decisions as to where to locate a firm, increase production and investment in certain regions and the reasons for divestment and possible loss of work in others. This type of research is new and different from other studies, as it contrasts the existence of spillover effects and their reach to frontier techniques. The use of frontier techniques offers the possibility of incorporating the influence of levels and evolution of technical efficiency on production areas into the study. The defining of production frontiers therefore enables us to establish a regionally balanced model designed to avoid the problems associated with the assumption that all economic units operate efficiently.

The structure of the paper is as follows: Section 2 presents the stochastic production frontiers used for the analysis and the chosen model of spillover effects. Section 3 describes the evolution of investment in the high capacity network infrastructure over the period studied and the variables used in the empirical analysis, as well as the results obtained. Section 4 provides the conclusions of the study and summarizes the main features of the analysis carried out.

Methodological approach to the analysis of the impact of investment on transport infrastructure

In order to quantify the effects of investment in transport infrastructure, several methodologies exist. They all analyze the impact of such investment

3 The importance and interest in the *Plan Estratégico de Infraestructuras y Transportes (*Ministery of Public Works, 2004*)*, has given rise to several studies on the effected effects of such investments (Delgado and Álvarez, 2003).

from a dual supply and demand perspective. According to the *Aggregate Supply* approach, investment in the road network enables productive capacity growth in production sectors, thus allowing private sector competitiveness in the country to improve and channel benefits towards a reduction of transport costs and increase in production factor productivity. According to the *Aggregate Demand* approach, investment in road networks is a component of public investment which, as such, plays an important role in promoting economic activity and generating employment and income.

With the above approaches in mind, a series of models were developed for the purpose of providing empirical evidence. They include the development of models based on frontier techniques, which contribute to extending theoretical and empirical knowledge designed to measure the technical efficiency of firms as well as productive sectors and regions[4]. The considerable number of empirical applications in which frontier function estimates highlight the existence of inefficiencies in the use of private production factors (Gumbau and Maudos (2002) has given rise to a prolific line of research into identifying the reasons behind such results.

One of the alternatives proposed was to perform the analysis in two stages; firstly, technical efficiency indexes are calculated, using econometric techniques as well as linear programming methods, followed by regressions between the estimated efficiency values and the explanatory variable vectors to be contrasted, including that of infrastructure (Boisso *et al*., 2000). This type of analysis, however, is not exempt of criticism, as pointed out by Wang and Schmidt (2002) and Kumbhakar and Lovell (2000), amongst others, who claim that it leads to biased estimates and also contradicts the assumption that the effects of technical inefficiency obtained in the first stage are identically distributed and non-correlated with the error term, which is a requisite in order to obtain predictions of inefficiency values. As an alternative to two stage estimates, BC propose a model in which the stochastic production frontier parameters and variables influencing productive unit inefficiency are estimated together (in one stage).

The starting point of our estimate is the following stochastic production frontier, with a panel of data:

$$Y_{it} = \exp(X_{it}\beta + v_{it} - u_{it}), \qquad t = 1,\dots, T \qquad (1)$$
$$i = 1,\dots,N$$

4 The objective of many such studies has been to compare firms in specific areas. However, they have almost all been extended to the analysis of economic growth and productivity, given that the omitting of inefficiency, if it exists, can lead to biased results. Therefore, and despite the reserves that could be used as aggregate data by a method initially intended to analyze firms, this alternative constitutes an appropriate theoretical approach to estimation, as it introduces the inefficiency component into the model's specifications.

where Y_{it} is production in period t and for the productive unit i, X_{it} a vector (1 x k) of explanatory variables and β a vector (k x 1) of parameters to be estimated.

Parametric approximation to the stochastic frontier estimates a function of production in which the deviation between the observed level of output and the possible maximum has two components: an error term (v_{it}) which measures the effect of variables that are not controlled by the production unit analyzed, and a second term (u_{it}) which can be interpreted as an indicator of inefficiency. The term v_{it} represents the random independent variables that are identically distributed as a constant with a zero average and σ^2_v variance, independently distributed from u_{it}. The inefficiency indicator u_{it} is comprised of random non-negative variables, associated to technical production inefficiency and obtained by means of zero truncated normal distribution[5] with a $Z_{it}\delta$ average and σ^2 variance. Z_{it} is a vector (1 x m) of explanatory variables associated to the technical inefficiency susceptible to variation over time and δ is a vector (m x 1) of coefficients to be estimated.

Technical efficiency u_{it} can be expressed as:

$$u_{it} = Z_{it}\delta + W_{it} \qquad (2)$$

Where the error term W_{it} follows a truncated normal distribution in $-Z_{it}\delta$ with a zero average and σ^2 variance. This distribution implies that $W_{it} \geq -Z_{it}\delta$ y is consistent with the distribution assumption of the inefficiency term u_{it}.

This methodology enables us to explore the locating of the sectorial economic impact of high capacity networks. The lack of conclusive evidence on the existence of spillover effects by using production functions has brought criticism of the validity of this approach. The use of frontier techniques in the study will avoid the problem derived from considering that economic units operate efficiently, which is a common assumption used in the literature employing production functions to estimate the impact of public capital investment. Furthermore, this approach enables regionally balanced models by incorporating information on the existence of different levels of regional productive sector efficiency into the analysis.

According to the above, the basic model used in this study begins with the production function in which production (Y) is related to the amount of

5 According to Battese and Coelli (1995) it has been assumed that technical inefficiency in production follows a zero truncated normal distribution. Given that inefficiency can only reduce production within the frontier, it is necessary to assume asymmetrical distributions associated to the term, where half-normal and exponential distributions are also equally acceptable.

labor (L) and private capital (K) added to the High Capacity Network (HCN) structure of a region:

Using this structure, the first analysis will be of the High Capacity Network's contribution to sectorial regional production, thereby enabling us to differentiate the importance of this infrastructure to each sector. This is also followed by a contrast of the sign and magnitude of the spillover effects. In order to do so, we opted for extending the production function (4) and including variable which represents the capital in HCN within the other regions:

The sign and magnitude of the parameter allows us to determine the presence of spillover effects. One of the reasons for considering that investment in transport infrastructure in a particular area has a positive effect on the economic activity of other regions is based on its network nature. As a result, some of the benefits derived from the investment are extended outside the territorial limits of the region in which it is located. In recent years, several studies have confirmed the existence of negative spillover effects (Boarnet, 1998, Kelejian and Robinson, 1997, Holtz-Eakin and Schwartz, 1995). This type of effect comes from the possibility that production factors are transferred from one region to another in search of capital, the availability of capital within a high capacity network therefore being able to influence the location of economic activity.

In the model employed, we assume that capital within a High Capacity Network is complementary to employment and regional private capital. If we assume that production factors are mobile, given a certain amount of capital within the High Capacity Network, _______ a decision external to firms.

An issue that arises when studying the spillover effects derived from capital within high capacity networks on other regions is how to define the variable, given that it is able to affect the sign and magnitude of the impact. To perform the analysis, we referred to recent literature on regional economics and different definitions were proposed. Firstly, three definitions of spillover effects (A), (B) y (C) were presented, focusing on the physical adjacency criteria. In these cases, it is assumed that territorial proximity is the most important criterion in defining spillover effects and therefore adjacent regions are those most affected by the impact of capital in the high capacity network of the region analyzed. In order to obtain a more accurate measure of this impact, three alternative definitions were proposed for this type of spillover. Firstly, HCN_A1: obtained by adding that of adjacent regions (equation A). HCN_ A2: measured by taking the average capital in adjacent regions (equation B). Variable HCN_A3: calculated as the weighted total per surface area of adjacent regions (C).

(A) $$\log Y_{it} = c + \alpha \log L_{it} + \beta \log K_{it} + \gamma \log RGC_{it} + \gamma_1 \log RGC\_A1 + v_{it} - u_{it}$$

(B) $\log Y_{it} = c + \alpha \log L_{it} + \beta \log K_{it} + \gamma \log RGC_{it} + \gamma_1 \log RGC\_A2 + v_{it} - u_{it}$

(C) $\log Y_{it} = c + \alpha \log L_{it} + \beta \log K_{it} + \gamma \log RGC_{it} + \gamma_1 \log RGC\_A3 + v_{it} - u_{it}$

The consideration of physical proximity as the principal justification of spillover effects is the most common. Boarnet (1998) suggests the strategy of adopting different criteria to measure the variable representing spillover effects, thus identifying the existence of different types of positive and negative effects and enabling us to understand the scope and importance of networks on economic activity. With this objective in mind, our research project also explored the possibility that high capacity networks in regions with similar economic and social characteristics and similar sized public sectors, may influence the economic activity of other regions, either because such networks allow separate centers of economic activity to be connected and thus intensify their relations, or because they allow them to compete in markets with more production factors.

In this analysis, we classify regions into five clusters based on the information on private sector participation in overall regional production and population density. This type of cluster analysis follows the criteria presented by Case *et al.* (1993). We propose that public policy implemented in regions with similar economic and social characteristics influences those of the region analyzed. Our research assumes that regions sharing similar characteristics have access to similar levels of capital in the network, which can be used to stimulate the potential growth of the region and act as a way of attracting economic activity from other regions. In this case, variable HCNC: represents the total capital in regions considered to be competitors.

(D) $\log Y_{it} = c + \alpha \log L_{it} + \beta \log K_{it} + \gamma \log RGC_{it} + \gamma_1 \log RGCC + v_{it} - u_{it}$

The groups of regions used were:

Region I: Balearic Islands, Catalonia, Basque Country, Madrid.
Region II: Navarre, Valencia, Canary Islands.
Region III: Cantabria, Asturias and Aragon.
Region IV: Murcia, Galicia, Castile La Mancha, Castile Leon.
Region V: Andalusia, Extremadura and La Rioja.

Capital within Spanish Regional High Capacity Networks

The proposed stochastic frontiers were estimated using information on the 17 Spanish Autonomous Communities from 1970 to 1998. Two main sources of statistics were employed. For Value Added by the private sector to the cost of factors and for private sector employment (total number of jobs), we used the "Spanish National Income and Provincial Distribution" (*Renta Nacional de España y su Distribución Provincial)* provided by the FBBVA. Private capital figures were obtained from "Capital Stock in the Spanish Economy" (*el stock de Capital en la Economía Española),* which were estimated using the permanent inventory method. All variables are expressed in 1986[6] constant figures.

The availability of figures on capital for roads with sufficient geographic and time information would have made it possible to perform an analysis of the spillover effects derived from HCN infrastructure[7]. However, we decided to focus our research on analyzing high capacity networks, as they are the main roads connecting Spanish regions and all other European networks, in which spillover effects are more likely. Therefore, in order to achieve the objectives of the study, we required HCN figures on Spanish provinces that would serve as a basis for empirical contrast of economic influence. Estimates of HCN were obtained by comparing the information available on investment in roads in monetary terms and expressed in 1986 constant prices, with those provided by the FBBA on "Spanish Economy Capital Stock" after obtaining the investment figures and applying the permanent inventory method[8].

All estimates maintain the assumptions on average life, survival and depreciation functions used in the BBVA-Ivie Foundation study. For road stock, we considered an average life of 60 years until 1965, and 40 years as of 1966. When calculating this capital, we used the *Winfrey S-3* survival function, which is common is this type of analysis.

As of the base year, the estimated capital stock for the rest of the period was calculated using the permanent inventory method and implementing the following expression:

Where the letter I in the different subscripts refers to the initial year. As we can see, according to equation (5), capital stock is calculated as the total weighted amount of investment from the beginning of the period, plus the initial capital depreciated over time.

This purpose of this study is to analyze a specific component of capital infrastructure in a particular area: that of high capacity networks. In order to

6 The most complete and widely used database in analyzing public capital, due to its functional (roads, urban structure, hydraulic infrastructure, ports, coastline and marine signalling, health, education and other Public Administration functions) and territorial breakdown (data per province and region), is the estimate in monetary terms developed by the BBVA Foundation (*Fundación BBVA*) (2004) focused on Public Administration capital stock.

7 The classification of roads was based on ownership (Public Administration networks and Toll Highways), authority (network controlled by the State, Autonomous Community or Provincial or Local Island Authorities) and physical characteristics (High Capacity Network or other).

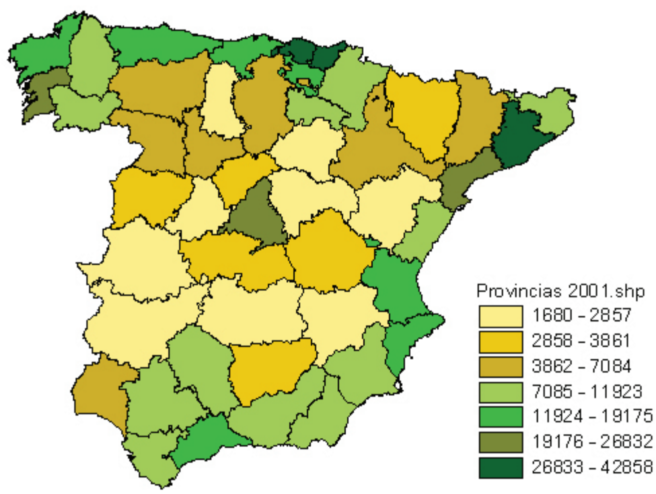
8 We therefore obtained an average monetary measure that was in line with that of the other infrastructure information provided by FBBVA database. See Delgado and Álvarez (2004) for estimate details.

complete the descriptive analysis and endeavor to gain a better understanding of the investment strategy employed in the Spanish economy, we present a map showing the distribution of capital in the Spanish High Capacity Network.

$$K_{t+j} = \sum_{s=1}^{j} (1-\delta)^{s-1} I_{t+j-s} + (1-\delta)^{j} K_t \qquad (5)$$

The analysis performed shows a trend towards an accumulation of capital in the Northwest and Madrid High Capacity Networks. Examination of such capital confirms two important differences between regions: the Community of Madrid, the Basque Country and Catalonia have the greatest amount of infrastructure and the opposite extreme is Castile la Mancha and Extremadura, with very little. Furthermore, there are many regions with limited capital investment in infrastructure. By showing the results in a territorial map, it is

Map 1. Distribution of capital in the High Capacity Network / surface area. 1990 Euros



Source: Delgado and Álvarez (2004).

possible to trace the country's high capacity networks, such being the case of the Cantabrian and Mediterranean highways.

Sectorial economic analysis of spillover effects

This study employs the described frontier technique methodology to the analysis of the effects of infrastructure on the overall economy and the productive sectors of Spanish regions from 1970 to 1998. The period of time used is of special interest, given that it coincides with an increase in the decentralization of public functions and Spain's joining the European Community. Both events gave rise to substantial growth in public investment, intended to improve regional infrastructure.

The stochastic production function was estimated using a panel of data on regional productive sectors and the overall economy relating to the period 1970-1998. In order to do so, as in most empirical studies, it is accepted that the underlying technology of the production function is of a Cobb-Douglas type. Based on this function, we analyze the contribution of the high capacity network as additional input.

Road infrastructure forms part of an economy's productive resources, characterized by being principally oriented towards business by conditioning the capacity and functioning of the overall productive system. Current classifications of different road categories are based on the level of traffic capacity: large or high capacity networks and other remaining networks. By focusing our attention on high capacity networks, we only deal with roads in which lanes are separated and access is controlled to a certain extent. This includes: toll motorways, free motorways, highways and dual lane roads. This distinction of the road network is of particular interest, given that over the last decade, Public Administration has made a substantial investment in increasing connections between high capacity networks, with the objective of improving access to the main national areas of economic activity, as well as to the trans-European network.

Results are shown for the entire economy (Table 1) and per productive sector: agriculture, fishing and forestry, energy sector, construction, industry and services designed for selling (Tables 2-6). In all areas, we obtained data on both the role played by high capacity networks themselves, as well as by the capital invested in HCN networks in adjacent regions, the variable being defined according to the three specifications mentioned in the previous section (HCN_A1: the total of adjacent regions, HCN_A2: calculated as the average of capital in adjacent regions, HCN_A3: calculated as the weighted total per surface area and that of competitive regions (HCNC).

We firstly present the total sector results obtained. Evidence of the impact of High Capacity Networks on the private sector (first column of the regional stochastic production function estimate) shows that, although the impact is limited, it is positive and significant (0.0051). Furthermore, this result is coherent with recent evidence of the impact of public capital, showing that the effect is less than expected in earlier studies. Another interesting result is obtained by incorporating the variable that measures the spillover effects derived from the capital invested in High Capacity Networks in adjacent regions. When the variable is included, we see that the greater level of funds in a network of the region itself, as well as adjacent regions, favors private production. Despite this positive conclusion, when analyzing the distribution of high capacity networks between regions with similar social and economic characteristics, the results vary significantly, and it can be said that such regions compete for available production factors, in such a way that within the overall economy, the availability of the factor is jointly taken into account by firms when making decisions, without an obvious increase in private production.

The same structure is maintained in the analysis of productive sectors, in which we firstly present the results of the impact of a region's high capacity network and contrast the spillover effects. Results for the agriculture, fishing and forestry sector show that high capacity networks have a highly favorable effect on the economic activities of the sector. Greater capital in the network has enabled all agriculture activities to benefit and no signs of negative spillover were detected.

One of the sectors arousing the greatest interest is the industrial sector, as confirmed by the number of studies dedicated to this type of economic activity. An analysis of the impact of high capacity networks on private production confirms the importance of connected economic activity centers. In all cases, we see that capital in adjacent regions favors private production. In the case of competing regions, an increase in capital in this type of infrastructure does not affect industrial production in regions with similar social and economic characteristics. This is surprising, especially considering the results obtained for the overall economy. The lack of conclusive results on competing regions could be related to the degree of aggregation used in this study and suggests the advisability of further studies with a greater breakdown of figures.

As to the results obtained for the sectors of energy, construction and services designed for selling, we can confirm, in general, that neither capital in the high capacity network, nor in adjacent or competing regions influences private activity in such sectors. The lack of significance of the impact of such capital on production in these areas can be explained by the fact that they are not directly linked to HCN infrastructure, either because they have their own distribution networks (this being the case of the energy sector) or their production does not require external regional distribution, as in the construction and services sectors.

Table 1. Regional stochastic production function (1970-1998). Total sectors

Independent Variable	HCN	HCN_A1	HCN_A2	HCN_A3	HCNC
Stochastic Frontier					
Constant (C)	-5.53(-82.49)**	-5.11(-77.85)**	-5.087(-81.64)**	-5.058(-90.57)**	-6.47(-104.96)**
Trend (T)	0.0089(15.47)**	0.0093(18.49)**	0.0091(17.82)**	0.0096(17.77)**	0.052(6.74)**
Employment (lnL)	0.66(27.31)**	0.75(29.84)**	0.74(33.32)**	0.77(36.021)**	0.34(13.68)**
Private Capital (lnK)	0.34(15.066)**	0.25(10.74)**	0.25(12.097)**	0.23(11.79)**	0.66(28.56)**
Gran Capacity Network (lnHCN)	0.0051(5.52)**	0.0031(3.49)**	0.0034(3.87)**	0.0032(3.75)**	0.0034(0.31)
Type I adjacent region HCNs (ln		0.0086(12.24)**			
HCN_A1)			0.0092(13.017)**		
Type II adjacent region HCNs				0.0091(12.24)**	
(lnHCN_A2)					-0.0038(-3.87)**
Type III adjacent region HCN					
(lnHCN_A3)					
Competitive reg. HCNs (lnHCNC)					
Fixed effect inefficiency model					
Constant (C)	0.032(1.70)**	0.069(4.29)**	0.097(6.89)**	0.067(4.97)**	-0.12(-3.29)**
Trend (T)	-0.0091(-6.13)**	-0.014(-8.26)**	-0.013(-9.54)**	-0.014(-9.29)**	-0.051(-3.17)**
T^2	0.000104(2.69)**	0.00015(3.62)**	0.00014(3.96)**	0.00017(4.12)**	0.047(3.18)**
Parameter variance σ^2_s	0.0015(13.25)**	0.0015(16.0095)**	0.0014(17.77)**	0.0015(16.32)**	0.0027(12.95)**
γ	0.24(7.15)**	0.504(8.37)**	0.52(9.22)**	0.49(9.72)**	0.202(2.15)**
$H_0: \gamma = \delta_0 = ... = \lambda_{19} = 0$	1041.902	1058.48	1064.53	1061.39	692.36
Log. Function Probability	1026.48	1067.75	1066.59	1066.53	861.43

T-statistic in parenthesis.
*Parameter significant at 90%.
**Parameter significant at 95%.
HCN_A1: total adjacent regions.
HCN_A2: average adjacent regions.
HCN_A3: weighted total per surface area of adjacent regions.

Table 2. Regional stochastic production function (1970-1998). Agriculture, fishing & forestry

Independent Variable	HCN	HCN_A1	HCN_A2	HCN_A3	HCNC
Stochastic Frontier					
Constant (C)	-6.25(-42.53)**	-6.099(-48.61)**	-6.29(-41.41)**	-6.23(-38.61)**	-6.23(-37.15)**
Trend (T)	0.051(10.83)**	0.043(26.79)**	0.059(16.33)**	0.059(15.56)**	0.06004(13.44)**
Employment (lnL)	0.77(25.86)**	0.78(42.72)**	0.77(39.35)**	0.78(33.18)**	0.77(34.29)**
Private Capital (lnK)	0.24(7.048)**	0.22(9.45)**	0.24(9.26)**	0.23(7.57)**	0.23(7.89)**
Gran Capacity Network	0.0102(3.57)**	0.011(4.14)**	0.011(4.56)**	0.011(4.58)**	0.012(5.037)**
(lnHCN)		0.0074(3.0022)**			
Type I adjacent region HCNs			0.017(5.21)**		
(ln HCN_A1)				0.017(4.57)**	
Type II adjacent region HCNs					0.013(4.36)**
(lnHCN_A2)					
Type III adjacent region HCNs					
(lnHCN_A3)					
Competitive reg. HCNs					
(lnHCNC)					
Fixed effect inefficiency model					
Constant (C)	-0.29(-3.54)**	-0.52(-7.24)**	-0.33(-4.39)**	-0.31(-4.47)**	-0.39(-4.41)**
Trend (T)	0.32(5.078)**	0.47(8.103)**	0.25(5.11)**	0.25(5.63)**	0.28(5.57)**
T^2	-0.046(-1.75)**	-0.098(-6.19)**	-0.0037(-0.21)	-0.0042(-0.25)	-0.0086(-0.43)
Parameter variance σ^2_s	0.016(15.17)**	0.017(12.66)**	0.016(16.31)**	0.016(15.202)**	0.016(15.21)**
γ	0.13(1.79)**	0.24(3.19)**	0.92(10.68)**	0.93(12.35)**	0.76(4.83)**
$H_0: \gamma = \delta_0 = ... = \lambda_{19} = 0$	786.47	782.73	808.29	810.54	811.17
Log. Function Probability	361.47	359.37	372.28	373.86	373.67

T-statistic in parenthesis.
*Parameter significant at 90%.
**Parameter significant at 95%.
HCN_A1: total adjacent regions.
HCN_A2: average adjacent regions.
HCN_A3: weighted total per surface area of adjacent regions.
HCNC: total competitive regions.

Table 3. Regional stochastic production function (1970-1998). Energy

Independent Variable		HCN	HCN_A1	HCN_A2	HCN_A3	HCNC
Stochastic Frontier						
Constant (C)		-2.88(-8.86)**	-4.64(-27.65)**	-4.78(-19.51)**	-4.88(-24.084)**	-5.15(-40.11)**
Trend (T)		0.0056(2.66)**	0.0061(3.46)**	0.0065(3.74)**	0.0057(3.15)**	-0.023(-1.96)**
Employment (lnL)		0.39(14.28)**	0.56(20.29)**	0.57(9.29)**	0.59(21.15)**	0.32(19.14)**
Private Capital (lnK)		0.39(11.47)**	0.37(14.054)**	0.37(6.45)**	0.38(11.401)**	0.59(33.29)**
Gran Capacity Network (lnHCN)		0.0028(0.94)	0.0086(2.94)**	0.0095(2.37)**	0.0077(2.48)**	0.0026(0.86)
Type I adjacent region HCNs (ln			0.048(9.23)**			
HCN_A1)				0.051(7.44)**		
Type II adjacent region HCNs					0.046(11.68)**	
(lnHCN_A2)						-0.0034(-0.83)
Type III adjacent region HCNs						
(lnHCN_A3)						
Competitive reg. HCNs (lnHCNC)						
Fixed effect inefficiency model						
Constant (C)		1.13(9.75)**	-0.14(-1.28)	-0.34(-0.49)	-0.63(-7.33)**	0.37(4.27)**
Trend (T)		0.0201(3.95)**	-0.047(-8.53)**	-0.047(-8.28)**	-0.046(-5.61)**	0.15(5.98)**
T^2		-0.00068(-4.029)**	0.13(9.602)**	0.14(9.55)**	0.13(6.37)**	-0.00059(-6.64)**
Parameter variance	σ_s^2	0.022(11.92)**	0.0202(14.00)**	0.02004(6.73)**	0.021(12.37)**	0.022(11.49)**
	γ	0.55(7.033)**	0.43(2.82)**	0.32(1.29)*	0.39(7.61)**	0.25(5.78)**
$H_0 : \gamma = \delta_0 = ... = \lambda_{19} = 0$						
		614.29	603.25	595.19	592.17	590.56
Log. Function Probability		304.17	311.86	309.28	307.91	293.64

T-statistic in parenthesis.
*Parameter significant at 90%.
**Parameter significant at 95%.
HCN_A1: total adjacent regions.
HCN_A2: average adjacent regions.
HCN_A3: weighted total per surface area of adjacent regions.
HCNC: total competitive regions.

Table 4. Regional stochastic production function (1970-1998). Industrial sector

Independent Variable		HCN	HCN_A1	HCN_A2	HCN_A3	HCNC
Stochastic Frontier						
Constant (C)		-5.43(-30.45)**	-4.042(-49.66)**	-3.95(-49.32)**	-3.89(-51.57)**	-4.23(-44.85)**
Trend (T)		0.16(7.57)**	0.17(15.73)**	0.17(14.083)**	0.14(9.59)**	0.204(20.14)**
Employment (lnL)		0.44(10.94)**	0.83(30.78)**	0.85(34.73)**	0.82(28.81)**	0.76(34.47)**
Private Capital (lnK)		0.52(13.19)**	0.11(4.47)**	0.087(3.84)**	0.11(4.22)**	0.18(8.23)**
Gran Capacity Network (lnHCN)		0.0011(1.43)*	0.0038(2.85)**	0.0033(2.017)**	0.0031(1.99)**	0.0067(4.29)**
Type I adjacent region HCNs (ln			0.0092(6.901)**			
HCN_A1)				0.011(6.34)**		
Type II adjacent region HCNs					0.012(7.32)**	
(lnHCN_A2)						0.00052(0.29)
Type III adjacent region HCN						
(lnHCN_A3)						
Competitive reg. HCNs (lnHCNC)						
Fixed effect inefficiency model						
Constant (C)		0.13(2.39)**	0.43(11.97)**	0.46(12.66)**	0.53(12.19)**	0.27(7.74)**
Trend (T)		0.052(1.37)*	0.049(4.031)**	0.045(3.76)**	0.022(1.52)*	0.29(11.503)**
T^2		-0.00024(-1.94)**	-0.00053(-15.28)**	-0.00055(-15.42)**	-0.00052(-15.51)**	-0.082(-14.37)**
Parameter variance.	σ_s^2	0.0095(16.79)**	0.0036(11.88)**	0.0038(12.55)**	0.0037(12.24)**	0.0035(13.19)**
	γ	0.304(6.76)**	0.22(5.11)**	0.26(2.34)**	0.18(1.52)*	0.13(2.028)**
$H_0 : \gamma = \delta_0 = \ldots = \lambda_{19} = 0$		361.91	748.84	741.64	740.16	740.66
Log. Function Probability		590.062	783.94	780.27	779.44	779.44

T-statistic in parenthesis.
*Parameter significant at 90%.
**Parameter significant at 95%.

HCN_A1: total adjacent regions.
HCN_A2: average adjacent regions.
HCN_A3: weighted total per surface area of adjacent regions.
HCNC: total competitive regions.

Table 5. Regional stochastic production function (1970-1998). Construction

Independent Variable		HCN	HCN_A1	HCN_A2	HCN_A3	HCNC
Stochastic Frontier						
Constant (C)		-5.032(-48.65)**	-4.502(-31.78)**	-4.51(-31.58)**	-4.61(-49.58)**	-4.94(-23.012)**
Trend (T)		0.15(19.38)**	0.0079(6.42)**	0.0079(6.39)**	0.14(13.82)**	0.17(7.89)**
Employment (lnL)		0.88(38.68)**	0.77(37.0099)**	0.77(34.91)**	0.84(37.27)**	0.89(30.27)**
Private Capital (lnK)		0.15(19.57)**	0.22(10.89)**	0.22(10.65)**	0.15(7.43)**	0.13(7.25)**
Gran Capacity Network (lnHCN)		-0.0011(-0.68)	0.0015(1.087)	0.0015(1.076)	0.00039(0.31)	0.00026(0.14)
Type I adjacent region HCNs (ln HCN_A1)			-0.0039(-2.53)**			
Type II adjacent region HCNs (lnHCN_A2)				-0.0041(-2.59)**		
Type III adjacent region HCNs					-0.0048(-3.32)**	
(lnHCN_A3)						0.0019(0.85)
Competitive reg. HCNs (lnHCNC)						
Fixed effect inefficiency model						
Constant (C)		0.0019(0.096)	0.32(4.73)**	0.32(4.98)**	0.18(4.36)**	0.033(0.87)
Trend (T)		0.017(10.81)**	-0.0087(-3.93)**	-0.0087(-3.83)**	0.016(5.96)**	0.021(5.103)**
T^2		-0.00049(-10.36)**	0.00016(2.42)**	0.00016(2.23)**	-0.00051(-7.56)**	-0.00057(-6.37)**
Parameter variance	σ_s^2	0.0038(7.303)**	0.0051(11.64)**	0.0051(11.34)**	0.0042(11.58)**	0.0036(15.31)**
	γ	0.28(2.28)**	0.79(7.82)**	0.78(7.037)**	0.84(8.038)**	0.89(2.12)**
$H_0: \gamma = \delta_0 = \ldots = \lambda_{19} = 0$		500.44	388.72	390.17	483.27	501.24
Log. Function Probability		768.76	718.82	718.56	772.081	774.87

T-statistic in parenthesis.
*Parameter significant at 90%.
**Parameter significant at 95%.
HCN_A1: total adjacent regions.
HCN_A2: average adjacent regions.
HCN_A3: weighted total per surface area of adjacent regions.
HCNC: total competitive regions.

Table 6. Regional stochastic production function (1970-1998). Services designed for selling

Independent Variable		HCN	HCN_A1	HCN_A2	HCN_A3	HCNC
Stochastic Frontier						
Constant (C)		-4.78(-41.15)**	-5.93(-53.59)**	-5.34(-38.56)**	-5.701(-31.36)**	-5.15(-58.69)**
Trend (T)		0.013(17.18)**	0.014(18.87)**	0.093(10.52)**	0.076(6.62)**	0.103(20.43)**
Employment (lnL)		0.93(31.88)**	0.94(28.79)**	0.85(19.55)**	0.68(12.83)**	0.93(37.24)**
Private Capital (lnK)		0.096(3.29)**	0.16(5.31)**	0.18(4.39)**	0.34(6.47)**	0.11(4.703)**
Gran Capacity Network (lnHCN)		-0.0011(-1.21)	0.000034(0.032)	0.00074(0.53)	0.0011(0.68)	-0.0014(-1.78)**
Type I adjacent region HCNs (ln HCN_A1)			0.0103(10.27)**			
Type II adjacent region HCNs (lnHCN_A2)				-0.0013(-0.98)		
Type III adjacent region HCNs (lnHCN_A3)					-0.0099(-7.59)**	
Competitive reg. HCNs (lnHCNC)						-0.0014(-1.18)
Fixed effect inefficiency model						
Constant (C)		0.26(11.67)**	-0.12(-4.404)**	0.096(3.76)**	0.17(5.094)**	0.16(8.13)**
Trend (T)		-0.0064(-5.75)**	-0.057(-6.24)**	-0.014(-5.46)**	-0.0097(-2.75)**	0.029(17.71)**
T^2		0.000201(6.12)**	0.025(8.401)**	0.029(4.93)**	0.022(2.41)**	-0.00023(-20.23)**
Parameter variance.	σ_s^2	0.0013(14.303)**	0.0014(16.87)**	0.0045(17.47)**	0.0052(11.49)**	0.0014(16.81)**
	γ	0.23(4.54)**	0.25(5.12)**	0.033(5.73)**	0.13(4.55)**	0.064(11.37)**
$H_0 : \gamma = \delta_0 = ... = \lambda_{10} = 0$		1012.91	941.28	309.13	259.69	1039.41
Log. Function Probability		1045.75	1038.68	704.36	679.26	1042.89

T-statistic in parenthesis.
*Parameter significant at 90%.
**Parameter significant at 95%.
HCN_A1: total adjacent regions.
HCN_A2: average adjacent regions.
HCN_A3: weighted total per surface area of adjacent regions.
HCNC: total competitive regions.

Principal results

The purpose of this paper is to evaluate the economic effects of investment in high capacity road networks on private regional activity. In order to do so, the analysis incorporates capital in the high capacity network of the region analyzed as well as the rest of other regional networks as additional production factors. In addition, further evidence is provided by incorporating different definitions of capital in the remainder of the network, with the aim of accurately measuring the role of spillover effects. Firstly, we incorporate alternative measures of capital in high capacity networks in adjacent regions. An analysis was then performed after incorporating the capital in regions with similar social and economic characteristics, as a variable explaining regional private production. By including these different definitions of the variable, our objective is to differentiate positive and negative spillover effects.

The empirical analysis was not only carried out on the total private sector of the economy, but also designed to delimit the effects on different productive sectors: agriculture, fishing and forestry, industry, energy, construction and services destined for selling. The use of frontier techniques allows the possibility of incorporating the influence of the level and evolution of technical production efficiency areas into the study. The defining of production frontiers therefore enables the establishing a regionally balanced model designed to avoid the problems associated with the assumption that all economic units operate efficiently.

Principal results that can be highlighted are the high and continued level of investment made by the Public Administration in the High Capacity Network as of the mid eighties, which has allowed an increase in the net HCN capital in Spanish economic infrastructure. This increased investment in the high capacity network can be related to greater economic activity. In other words, regions with higher levels of capital within the network have more private production.

Different measurements are made of the capital within the high capacity road network in other regions, in order to identify spillover effects and thus determine the impact of HCN infrastructure on the Spanish economy, following the strategy of separating positive and negative spillover effects. The empirical analysis designed to evaluate this economic impact confirms the importance of HCN infrastructure to private production, despite this impact being limited, however greater when spillover effects from adjacent regions are taken into account. The study shows that the high capacity network represents a conditioning factor for growth in agricultural and industrial sectors. Results for the construction, energy and selling services sectors do not provide conclusive evidence showing that the influence of the high capacity network is less in such sectors.

The study highlights the high capacity road network as infrastructure in which spillover effects are of great interest. The condition of the network assumes that increases in HCN infrastructure in a particular province are linked to increases in other adjoining regions, meaning that their effects are not only located in the region itself, but also "spillover" to other regions. The results show that it is important for regions to not only have high levels of infrastructure in their own territories, but also in adjoining regions, thus proving the existence of spillover.

Finally, the evidence provided by our research supports recent literature on the existence of negative spillover effects. Increasing capital in the high capacity network in regions with similar social and economic characteristics has negatively influenced total sector private production. This is an important result of the research and confirms the importance it has on the investment decision making process, given that in addition to generating positive effects, it can provoke a re-distribution of economic activity, thus creating problems for areas that are negatively affected. The results per sector did not allow us to determine the activities in which these findings condition nationwide results, and it would therefore be of interest to continue this line of research using a greater level of data breakdown for the purpose of providing more information on the effects of HCN infrastructure.

References

Álvarez, R., 2001: "Modelos con Eficiencia Técnica Variante en el Tiempo" en Alvarez A., Coord.: *La Medición de la Eficiencia y la Productividad*. Ediciones Pirámide, Madrid.

Arias, C., 2001: "La estimación de eficiencia en modelos con datos de panel" en Alvarez A. (Coord.) *La Medición de la Eficiencia y la Productividad*. Ediciones Pirámide, Madrid.

Anselin, L., 1988: *Spatial Econometrics: Methods and Models*, Kluwer Academic Publishers, The Netherland.

Battese, G. y T. Coelli, 1993: *A Stochastic Frontier Production Function incorporating a model for technical inefficiency effects*, Working Paper in Econometrics and Applied Statistics 69/93, Department of Econometrics, University of New England.

Battese, G. y T. Coelli, 1995: "A model for technical inefficiency effects in a stochastic frontier production function for panel data", *Empirical Economics*, 20, 325-332.

Boarnet, M.G., 1998: "Spillovers and the locational effects of public infrastructure", *Journal of Regional Science*, 38 (3), 381-400.

Boisso, D., S. Grosskopf y K. Haynes, 2000: "Productivity and Efficiency in the US: Effects of business cycles and Public capital", *Regional Science and Urban Economics*, 30, 663-681.

Cantos, P., Gumbau-Albert, M. y Maudos, J., 2002: *Transport infrastructure and regional growth: evidence of the Spanish case*, WP-EC 2002-27, IVIE.

Case, C.A., Rose, H.S. y Hines, J.R., 1993: "Budget spillovers and fiscal policy interdependence. Evidence from the states", *Journal of Public Economics*, 52, 285-307.

Chandra, A. y Thompson, E., 2000: "Does public infrastructure affect economic activity? Evidence from the rural interstate highway system", *Regional Science and Urban Economics*, 30: 457-490.

Coelli, T., 1996: *A Guide to Frontier Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*, CEPA Working Paper, 96/07.

Cohen, J.P. y Morrison, C.J., 2002: *Public infrastructure investment, inter-state spatial spillovers, and manufacturing costs*. Mimeo, Department of Agricultural & Resources Economics, UC Davis.

Cuesta, R.A., 2001: Modelos con eficiencia técnica variante en el tiempo, in A. Álvarez (Coord.) *La Medición de la Eficiencia y la Productividad*, Madrid, Ed. Pirámide.

Delgado, M.J. y Álvarez, I., 2003:, "Efectos de la Red Viaria de Gran Capacidad sobre el Desarrollo Territorial", *Economía Industrial*, 353: 57-78 .

Delgado, M.J. y Álvarez, I., 2004: "Una Aproximación a la Dotación de la Red Viaria de Gran Capacidad en las Provincias Españolas", *Estudios sobre la Economía Española*, FEDEA, 187/2004, 1-41. Madrid.

FBBVA-IVIE, 2004: *El stock de capital en España y su distribución Territorial,* 1964-2000, Bilbao.

FUNDACIÓN BBVA (VV.AA): *Renta Nacional de España y su Distribución Provincial*, Bilbao.

Gumbau, A. M. y J. Maudos, J., 2002: "The determinants of efficiency: the case of the Spanish industry", *Applied Economics*, 34, 1941-1948.

Holtz-Eakin, D. y Schwartz, A., 1995*: "Spatial productivity spillovers from public infrastructure: evidence from state highways"*, National Bureau of Economic Research, Working Paper 5004.

Kelejian H.H. y Robinson D.P., 1997: "Infrastructure productivity estimation and its underlying econometric specifications: a sensitive analysis", *Papers in Regional Science*, 76, 1:115-131.

Kodde, D.A. y Palm, F.C., 1986: "Wald Criteria for Jointly Testing Equality and Inequality", *Econometrica*, 54: 1243-1248.

Kumbhakar, S. y C. Lovell, 2000: *Stochastic Frontier Analysis*. Cambridge University Press.

Maudos, J., J.M. Pastor y L. Serrano, 1998: "Convergencia en las regiones españolas: cambio técnico, eficiencia y productividad", *Revista Española de Economía*, 15 (2) 235-264.

Ministerio de Fomento, 2004: *Plan Estratégico de Infraestructuras del Transporte*, PEIT:, Secretaría de Estado de Infraestructuras y Planificación, Madrid.

Ministerio de Fomento (VV.AA): *Anuario Estadístico,* Ministerio de Fomento, Madrid.

Pereira, A.M. y Andraz, J., 2004: "Public highway spending and State spillovers in the USA", *Applied Economics Letters*, 11, 785-788.

Wang, H. y P. Schmidt, 2002: "One-step and two-step estimation of the effects of exogenous variables on Technical efficiency levels", *Journal of Productivity Analysis*, 18, 129