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EVALUATING THE ECONOMIC AND REGIONAL IMPACT ON NATIONAL TRANSPORT AND INFRASTRUCTURE POLICIES WITH ACCESSIBILITY VARIABLES

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Abstract. This research aims to gauge the economic impact of the measures set out in the Strategic Infrastructure and Transport Plan, 2005–2020, as implemented by the Spanish government, on regional development. Contributing to regional development, this plan extends high capacity road networks and high performance rail networks in Spain between 2005 and 2020. To evaluate the plan, this research relies on an innovative technique based on panel data and accessibility indicators, which can quantify the plan's economic impact on regional development. Findings from the study provide a valuable tool for economic, geographic, and territorial assessments of policies implemented in the field of transport and infrastructure, whilst also pointing to guidelines for the design and development of further proposals and actions.

Keywords: economic development, regional development, road systems, railway systems, transport infrastructure, accessibility.

1. Introduction

The European Union's transport policy is oriented generally toward achieving the rational, coordinated employment of railways and roads. It also aims to promote railway systems, in an attempt to reallocate road traffic and reduce environmental stresses. Beneficial outcomes might derive from the coordinated design of these two types of infrastructure. For example, greater reliance on railways can reduce traffic loads on arterial road networks. Joint operations of road and railway transport systems, integrated in a uniform transportation system, also offer a good alternative for cargo handling, ensuring flexible customer services, and preventing traffic congestion.

These beneficial effects of coordinated planning of road and railway infrastructures are the keys for national and transnational planning authorities. But coordinated planning also makes economic sense, in that transport infrastructures exert major socioeconomic influences, including impacts on demographic growth, the spread of financial activities, the increase of productive sectors, and mobility (Obregón-Briosca 2008). Thus, an efficient transport system is a necessary precondition for the successful development of human well-being.

Further infrastructure is fundamental for determining the efficiency of transport activities; thus, policy decisions regarding transport infrastructure usually require knowledge of the welfare generated by the infrastructure at a regional level (Bröcker *et al.* 2010). Accordingly, this research assesses the positive effects of a specific transport and infrastructure action plan, drawn up by the Spanish government, on the economic development of regions in Spain. Of the many approaches available to measure these socioeconomic impacts (Obregón-Briosca 2008), we draw on studies of the structuring effects that transport can generate (Burmeister, Joignaux 1997; Dubois-Taine 1990; Navarre, Prud'Homme 1984; Plassard 1976). In turn, we extend prior research and explore the links of transport, infrastructure, and regional development.

With this perspective, we find that improvements in infrastructure and transport have positive impacts on regional development, in that they act as hubs and exert a functional effect on the area. To measure these effects, we use accessibility indicators and consider how enhanced access to various destinations (*opportunities*) offers advantages that benefit society as a whole. Such social improvements have significant implications for the economy, both directly by facilitating freight transport and indirectly by enabling access to goods and services.

Yet accessibility also is an abstract concept that can be defined in mathematical terms, using specific indicators. To calculate this value, we must integrate an analysis of the quality of the transport system with the particular features of any regional system. This integration in turn requires aggregated accessibility indicators that encompass the quality of the connections between centres of financial activity and their socio-economic importance.

The infrastructure and transport plan that we evaluate is the Strategic Infrastructure and Transport Plan (PEIT – *Plan Estratégico de Infraestructuras y Transporte* – 2005–2020) drawn up by the Spanish government for 2005–2020, which seeks to implement a series of measures to achieve two key goals: (1) expand the Spanish road network to reach 15000 km of high capacity roads, in addition creating a grid structure to reduce the radial nature of the current system, and (2) reach 9000 km of high performance rail track (MF 2005). For the road network, the action mainly entails changing national roads into high performance and high capacity roads, without substantially increasing surface densities. For the rail network though, the aim is to create a new, high performance infrastructure.

To assess the benefits of investing in transport, prior literature has used microeconomic models such as the basic, Wardrop, or logit models, which use the consumer as the unit of analysis (e.g., Kidokoro 2006). Bröcker *et al.* (2010) also has developed a spatial computable general equilibrium model that includes household and production sectors, as well as industries. Because our goal is to gauge effects on endogenous regional development, and considering the data available (i.e., macroeconomic data provided by regional bodies), we adopt a panel data model that allows for the inclusion of socioeconomic data from different regions.

Therefore, we assess the positive effects of the specific transport and infrastructure action plan designed by the Spanish government for the economic development of Spanish regions. In so doing, we account for potential structuring and accessibility effects of transport and focus on the links among transport, infrastructure, and regional development. With our panel data model, we pursue this analysis using macroeconomic data provided by the affected regional bodies.

In the next sections, we describe our method and its application, then outline the main outcomes. The findings suggest various recommendations for policy and management, with a view to determining the most adequate profiles for planning roads and rail networks. We thus offer a useful tool to support decision making and planning, based on a comprehensive view of the socioeconomic impact on building road and rail networks.

2. Method

2.1. Evaluation Scenarios and Study Area of the Road and Rail Infrastructure

To analyze the possible effects of implementing the infrastructure proposed by PEIT 2005–2020, we consider two reference scenarios. First, we examine the initial infrastructure and transport situation. Second, we imagine a possible final scenario. Thus, we can assess the full execution of PEIT in a context that follows the trends and development of the socioeconomic variables. Our horizontal timeline implies that infrastructure remains unaltered from the base year (2005) to the last year (2020), with an unchanging socioeconomic context. Therefore, we measure the impact by accounting for the difference between the existing indicators in both scenarios.

The focal area for this study covers the Iberian Peninsula, comprising Spain and Portugal, as well as three regions in southern France. This expansive assessment is necessary because of calculating the accessibility levels, we must account for infrastructure planning by neighbouring countries, which affects the levels of accessibility in Spain. We also calculated indicators using the points of origin and destinations of various journeys, including (1) Spanish municipalities (total of 8176); (2) Portuguese *concelhos* (total of 278); and (3) the capitals of the three southern French regions (total of 18 *départements*). However, we only assess the impact of the PEIT on Spanish regions, for both road accessibility indicators and rail accessibility indicators.

The population living in this area and its potential shifts must be known to calculate the accessibility indicators. Therefore, we gathered information about the number of residents in Spanish areas from the 1996–2004 population data series published by the Spanish National Statistics Institute. We then estimated the population growth in each municipality through 2020, using a linear estimation model with prediction intervals adjusted according to a linear regression. The population figures for Portugal and southern France were calculated similarly, taking their official population databases as starting points.

Our considered Spanish infrastructure corresponds to the two PEIT 2005–2020 scenarios. With the same criterion, we assume the infrastructure planned for southern France and Portugal will have been finished by 2020 (Decision No 884/2004/EC).

Roads

- Reference scenario: Road accessibility indicators refer to the Spanish road network existing in 2005 and the high capacity track planned for 2020 in Portugal and southern France;
- PEIT scenario 2005–2020: Road accessibility indicators refer to the network expected to be in place subsequent to the action included in the PEIT by 2020, as well as the high capacity lines planned for that year in Portugal and southern France.

Fig. 1 shows the road network in these reference scenarios.

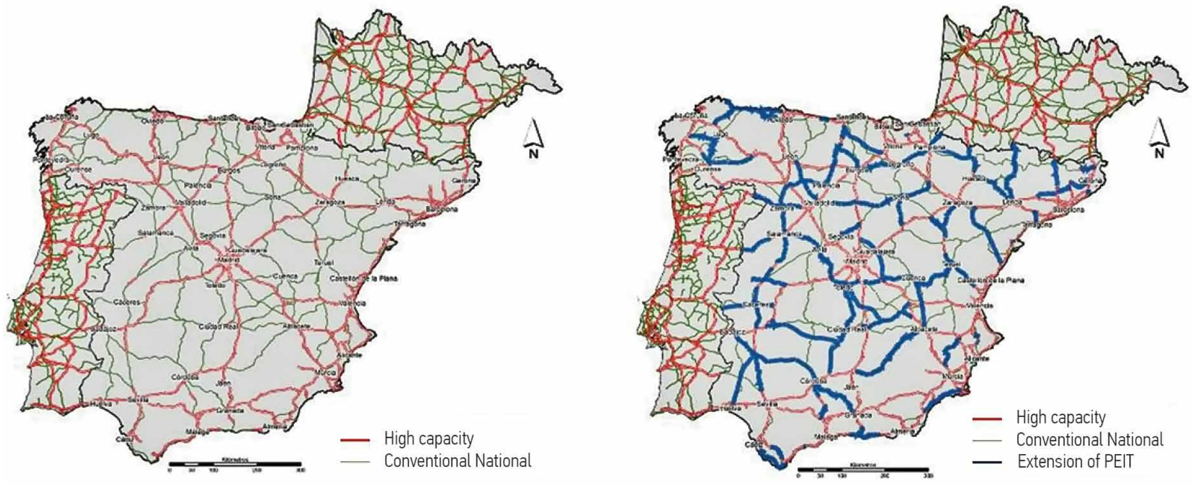

Fig. 1. Road networks in the reference (2005) and PEIT (2020) scenarios

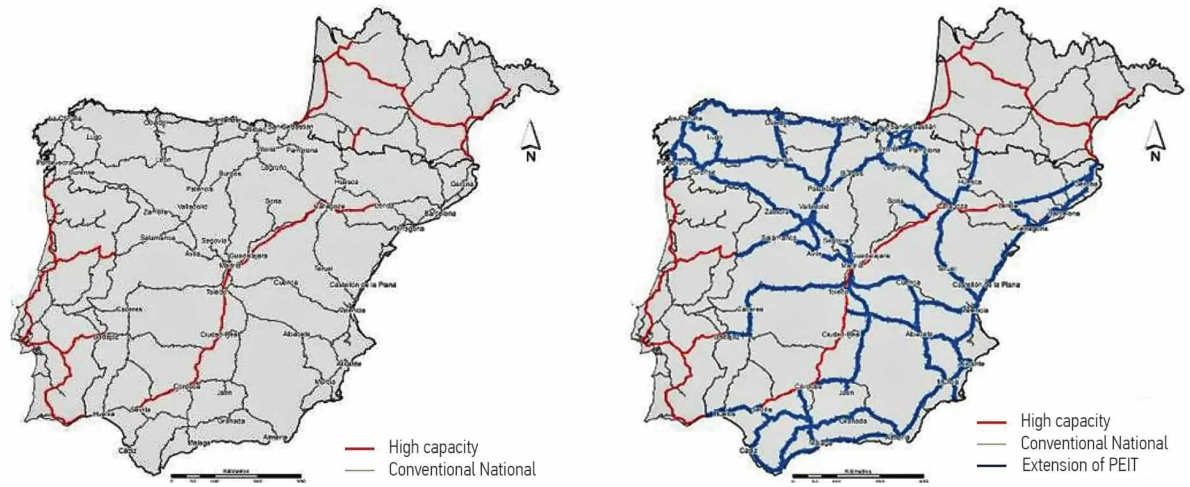

Fig. 2. Rail networks in the reference (2005) and PEIT (2020) scenarios

Railways

- Reference scenario: Rail accessibility indicators refer to the situation in 2005 in the Spanish rail network, with the planned situation for networks in Portugal and France in 2020.
- PEIT scenario 2005–2020: Rail accessibility indicators refer to the rail structure contained in the PEIT for 2020 and the planned situation for networks in Portugal and France for that same year.

Fig. 2 shows the railway network in the reference scenarios.

2.2. Accessibility Indicators

The wide range of accessibility indicators (Geurs, Ritsema Van Eck 2001) reflects their dependence on the type of effect to be measured, time, and geographical scale. The information available also must be taken into account, which helps determine their design. In some instances, information exists but not at the required level. Moreover, handling systems may limit information availability, though their capacity is increasing with new technologies. For our study, we developed a series of computer tools (Mancebo 2007a, 2007b), based on a geographical information system, that support detailed calculations of all the indicators. The indicators are based on the same variables and zoning as those developed by Gutiérrez but use a different formulation, specific to each impact we sought to measure. The basic accessibility indicator measures are as follows (Gutiérrez *et al.* 1996, 1998; Gutiérrez, Urbano 1996):

- **Opportunities (D_j) at destination (j):** A socio-economic variable that represents the size of the destination. For this initial approach, destination opportunities are proportionate to the population (P_j).
- **Travel cost (C_{ij}) from origin (i) to destination (j):** For this initial approach, cost is proportionate to the travel time (t_{ij}) between the origin and the destination. The minimum cost to cover this distance exists when a person travels in a straight line—though technically it is not a straight line but rather a curve known geometrically as a geodesic line or a maximum circle. Given a maxi-

mum travel speed (V_{max}), this cost translates to a minimum time, which we refer to as the ideal (T_{ij}).

Accessibility for each municipality (origin) depends on destinations. Origins are thus all the municipalities in (peninsular) Spain, and destinations are all the municipalities in (peninsular) Spain and capitals of Portuguese *concelhos* and French *départements*. In Spain, the level of disaggregation was the NUTS-5 municipal level; in France and Portugal, we used the NUTS-3 level (note – created by the Statistical Office of the European Communities (Eurostat) to standardise European regional statistics, NUTS is the French acronym *La nomenclature d'unités territoriales statistiques* (Nomenclature of Territorial Statistical Units) used in the European Union for statistical purposes). To calculate the minimum time to cover the distance from origin to destination, we used the geographical information system with network analysis routines.

We also calculated three indicators related to different ways to understand accessibility. First, *potential indicators* measure the capacity to access any type of opportunity in the area. They can be generalised according to the following equation (Geurs, Ritsema Van Eck 2001):

$$A_i = \sum_j D_j F c_{ij}, \quad (1)$$

where: A_i is accessibility of area i; D_j are the opportunities for area j; c_{ij} is a measure of the travel cost from i to j; F is an impedance function that measures the minimum attraction of destination j due to cost c_{ij}. Replacing opportunities (D_j) with the population (P_j), replacing cost (c_{ij}) with actual (t_{ij}) and ideal times (T_{ij}), and using the linear impedance function (F), we can obtain various potential indicators, as shown in Table 1. Actual (t_{ij}) value equals minimum time routes using the corresponding transport network (road or rail). Each node in the network is thus allocated a series of values, which are the time taken to cover the distance from the node and each destination centroid defined. Ideal (T_{ij}) value equals the distance in a straight line between each pair of centroids and the time needed to travel that distance at the maximum speed for each network (120 km/h by road, 220 km/h for a high speed rail link).

Second, *locational indicators* measure the cost to be paid to access these opportunities,

$$A_i = \sum_j c_{ij} w_{ij}, \quad (2)$$

where: A_i is accessibility to area i; c_{ij} is a measure of the travel cost from i to j; w_{ij} is the weight of the destination j for origin i. This weight indicates the number or percentage of trips made to each destination j from origin i. For our study, actual times (t_{ij}) and ideal times (T_{ij}) measure the travel cost (c_{ij}) from i to j. To construct these indicators, we need to know the weight (w_{ij}) or potential of each destination to estimate the percentage of trips in terms of actual times (t_{ij}) and ideal times (T_{ij}):

$$w_{ij} = \text{relative weight of destination } j \text{ for origin } i = \frac{\frac{P_j}{t_{ij}}}{\sum_j \frac{P_i}{t_{ij}}}; \quad (3)$$

$$w_{ij} = \text{relative weight of destination } j \text{ for origin } i = \frac{\frac{P_j}{T_{ij}}}{\sum_j \frac{P_i}{T_{ij}}}. \quad (4)$$

These cost or locational indicators are presented in Table 2.

Third, *efficiency indicators* measure the efficiency of the trip achieved because of the infrastructure, which take two basic types. The first basic type is the following one:

$$A_i = \frac{AR_i}{AI_i}, \quad (5)$$

where: AR_i is the actual accessibility of zone i; AI_i is the ideal accessibility of zone i. The second basic type, the relationship between the homologous indicators, actual and ideal, provides us a measure of the efficiency with which the actual infrastructures grant access different opportunities:

$$A_i = \sum_j \frac{c_{ij}}{C_{ij}} w_{ij}, \quad (6)$$

where: A_i is the accessibility of zone i; c_{ij} is a measure of the cost of the actual movement from i to j; C_{ij} is a measure of the cost of the ideal movement from i to j;

Table 1. Potential accessibility indicators

Type	Indicator	Equation	Units	Scale
potential	indicator of actual potential accessibility	$ACPR = \sum_j \frac{P_j}{t_{ij}}$	inhabitants per time unit	absolute direct
	indicator of ideal potential accessibility	$ACPI = \sum_j \frac{P_j}{T_{ij}}$	inhabitants per time unit	absolute direct
	indicator of potential accessibility efficiency	$ACPE = \frac{ACPR}{ACPI}$	one-dimensional	absolute direct

Source: Monzón *et al.* (2010)

Table 2. Cost accessibility indicators

Type	Indicator	Equation	Units	Scale
cost	actual indicator of locational accessibility	$ACLR = \sum_j t_{ij} w_{ij}$	unit of time (measures the actual mean time cost)	absolute inverse
	ideal indicator of locational accessibility	$ACLR = \sum_j T_{ij} w_{ij}$	unit of time (measures the ideal mean time cost)	absolute inverse
	efficiency indicator of locational accessibility	$ACLE = \frac{ACLR}{ACLI}$	one-dimensional (measures 'time efficiency' as the relation between actual and ideal costs)	absolute inverse
	indicator of time efficiency – inverse	$ACLEI = \frac{ACLI}{ACLR}$	one-dimensional (measures 'time efficiency' as the relation between ideal and actual costs)	absolute direct
	indicator of efficiency – speed	$ACLEV = V_{\max}\, ACLEI$	unit of speed (measures 'effective mean speed' – the term 'effective' refers to the speed obtained if we moved in a straight line; we convert it to the speed actually needed to cover the distance between the origin and destination)	absolute direct

Source: Monzón *et al.* (2010)

w_{ij} is the weight of zone j for origin i. This second type measures the weighted efficiency of the infrastructure, substituting the cost of the actual movement (c_{ij}) for the real time (t_{ij}), the cost of the ideal movement (C_{ij}) for the ideal time (T_{ij}), and the weight (w_{ij}) of destination j for departure i for:

$$w_{ij} = \text{relative weight of destination } j \text{ for origin } i = \frac{\frac{P_j}{t_{ij}}}{\sum_j \frac{P_i}{t_{ij}}}; \quad (7)$$

$$w_{ij} = \text{relative weight of destination } j \text{ for origin } i = \frac{\frac{P_j}{T_{ij}}}{\sum_j \frac{P_i}{T_{ij}}}. \quad (8)$$

The efficiency indicator we use, as displayed in Table 3, measures the average temporal efficiency.

Finally, the scales for the three types of accessibility indicators are

- ***direct***, such that a value greater than the indicator implies greater accessibility;
- ***inverse***, such that a value greater than the indicator leads to less accessibility;
- ***absolute*** or a direct scale on which a value of 0 on the indicator signifies no accessibility.

2.3. Regional Development Indicators

To analyze the effects on social cohesion, we adopt the *gravitational indicator of network efficiency* to measure the efficiency of network accessibility. This indicator details the efficiency of the connections established between each node and different activity centres. Other indicators suffer significant bias related to the geographical location of the nodes, because distance – generally expressed in time – is normally included in the calculations. Thus distant locations, though situated on the periphery, may invariably appear inaccessible and in need of investment, even if they already have very good transport infrastructures.

Therefore, in addition to use the gravitational indicator of network efficiency, we attempt to neutralise the effect of geographical location and emphasise the effect of the provision of new infrastructures by substituting a measure of distance that expresses ease of access in relative terms. The network efficiency indicator relates actual access times to ideal ones.

The gravitational indicator of network efficiency reflects improvements introduced in the transport system by providing information about the contrasts between areas that are better and worse equipped. This indicator, with its infrastructural approach, is interesting as a method for measuring the effects of an infrastructure plan. It represents the weighted mean of the ratio between actual and ideal access times – the latter defined as the times obtained from a straight line on a hypothetical motorway or high-speed railway line. In contrast with the localization indicator, the weighting factor used to calculate this measure is the coefficient between the destination population and the access time to that destination, which constitutes a gravitational formulation. Accordingly, the values for this indicator depend on the efficiency the network offers for each node in its connec-

Table 3. Efficiency accessibility indicators

Type	Indicator	Equation	Units	Scale
efficiency	gravitational indicator of the network efficiency	$ACE = \sum_j \frac{t_{ij}}{T_{ij}} w_{ij}$	a dimensional	absolute inverse

Source: Monzón *et al.* (2010)

tions with activity centres, which in turn depend on the speed of movement the infrastructure allows, together with the so-called detour index.

This indicator thereby offers information about the accessibility of each node, in comparison with an ideal situation. Thus, the interpretation of the findings must adopt an infrastructural perspective, because network efficiency is measured for the relationships of each node with the activity centres. This indicator is very valuable as a system for measuring network efficiency but also supports a comparative assessment of the two distinct situations that facilitates the evaluation of the effects of the actions foreseen by the infrastructure plan. That is, we measure the relative differences as follows:

$$\%\text{ improvement of } A_i = \frac{A_{i0} - A_{if}}{A_{i0}} \cdot 100, \quad (9)$$

where: A_{i0} indicates network efficiency in the reference scenario; A_{if} reveals the efficiency of the network in the final scenario.

We thus perform a concrete aggregation of the accessibility value of the municipalities for each autonomous region in Spain, weighted by their population (the results for roads are in Table 4; those for rail are in Table 5), and obtain a summary of the changes in the accessibility values. The results in these tables reveal that, in general, regions with a low or medium level of accessibility in the reference scenario enjoy a higher percent-

Table 4. Values and variation of accessibility by road in different autonomous regions

ROAD						
Region	Efficiency in reference scenario	Order in reference scenario	Efficiency in PEIT scenario	Order in PEIT scenario	Improvment (%)	Rank of improvement
Extremadura	1.42	9	1.34	6	5.68	1
Navarre	1.50	14	1.43	12	4.47	2
La Rioja	1.41	7	1.35	8	4.29	3
Aragon	1.34	1	1.29	1	3.80	4
Castilla-La Mancha	1.39	6	1.34	4	3.52	5
Asturias	1.38	4	1.33	3	3.32	6
Castilla y León	1.37	3	1.32	2	3.19	7
Cantabria	1.39	5	1.35	7	2.85	8
Andalusia	1.47	12	1.43	11	2.55	9
Galicia	1.44	10	1.41	9	2.29	10
Region of Murcia	1.36	2	1.34	5	1.60	11
Basque Country	1.48	13	1.46	14	1.43	12
Valencia Region	1.45	11	1.43	13	1.34	13
Catalonia	1.51	15	1.50	15	0.82	14
Madrid Region	1.42	8	1.41	10	0.50	15
Source: Monzón *et al.* (2010)						

Table 5. Values and variation of accessibility by rail for different autonomous regions

RAIL						
Region	Efficiency in reference scenario	Order in reference scenario	Efficiency in PEIT scenario	Order in PEIT scenario	Improvment (%)	Order of improvment
Cantabria	6.06	13	2.76	2	54.47	1
Asturias	5.93	12	2.92	7	50.70	2
Galicia	5.15	9	2.78	3	46.08	3
Castilla y León	4.89	7	2.79	4	42.94	4
Navarre	4.80	6	2.86	5	40.52	5
Basque Country	6.20	14	3.74	12	39.64	6
Region of Murcia	5.06	8	3.08	9	39.12	7
La Rioja	4.64	4	2.87	6	38.01	8
Andalusia	4.58	2	2.97	8	35.10	9
Castilla-La Mancha	4.60	3	3.21	10	30.29	10
Valencia	5.44	11	3.84	13	29.46	11
Extremadura	4.66	5	3.35	11	28.11	12
Aragon	3.65	1	2.70	1	26.22	13
Catalonia	6.24	15	5.02	15	19.52	14
Madrid	5.40	10	4.40	14	18.42	15
Source: Monzón *et al.* (2010)						

age improvement. In particular, the regions that most benefited from PEIT 2005–2020 in terms of roads were Extremadura, Navarre, and La Rioja. Aragon remains the region with the highest efficiency.

The effects are even more notable for railways, because the improvements are great in relative terms and substantially change network efficiency. The values in Table 5 show that PEIT 2005–2020 will lead to increased accessibility to regions that started at low levels, including Cantabria, Asturias, and Galicia, which in 2005 occupied positions 13, 12 and 9, respectively. Those regions in top positions in 2005 achieve fewer improvements (i.e., Aragon, Andalusia, and Castilla La Mancha).

2.4. Economic Development Potential

One of the key determinants of the economic welfare of a region is the presence of a reliable and efficient transport infrastructure (Ozbay *et al.* 2003). A well-developed transport system provides sufficient accessibility to ensure the efficient working of entrepreneurial and industrial society. According to Banister and Berechman (2001) (see Fig. 3), who describe the relationship between the transport system and economic growth, greater accessibility results from investments in transport. This improvement in accessibility in turn alters travel and land use models, leading to economic growth.

This scheme serves as our reference for determining the impact of PEIT 2005–2020 on economic growth in Spanish regions. A widespread belief indicates that development of transport networks plays a fundamental role in strengthening economic growth by lowering production and distribution costs, even as it improves productivity and stimulates private investments and technological innovation. This conviction is based on the theory that the availability of fast, reliable, economic transport historically has been the foundation for cities and regions. Today, this justification persists; some of the relative economic advantages of certain regions and countries derive from their capacity to move people and freight easily and economically.

Understanding the relationship between investment in transport infrastructures and development requires an adequate accessibility indicator. We thus define 'investment in transport infrastructure' as an expansion of capacity or addition to existing networks of roads, railways, canals, tunnels, bridges, airports, and ports. Improvements in these stocks of transport capital occur incrementally, over several years. The evaluation criteria for each transport project thus include the impacts on travel times, costs, and traffic volume as a result of network improvements.

Economic growth is the process of annual increases in per capita income, measured by per capita gross domestic product (GDP), productivity, or national or regional employment. The concept of economic development incorporates other criteria, such as changes in the locations of companies and families, changes in urban layout, equity, and so on. In general, economic development refers to changes in economic opportunity as a result of improvements in accessibility, brought about by new transport investments, which are capitalised in the form of greater use of productive factors and welfare improvements in the focal zone.

According to Bruinsma (1994), constructing transport infrastructures influences transport costs by reducing the distances and/or increasing the average speed (Relationship 1). This influence also entails changes in choices of the mode of transport and routes, as well as the generation or attraction of new movements by zones (Relationships 2 and 5). The reduction of transport costs, combined with changes in the movements of

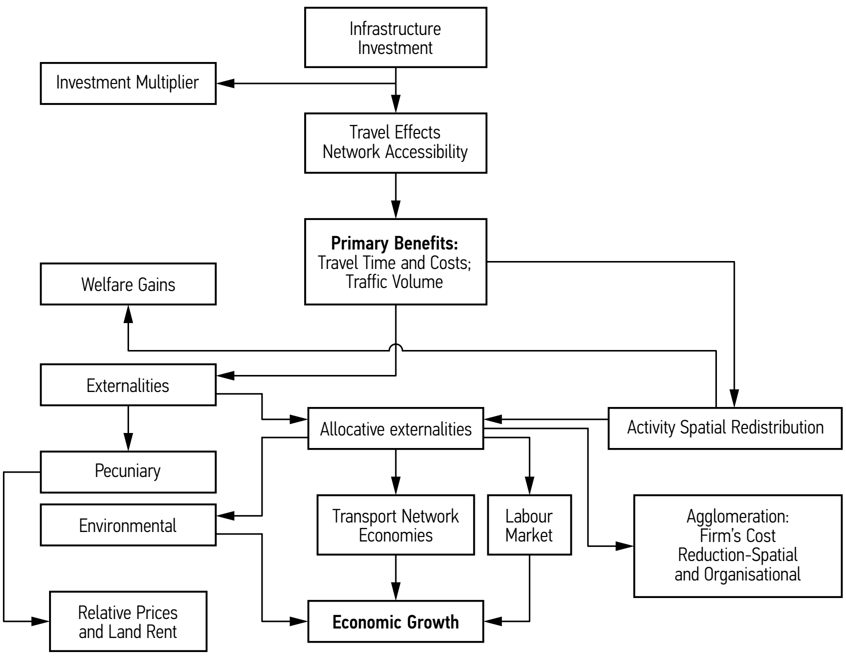

Fig. 3. Relationship of accessibility and economic growth (Banister, Berechman 2001)

families and companies, leads to greater productivity in the focal zones (Relationship 3 and 4). Another consequence is greater accessibility to a certain zone, which may lead to an expansion of economic activities and/or populations (Relationships 6 and 7).

Not only do these direct effects of the construction of transport infrastructures and the spatial model of economic activities emerge, but we also must consider important indirect relationships (feedback). For example, the relocation of economic activities may lead to changes in the zones, which then have impacts on the accessibility of those zones (Relationship 8). Location changes could affect the movements of freight and passengers (Relationship 9). In the case of congestion, this change in movements implies changes in transport costs (Relationship 10). Thus investments in infrastructure cannot be seen as exogenous, even if they correspond to government decisions, because changes in the networks have effects beyond the transport system. The principal objective of government infrastructure policy could be, as Bruinsma (1994) suggests, ensuring acceptable levels of accessibility for each zone (Relationships 11 and 12). Alternatively, economic policy could be oriented toward improving transport infrastructures in zones with a relatively positive economic development, perhaps to eliminate congestion. Then, the result would be depicted in Fig. 4.

This estimation relies on a series of macroeconomic variables, including employee compensation and the gross operating surplus (which form part of the gross value added at basic prices (*GVAbp*) of the Transport and Communications sector), that reflect the transport costs, modified by variations in accessibility. The *GVAbp* of the Transport and Communications sector will be directly affected by transport costs and movements of freight and passengers, as well as indirectly by accessibility and the productivity of companies and families. As the latter increase, greater transport services are required and costs decrease. The *GVAbp*, calculated on the basis of income, is the sum of employee compensation (*CE*), gross operating surplus and mixed income (*GOS*), and other net taxes on production (*ONTP*):

$$GVAbp = CE + GOS + ONTP. \quad (10)$$

In our case, we consider added value generated by companies devoted to transport and communications activities; the National Statistics Institute does not provide separate information for transport. If the value generated depends on income, it is shared across the production factors that have collaborated to produce it. Much income thus is devoted to remunerating work, or employee compensation. The rest of *GVAbp*, or *GOS*, is considered 'surplus' because it includes incomes that are not devoted to compensation; is 'gross' because it includes the consumption of fixed capital (similar to amortization); and is 'operating' because it includes the value generated by normal or typical activity by a company or a sector. The sum of *CE* and *GOS* comprises the *GVA* at the cost of the production factors, so that by using the sum of the taxes due, it can be possible to determine *GVAbp* and the *GVA* at market prices (*mp*).

On these premises, we construct an econometric model (Álvarez-Herranz 2009) to estimate the impact of investments in transport infrastructures on the economic growth of autonomous regions.

3. Econometric Model for Measuring the Impact of PEIT

The equations we propose enable us to assess the impact on regional and national *GDPmp* of investments in transport infrastructures, if the PEIT is wholly applied.

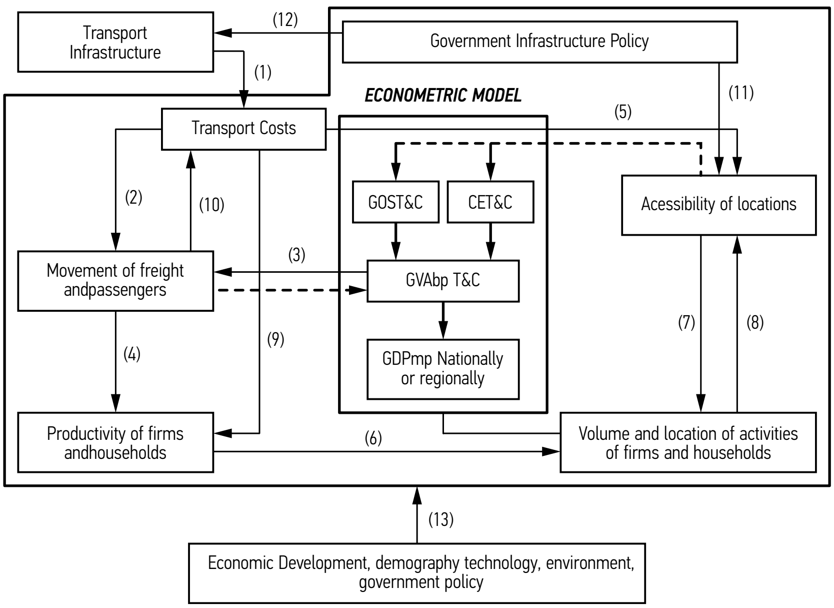

Fig. 4. Accessibility impact and macroeconomic variables to measure economic growth (own elaboration, based on Bruinsma (1994))

We measure the variation they would cause in the following accessibility indicators:

$$CET\&C_{it} = \alpha_i \cdot \prod_{j=1}^{k} IACC_{ijt}^{\beta_j} \cdot e^{\varepsilon_{it}}; \quad (11)$$

$$GOST\&C_{it} = \delta_i \cdot \prod_{j=1}^{k} IACC_{ijt}^{\mu_j} \cdot e^{\varepsilon_{it}}; \quad (12)$$

$$GVAbpT\&C_{it} = \gamma_i \cdot CET\&C_{it}^{\phi_1} \cdot GOST\&C_{it}^{\phi_2} \cdot e^{\varepsilon_{it}}; \quad (13)$$

$$GDPmp_{it} = \eta_i \cdot GVABbpT\&C_{it}^{\varphi_1} \cdot e^{\varepsilon_{it}}. \quad (14)$$

We make the equations linear using logarithms:

$$\ln\left(CET\&C_{it}\right) = \alpha_i + \sum_{j=1}^{k} \beta_j \ln\left(IACC_{ijt}\right) + \varepsilon_{it}; \quad (15)$$

$$\ln\left(GOST\&C_{it}\right) = \delta_i + \sum_{j=1}^{k} \mu_j \ln\left(IACC_{ijt}\right) + \varepsilon_{it}; \quad (16)$$

$$\ln\left(GVAbpT\&C_{it}\right) = \gamma_i + \phi_1 \ln\left(CET\&C_{it}\right) + \phi_2 \ln\left(GOST\&C_{it}\right) + \varepsilon_{it}; \quad (17)$$

$$\ln\left(GDPmp_{it}\right) = \eta_i + \varphi_1 \ln\left(GVABbpT\&C_{it}\right) + \varepsilon_{it}, \quad (18)$$

where: $GDPmp_{it}$ – gross domestic product at market prices of autonomous region i at time t; $GVAbpT\&C_{it}$ – gross value added at basic prices in the transport and communications sector of autonomous region i at time t; $CET\&C_{it}$ – employee compensation in the transport and communications sector of autonomous region i at time t; $GOST\&C_{it}$ – gross operating surplus for the transport and communications sector of autonomous region i at time t; $IACC_{ijt}$ – indicator of accessibility by type of transport j in autonomous region i at time t.

The econometric methodology applied to the equations uses panel data, combining time series with transversal data. This econometric technique is appropriate and highly useful for equations designed to analyse the behaviour of different bodies or individuals. In this case, the econometric variables represent different autonomous regions in Spain and may improve the estimations, should non-observable heterogeneities exist in each autonomous region or over time. To specify a regression with panel data, we use the following:

$$Y_{it} = \alpha + X_{it}\,\beta + \varepsilon_{it}, \text{ con } i = 1, ..., N;\ t = 1, ..., T, \quad (19)$$

where: i refers to the autonomous region (transversal); t is the dimension in time; α is a scalar; β is a vector of K parameters; X_{it} is the i-th observation at time t for the K explanatory variables. The error term ε_{it} can be broken down:

$$\varepsilon_{it} = \mu_i + \delta_t + e_{it}, \quad (20)$$

where: μ_i represents unobservable effects that differ between autonomous regions but not over time; δ_t identifies non-measurable effects that vary over time but not between autonomous regions; e_{it} refers to purely random error.

Most applications with panel data use the error component model $\varepsilon_{it} = \mu_i + e_{it}$, known as the one-way model, with $\delta_t = 0$. We suppose a fixed effect at μ_i that differs for each autonomous region, so the linear model is the same for all autonomous regions, but the ordinate at the origin is specific to each. In this case, the unobservable heterogeneity thus is incorporated into the model constant, specified as:

$$Y_{it} = \alpha + \beta\, X_{it} + d_{1t}\,\mu_1 + ... + d_{(N-1)t}\,\mu_{N-1} + e_{it}, \quad (21)$$

where: for each autonomous region j:

$d_{it} = 1$, if $i = j$;

$d_{it} = 0$, if $i \neq j$.

The data we used to estimate the equations correspond to actual information for 1990, 1995, 2000, and 2005 for 15 autonomous peninsular regions. The macroeconomic variables ($CET\&C_{it}$, $GOST\&C_{it}$, $GVAbpT\&C_{it}$ and $GDPmp_{it}$) come from the Regional Accounting, drawn by the National Statistics Institute, homogenised in Base95 and measured in millions of Euros at constant prices from 1995. The variables for the accessibility indexes ($IACC_{ijt}$) for transport mode j are newly developed for this study, calculated according to the infrastructure network in each year. Among the accessibility indicators, *ACPR* provides an indication of potential accessibility, or the actual total offer of both the road and the rail network. We chose this indicator because of its significant correlation with the macroeconomic variables. It measures the offer as the attraction (proportional to the population) of paying the temporal price (inversely proportional):

$$ACPR = \sum_j \frac{P_j}{t_{ij}}. \quad (22)$$

4. Results and Predictions for 2020

To estimate the equations for the impact model of investments in transport infrastructures on economic growth in autonomous regions, we used panel data and a generalised least squares method. We provide the results of each equation in the model next. In Table 6, we detail the estimation of employee compensation in the transport and communications sector, according to autonomous region.

The results of the estimation for *GOS* in the transport and communications sector, according to autonomous region, appear in Table 7.

For the estimation of the *GVAbp*, we provide Table 8, again with the results according to autonomous region.

Finally, in Table 9 we provide the results of the *GDP* estimation at market prices according to autonomous region.

After applying the equations of the economic model, in accordance with the accessibility values, we obtained key results related to the macroeconomic variables of the model, as the average annual accumulative growth rate (*TACM*) at both current and constant prices (year 2005 = 100). The results from the zero and reference scenarios (i.e., without PEIT) indicate only maintenance of the networks existing in 2005 and in the PEIT

Table 6. Estimation equation for employee compensation across autonomous regions

Dependent Variable: (LOG($CET\&C_{it}$))
Method: Pooled EGLS (Cross-section weights)
Sample: 1990, 1995, 2000 and 2005
Included observations: 4
Cross-sections included: 15
Total pool (balanced) observations: 60
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
C	−44.37173	1.615597	−27.46460	0.0000
LOG ($ACPRCARR_{it}$)	3.291393	0.209623	15.70145	0.0000
LOG ($ACPRFERR_{it}$)	0.862207	0.130579	6.602948	0.0000
Fixed Effects (Cross)				
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.999751	Mean dependent var	9.089775	
Adjusted *R*-squared	0.999658	S.D. dependent var	4.710456	
Unweighted Statistics				
R-squared	0.995280	Mean dependent var	6.538086	
Sum squared resid	0.332842	Durbin-Watson stat	1.930254	

Table 7. Estimation equation for gross operating surplus across autonomous regions

Dependent Variable: LOG($GOST\&C_{it}$)
Method: Pooled EGLS (Cross-section weights)
Sample: 1990, 1995, 2000 and 2005
Included observations: 4
Cross-sections included: 15
Total pool (balanced) observations: 60
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
C	−90.31284	3.676831	−24.56269	0.0000
LOG ($ACPRCARR_{it}$)	5.956007	0.644159	9.246171	0.0000
LOG ($ACPRFERR_{it}$)	1.978204	0.577840	3.423448	0.0014
Fixed Effects (Cross)				
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.997808	Mean dependent var	9.240522	
Adjusted *R*-squared	0.996993	S.D. dependent var	3.845104	
Unweighted Statistics				
R-squared	0.972653	Mean dependent var	6.683164	
Sum squared resid	1.918023	Durbin-Watson stat	2.341951	

Table 8. Estimation equation for gross value added at basic prices across autonomous regions

Dependent Variable: LOG($GVAbpT\&C_{it}$)
Method: Pooled EGLS (Cross-section weights)
Sample: 1990, 1995, 2000 and 2005
Included observations: 4
Cross-sections included: 15
Total pool (balanced) observations: 60
Linear estimation after one-step weighting matrix
Cross sections without valid observations dropped

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
C	−0.582176	0.294391	−1.977557	0.0544
LOG ($GOST\&C_{it}$)	0.199274	0.044547	4.473295	0.0001
LOG ($CET\&C_{it}$)	1.012218	0.085764	11.80242	0.0000
Fixed Effects (Cross)				
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.999638	Mean dependent var	8.390797	
Adjusted *R*-squared	0.999503	S.D. dependent var	2.975048	
Unweighted Statistics				
R-squared	0.997133	Mean dependent var	7.367573	
Sum squared resid	0.198758	Durbin-Watson stat	2.165987	

Table 9. Estimation equation for gross domestic product at market prices across autonomous regions

Dependent Variable: LOG($GDPmp_{it}$)
Method: Pooled EGLS (Cross-section weights)
Sample: 1990, 1995, 2000 and 2005
Included observations: 4
Cross-sections included: 16
Total pool (balanced) observations: 64
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
C	2.967960	0.190644	15.56806	0.0000
LOG ($GVAbpT\&C_{it}$)	0.949726	0.025143	37.77309	0.0000
Fixed Effects (Cross)				
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.999514	Mean dependent var	11.61888	
Adjusted *R*-squared	0.999348	S.D. dependent var	3.547987	
Unweighted Statistics				
R-squared	0.996099	Mean dependent var	10.16022	
Sum squared resid	0.391116	Durbin-Watson stat	2.243804	

scenario. The results in Fig. 5 show graphically the improvement that the autonomous regions (*CCAA*) would undergo with respect to the *GOS* of the transport and communications sector due to the variation in its costs because of changing accessibility. That is, the application of the PEIT would increase, compared with no application, by an average of 7.4 in real terms versus the base year 2005. Of all the autonomous regions, those with the most increased their growth rates would be Cantabria, Asturias, and Galicia; Madrid, Catalonia, and the Community of Valencia would experience the smallest variations.

Regarding employee compensation, we confirm in Fig. 6 that the application of the PEIT improves accessibility in the different regions and thus increases the activity of the transport sector, as reflected in an increase in wage costs by an average of 3.26 and 3.18 percentage points, respectively, at current and constant prices. The autonomous regions that would experience the greatest increase in this variable would be Cantabria, Asturias, Castilla y Leon, and Galicia, whereas Madrid, Catalonia, and the Valencia Community again would undergo the least increase.

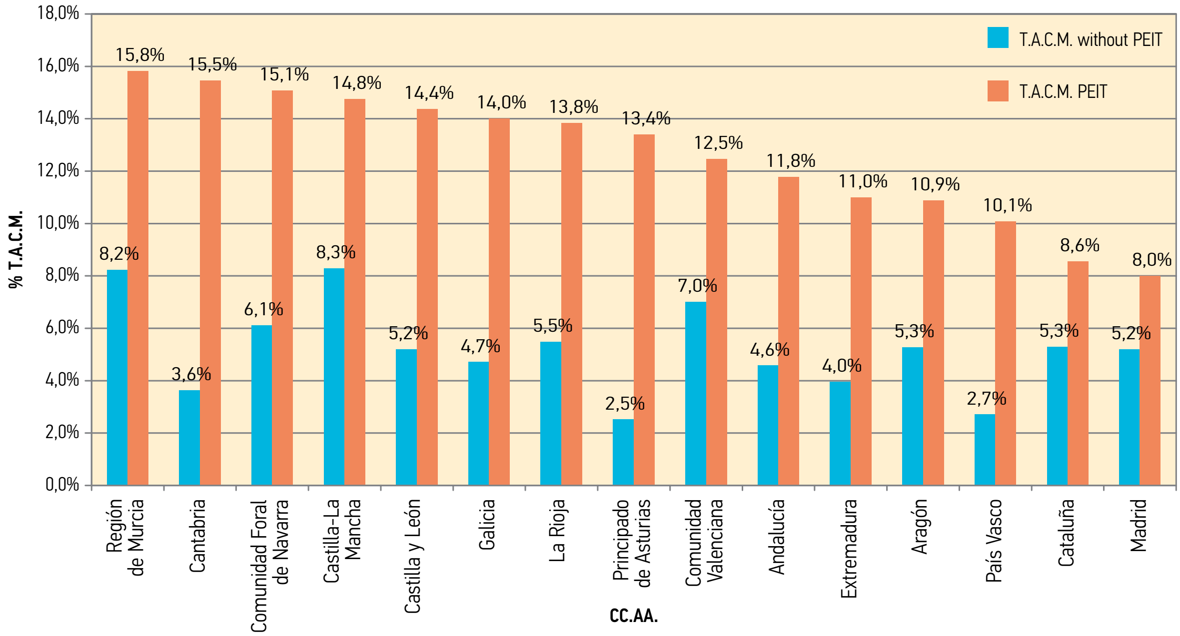

Fig. 5. Comparison of average annual accumulative *GOS* rates at constant prices (notes: base 2005 = 100; period – 2005–2020)

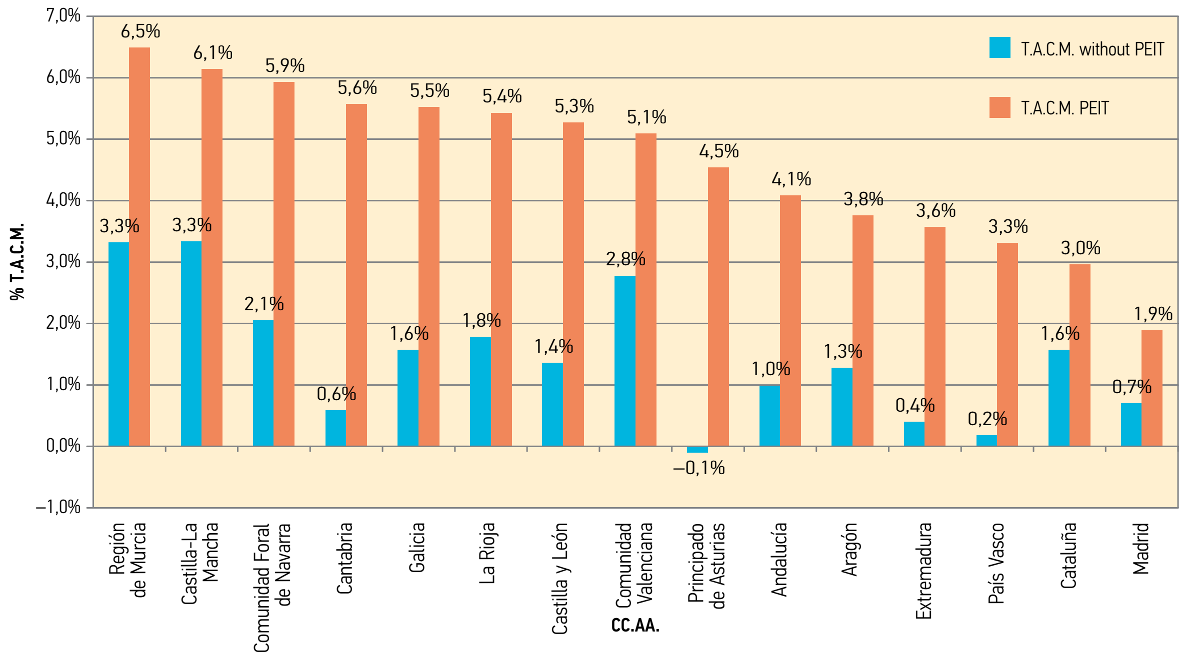

Fig. 6. Comparison of average annual accumulative rates of employee compensation at constant prices (notes: base 2005 = 100; period – 2005–2020)

The GVA at basic prices, which reflects the value of production in the focal sector, would increase during 2005–2020 (Fig. 7) by an average annual growth rate of 4.7 at constant prices. This increase would reflect reduced costs, with a consequent increase in the GOS and greater activity in terms of employee compensation through improved accessibility of the autonomous regions. The autonomous regions that would most increase their production would be Cantabria, Asturias, Castilla y Leon, and Galicia, whereas Madrid, Catalonia, and the Valencia Community would grow the least.

Finally, the impact of the PEIT with respect to the production, income, or GDP of each autonomous region, as shown in Fig. 8, in terms of the average annual growth rate would be 3.4 percentage points, compared with a base year of 2005. The autonomous regions with the most improvement would be Cantabria, Asturias, Galicia, Castilla y Leon, and Navarre.

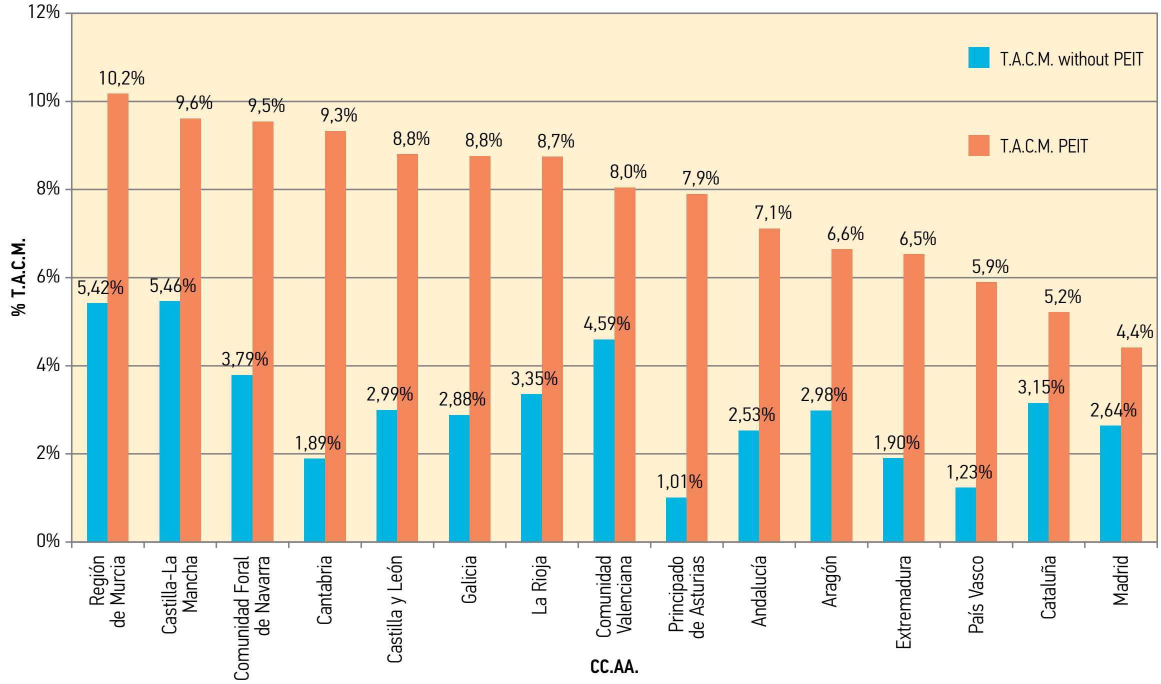

Fig. 7. Comparison of average annual accumulative rates of *GVAbp* at constant prices (notes: base 2005 = 100; period – 2005–2020)

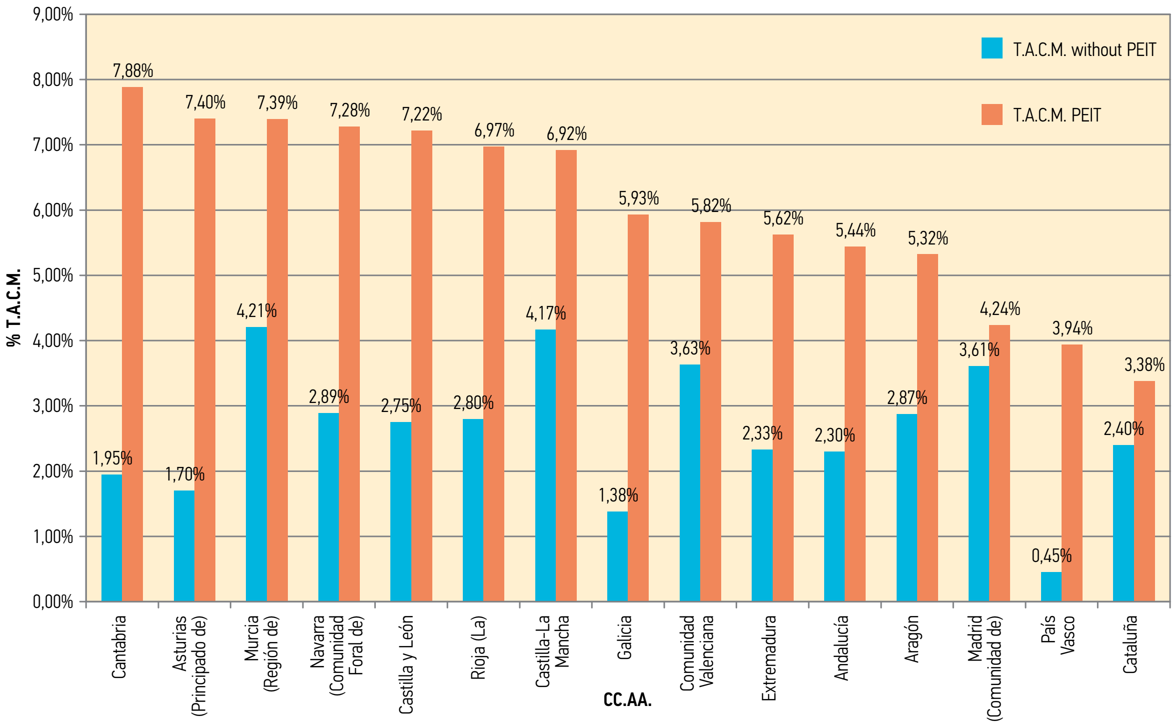

Fig. 8. Comparison of average annual accumulative rates of *GDPmp* at constant prices (notes: base 2005 = 100; period – 2005–2020)

However, the infrastructure planning foreseen in the PEIT also can affect production in the autonomous regions according to the relative position that each region occupies, according to its GDP growth rate. That is, if we establish a ranking of autonomous regions at current prices, ordered from greater to lesser growth rates, the zero scenario indicates Castilla-La Mancha, Murcia, Madrid, Valencia and Navarre as the top five. If the ranking reflects the application of PEIT, it is Cantabria, Murcia, Navarre, Castilla y Leon, and Castilla-La Mancha. Comparing these rankings reveals that planning infrastructures can alter the change in economic growth rates. Thus Cantabria would pass from position 12 in the zero scenario to number 1 in the PEIT scenario; Murcia maintains its number 2 position; Navarre goes from fifth to third place; Castilla y Leon moves seventh to fourth; and Castilla-La Mancha drops first to fifth place.

Madrid and the Valencia Community offer good examples of autonomous regions with strong initial infrastructures, such that the changed scenario does not increase their growth rates, and their accessibility does not improve as much as that of regions with greater needs. That lesser variation also is reflected as a drop in ranking, because PEIT benefits other autonomous regions more. Thus Madrid moves from position 3 to 13 and the Valencia Community from 4 to 11.

5. Conclusions

With this work, we have attempted to analyse the economic impact of the actions foreseen in the Strategic Infrastructures and Transport Plan (PEIT 2005–2020) of the Spanish government. These actions, which aim to contribute to regional development, plan to extend Spain's high-capacity road and rail networks by 2020.

Using a newly proposed model based on panel data, we demonstrate some significant likely outcomes and the possibilities that accessibility indicators offer for explaining the effects of transport infrastructures on regional development. Our indicators facilitate not only the estimation of territorial and economic impacts but also comparisons across regions. Their application to infrastructure plans, within the framework of an adequate system of geographical information, thus can put powerful planning tools at our disposal.

With these indicators, we evaluate different levels of accessibility, such as those before and after the introduction of the plan and those according to distinct perspectives, including efficiency, location, and market potential. We also analyse the results from the perspective of *cohesion* and thereby confirm if regions that improve most are really those that started with lower levels of accessibility. Likewise, the accessibility indicators allow for the analysis and monitoring of regional spillovers during planning. That is, in addition to direct investment in each region, investment flows between territories should be considered in determining the actual investment each territory receives (directly or indirectly). This approach overcomes a local view of demand and integrates effects distributed across neighbouring regions. It therefore is necessary to prioritise actions so that the first infrastructures built benefit for more regions or achieve specific financial procedures.

Finally, we offer a good explanatory variable for evaluating the economic effects of a transport infrastructure plan. With its application, we regionalise the economic impacts of the plan and differences in the scenario associated with the actual situation. With our economic model, we can confirm how investments in road and rail infrastructures, as contemplated in PEIT 2005–2020, bear on the economic growth of the Spanish peninsular regions, according to the improvements in territorial accessibility they achieve. This relationship of infrastructure, accessibility, and growth has been established by the impact of accessibility on reduced transport costs and the volume and location of entrepreneurial activities.

Our model contains four equations. In the first, we address the effect of the variations in accessibility, caused by road and rail infrastructure, and in transport costs, using the *GOS* of the transport and communications sector. The second equation instead shows the effect of a variation in accessibility on the volume of movement of freight and passengers, involving greater or lesser activity of the transport sector as reflected in labour costs. The changes in *GOS* and employee compensation due to the construction of new road and rail infrastructures enable us to calculate, in the third equation, the *GVAbp*. Finally, in the fourth equation we estimate the increase in *GDP* for each autonomous region by using, as explanatory variables, changes in *GVAbp* due to the construction of road and rail transport infrastructures.

The conclusions we have obtained reveal how the application of the PEIT is likely to affect the economic growth of Spanish peninsular regions, due to improvements in territorial accessibility. Moreover, our proposed methodology highlights the potential of accessibility indicators to reveal the economic growth of autonomous regions. Such desired growth can be achieved by benefits derived from reducing travel times, traffic volume costs, and land use costs.

The relationship of infrastructure, accessibility, and growth also has been effectively established. The effects are particularly apparent in the more peripheral regions and those with less income. In more populated, active regions, the effect is less marked. Thus, the provision of new infrastructure is less determinant of economic development in already well-established regions.

These results lead to several practical recommendations. First, when authorities design infrastructure transport plans, they must establish an efficient framework that attempts to develop a transport system integrated with diverse nodes. Second, they should attempt to consolidate transport systems as elements that contribute to overall economic and territorial development and improve territorial cohesion. Therefore, the authorities in charge of these policies should define their long-term strategic vision before designing their transport and infrastructure plan and ensure that vision is coherent with the procedures used to evaluate the planned actions. Third, it is necessary to evaluate the effects of the infrastructure plans from a holistic perspective, taking into account the various effects and the many targets involved.

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