Modelling Goods Transport In Spanish Autonomous Communities

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Synopsis

Although a significant development has taken place over recent years in demand models in the sector of passenger transport, the same cannot be said for demand models for freight transport in spite of the only difference between them being, from a conceptual perspective and that of global demand models, the actual meaning of the variables that characterise the flow of passengers or freight.
The objective of the present paper is to show the results of an investigation in which various models were assimilated to establish a series of relations between infrastructural facilities, freight traffic and diverse socio-economic factors, mainly family income and GDP. Obviously, given that the territorial area and the time range of the study has to be defined for the configuration of such models, two different lines of investigation were established:
The scope of study of the first line of investigation is the group of autonomous communities in mainland Spain. In order to carry this out the data referred to above had to be compiled for each of the autonomous communities (infrastructural offer, freight traffic and socio-economic factors) for 2001; i.e. over a specific year, the variable is the geographic location.
The scope of study of the second line of investigation is the analysis of two autonomous communities with different socio-economic conditions, in this case Andalusia and Catalonia. For each of these, the aforementioned relations were established based on a study period between 1996 and 2001. In this case, the autonomous communities were determined and the different relations over this period of time were studied by using a series of historical data.
The first of these investigation lines, the autonomous approach, allowed obtaining a function which correlates freight traffic and the provision of infrastructures. Of all the socio-economic variables analysed, those which best show such a correlation are the total amount of moved freight (expressed in tons-kilometre) and the kilometres of high-capacity road existing for each of the autonomous communities. The investigation continued to evolve in order to try to find various indexes that combine with the group of transport infrastructures and that relate it with this freight traffic.
The second of these investigation lines, the time approach, allowed analysing the evolution of freight traffic over a period of time. The correlation functions obtained allowed analysing the elasticity of the demand (the total amount of freight moved) with regard to the GDP (which is considered as the most representative socio-economic variable). The greater or lesser value of the function exponent allowed verifying the lesser or greater level of development of each of the autonomous communities analysed.
By analysing the results, we hope to reach conclusions which lead to establishing criteria for the planning of infrastructural facilities with operative indications for the areas examined.

Modelling Goods Transport In Spanish Autonomous Communities

The relations between freight transport and socio-economic indicators have been a topic of study widely analyzed for years. The objective of the present paper is to show the result of an investigation in the which various models are assimilated that establish a series of relations between infrastructural facilities, freight traffic and diverse socio-economic factors, mainly population and GDP. Obviously, given that the territorial area and the time range of the study has to be defined for the configuration of such models, two different lines of investigation were established:

a) The first of these concentrates on the scope of study for each of the autonomous communities in mainland Spain by compiling the aforementioned data for each of them (infrastructural offer, freight traffic and socio-economic factors) for 2001; i.e. for a specific year the geographic location “varies”.

b) The scope of study for the second line of investigation is the analysis of two autonomous communities with different socio-economic conditions (Andalusia and Catalonia). For each of these, relations were established separately based on a study period between 1996 and 2001. In this case, the autonomous communities are determined and the different relations over this period of time were studied by using a series of historical data.

STARTING POINT

The present paper is the fruit of the collaboration some months ago with two civil engineers from the Italian University of Bari who were spending a year in the Department of Transport in the University of Cantabria. One of the tasks to be undertaken during their stay was to carry out the investigation in question from their university and it was intended to complement others that were being carried out along the same lines in Italy. This investigation had to concentrate on the study of the correlations between infrastructural provision, freight traffic, value (declared) of the transported freight and the income of the region to which the data referred, although we quickly realised that it was impossible to keep elements regarding freight value as one of the elements to be correlated.

Based on the above, two different lines of investigation were embarked upon. The first had to start the search for these correlations for diverse geographical regions for a specific year. In the interests of more simple data capture, it was decided to establish each of the autonomous communities as geographical areas, except for the Balearic Islands and the Canary Islands. The year chosen upon which to base the study was 2001, the last about which there was relatively complete information available for the objectives of the investigation.

The second of the investigation lines had two autonomous communities with different socio-economic conditions as the scope of the study, in this case Andalusia and Catalonia. For each of these, the aforementioned correlations were established separately based on a study period between the years 1996 and 2001. In this case, the autonomous communities were determined and the different relations were studied over this period of time by using a series of historical data. The intention, through the study and analysis of the results, was to reach conclusions which would lead to establishing a hypothesis of criteria for the planning of infrastructural facilities with operative indications for the areas examined.

HYPOTHESIS

This survey tries to prove some hypotheses in order to help the analysis of the relations between freight transport and socio-economic indicators:

H-1. It’s well known the fact that transport strengthens the territory’s economic growth. If so, there should be some kind of relation between freight transport and socio-economic indicators in a specific territory.

H-2. Likewise, it’s reasonable believe that the more people live in a specific territory the higher the industry level will be (at least in the develop world) and, consequently, the more freight will be transported.

H-3. From relations between freight transport and socio-economic indicators it’s possible to determine the degree of development of a specific territory.

VARIABLES AND TYPES OF DEMAND MODELS

The first step to be able to develop a suitable analysis is to know the elements that characterize it. These elements are very different, but in general they can be gathered together in two big groups: socio-economic factors (that explain how the demand is generated) and factors tied to the offer characteristics (that take charge explaining the modal distribution and the flows). As the present analysis deals with the generation of the demand, exclusively socio-economic factors will be analyzed.

First of all, it is necessary to bear in mind that the flow of goods is intimately related to the existence of surplus zones and deficit zones with regard to certain products. That's why production levels and consumption levels, as well as the factors that depend on them, are factors that will determine the demand.

Therefore, it is necessary to quote firstly elements as population or family budget, since they are signs of the possibilities of private consumption. Secondly, there can be gathered together all those factors that characterize industrial activities or service activities and their possibilities of development.

Likewise, with a low disintegration degree, variables as the GDP and other economic similar magnitudes can be considered also.

Demand models

In order to establish the relation between freight traffic and the diverse socioeconomic variables (that express in monetary units the productive capacity of the territory throughout a period of time) global demand models are used.

There are several types of model that can be applied:

Linear models: Since as much the variables that quantify the economic development of a country as the variables that express the whole of mobilized goods constitute two increasing series, the models most used (and simultaneously simpler) are the linear models of the type:

$$y = a + b \cdot x$$

In its simplicity lies the principal fragility of this type of models. Generally the correlation coefficients are very low; furthermore, the adjustment process usually drives to a value of the parameter considerably much higher than zero (reality says that if the sum of goods and services is void the mobility of goods must be also void).

Potential models: These models do not have the disadvantages of linear models, because the calibration is carried out taking logarithms. They are of the type:

$$y = a \cdot x^b$$

Analyzing the values that the parameter *b* adopts, important conclusions can be extracted, because it represents the elasticity of the demand in relation to the endogenous variable chosen. In general, when the model applies to territories that are in their first stages of industrial development, the exponent reaches values lightly over the unit, whereas if the territory has a deeply placed development, the exponent frequently is equal to one or even lower.

The fact that the elasticity of the demand of freight transport (coefficient *b*) diminishes as the GDP increases it is due probably to the fact that as this development takes place certain tertiary activities increase, as well as the most sophisticated secondary activities and the more technological activities do, which are not big users of transport (at least in terms of transported tons). Likewise, probably the production industries and the distribution industries have reached their ideal emplacements in the territory, since in other case any industry better located and with lower logistic costs might compete with them in better situation.

FOCUS OF THE INVESTIGATION. INFORMATION

This section is not going to emphasise the usefulness and interest in conceiving correlations, models etc. that can provide us with forecasts for freight transport demand, even bearing in mind that their evolution has not reached the levels achieved in the case of modelling for passenger transport demand. Indeed, the primary objective of the investigation discussed in this paper has been to contrast and compare the behaviour of the freight transport demand in the different autonomous communities according to a series of explicit demand variables closely correlated with it.

By doing so, we hope to verify whether the freight transport demand in the group of autonomous communities adapts or not to such behaviour when related with different variables. What has not been done initially is to define the demand functions that predict demand at a specific point in the future, determined as part of the decision-making process as is usual practice. That is why this comparison in the demand behaviour of the autonomous communities is carried out for a specific year (2001); it is like an instant photograph from which only conclusions regarding the present can be reached and from which it is difficult, thus not the objective of the task, to reach conclusions regarding the future.

On the other hand, the second of the lines of investigation whose objective was to make a comparison over a period of time (1996-2001) of the freight transport demand behaviour in autonomous communities as socio-economically different as Andalusia and Catalonia, can, as will be shown, be used for making forecasts even although the objective of this paper continues to be the comparison of demand trends in both communities.

Once these two large objectives in the investigation had been established, the next step was to determine the variables which would have to be correlated and their search for each of the mainland autonomous communities. As was mentioned above, these variables would have to be classified into three large groups: freight transport demand, infrastructural facilities and socio-economic characteristics of the ACs to which the data referred.

As far as transport demand is concerned, we started to work with data related to global demand, demand by modes of transport, even, in some cases, with data regarding shipped and received freight for each community; and in any of these fields the data was presented both in tons and tons-Km. At a very early stage, and given that is was impossible to obtain reliable information for each community with regard to any of the modes of transport (rail specifically), it was decided to start focusing the study on demand in the case of national road transport, although in order to do this, references to maritime transport (in those communities where applicable) and air transport were not overlooked. Within road transport (national plus international), national transport represents more than 92% of the total; and within national transport in Spain, road transport represents more than 85% of the total; if, to this important point, we add the abundance of information and the lack of it with regard to the other transport modes, this decision is easier to understand.

As far as infrastructural facilities are concerned in autonomous communities, the search and procurement of data for the variables followed a parallel path to that of freight traffic seen above. For each transport mode we began to establish those variables susceptible to determined variations in transport demand. Data was obtained for variables related to roads (network kilometres by road typology, etc.), ports (length of quays depending on depths, land surface areas, storage, etc.) and airports. However, as happened with the rail mode above, the procurement of data on infrastructures by AC was completely impossible.

Finally, and as far as the social and economic characteristics are concerned in the autonomous communities, variables such as population, family income or the GDP of the ACs was examined.

CHOICE OF CORRELATIONS AND CONTRAST OF THE DEMAND BEHAVIOUR

Once the variables were determined, they were entered on a spreadsheet along with new variables and indexes derived from them. In total, more than 60 variables were worked with. After the study into the possible correlations existing amongst them, the investigation started to focus on a significantly reduced number of them, which, according to their meaning, was not particularly surprising since it confirmed previous investigations and studies both in Spain and abroad. The variables finally chosen directed the investigation to the study of freight transport demand in the autonomous communities from an additional perspective. The variables chosen for defining the transport demand corresponded (as already mentioned) to the tons or tons-kilometre moved by road, both globally and those shipped and received by each autonomous community, always within the remit of national transport.

The provision of infrastructures, as a determining factor in this freight transport demand, was represented by the variable “kilometres of roads with two lanes plus dual carriageways and free motorways plus toll motorways”. Finally, social and economic characteristics of the autonomous communities have been represented using two variables: their population and GDP.

The functions that best correlated the different variables with the freight transport demand at any time were linear and potential, although in practically all cases the latter were finally chosen. Moreover, the simplicity of the former makes them very delicate in many cases when trying to show these relations. On the other hand, the potential models provide the opportunity of analysing the results and, in some cases, of coming to some

interesting conclusions regarding the values taken by exponent b, the parameter which represents the elasticity of the demand with regard to the variable chosen as endogenous and whose value can "inform" as to the level of development in which a country or a specific region finds itself.

We will now examine the different correlations studied, followed by brief explanatory comments. Firstly, the results are shown for what is referred to as "the first line of investigation", i.e. the search for models for the group of autonomous communities on the mainland in 2001.

The first group of models has been configured for each autonomous community taking as an exogenous variable national freight road traffic and the GDP as the endogenous variable. The results are very similar to what they would have been taking traffic measured in total tons as the exogenous variable. The result was the following:

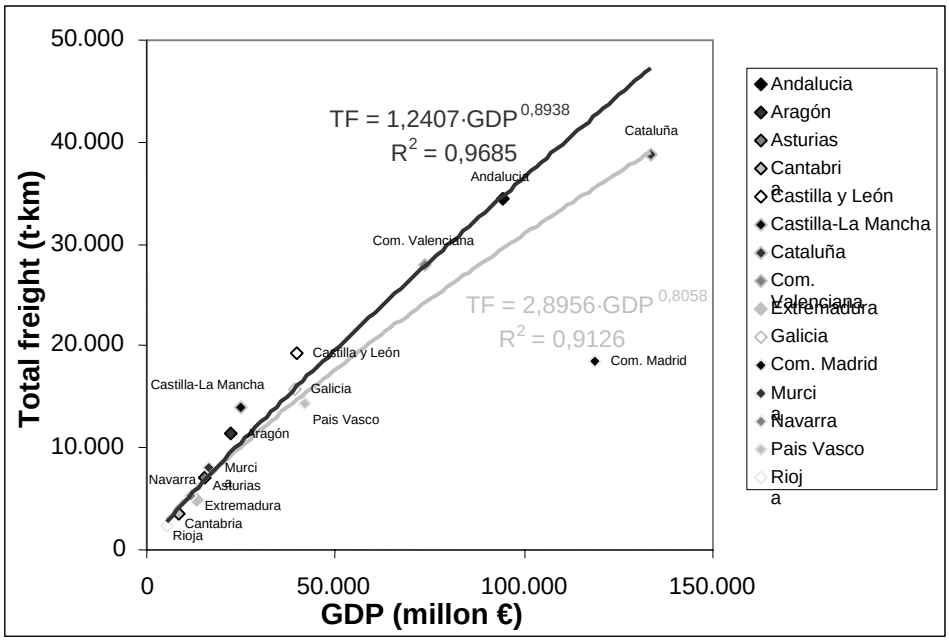

Figure 1: Relation between the GDP (current prices) and national road freight traffic

In figure 1 two different functions are shown. The one shown at the bottom (in a lighter tone) is the function relating GDP and national demand for road freight for the group of autonomous communities and the one at the top (in a darker tone) is the function relating the same variables for all of the autonomous communities except for the Community of Madrid. Moreover, if we observe the arrangement of the grouping of points making up the 15 autonomous communities it can clearly be seen that the point representing Madrid is outside the trend which the others follow; i.e. its high GDP does not translate into a high movement of freight.

An explanation for this situation could be found in the participation of industrial activity (one of the main factors in the formation of freight flows) in the GDP: whilst in practically all of the main autonomous communities industrial participation swings between 33% and 40%, in the case of Madrid it stays at around 25%.

In any of the cases, the correlation between both variables is very clear, being much more pronounced in the case of the second function highlighted (the one which does not take the data corresponding to the Community of Madrid), even reaching a correlation coefficient of $R^2 = 0.9685$.

Something similar happens when the variables which relate to each other are the national freight road transport (although in Fig. 2 the relation with this variable is shown measured in tons-kilometre, it would be very similar if this traffic were to be measured in tons) and the population of each autonomous community.

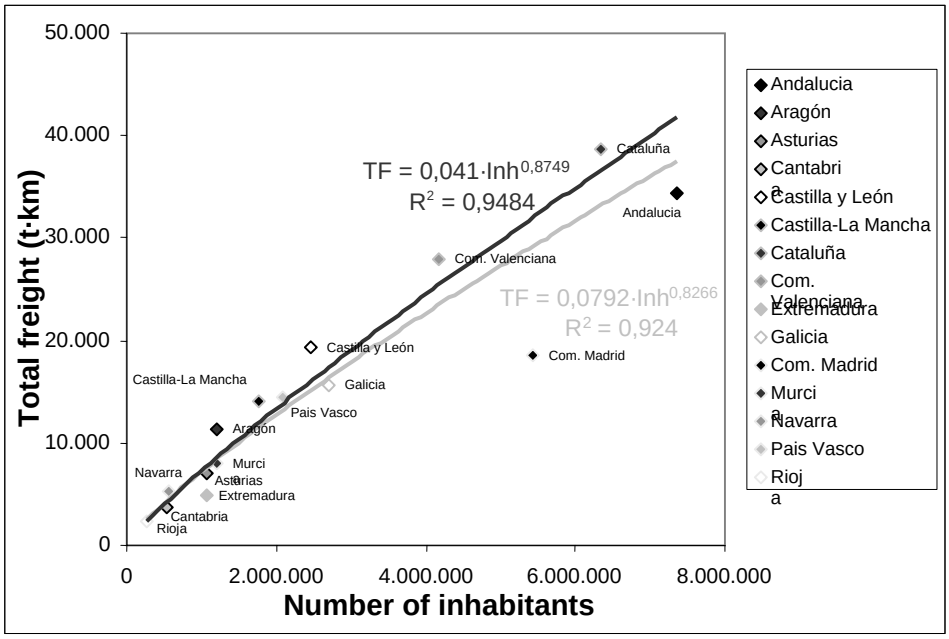

Figure 2: Relation between the population and national road freight traffic

As occurred in the previous case, two different functions are shown depending on whether the data corresponding to the Community of Madrid is taken into account or not. The fact of having a population mainly tied to the service sector, in a far higher percentage than the rest of the autonomous communities, separates it from the generalised behaviour in the rest of the country, which is very well represented through a potential function (its formulation is shown in the top part of the graph in Fig. 2), the correlation coefficient being close to the value $R^2 = 0.95$.

Finally, to end this first part with reference to the relations between variables for the group of autonomous communities, a function has been established that correlates the freight traffic and the provision of infrastructures. This is a part of the investigation that continues to evolve in order to try to find various indexes that combine with the set of transport infrastructures and that relate it with this freight traffic. However, a first sample is the function shown below and it relates the road transport infrastructures and national freight transport in this same transport mode.

We are working in an indicator that groups the set of road networks of each autonomous community depending on the capacity of each of their existing road typologies. Nevertheless, in the work shown here, the number of road kilometres is entered simply as a variable that could be referred to as “large capacity” and that includes the road Km with two lanes plus dual carriageways and open motorways plus those corresponding to toll motorways. In this case, no autonomous community is “discriminated” against as happened with the previous case of Madrid and a potential function is obtained whose correlation coefficient exceeds the value of $R^2 = 0.90$.

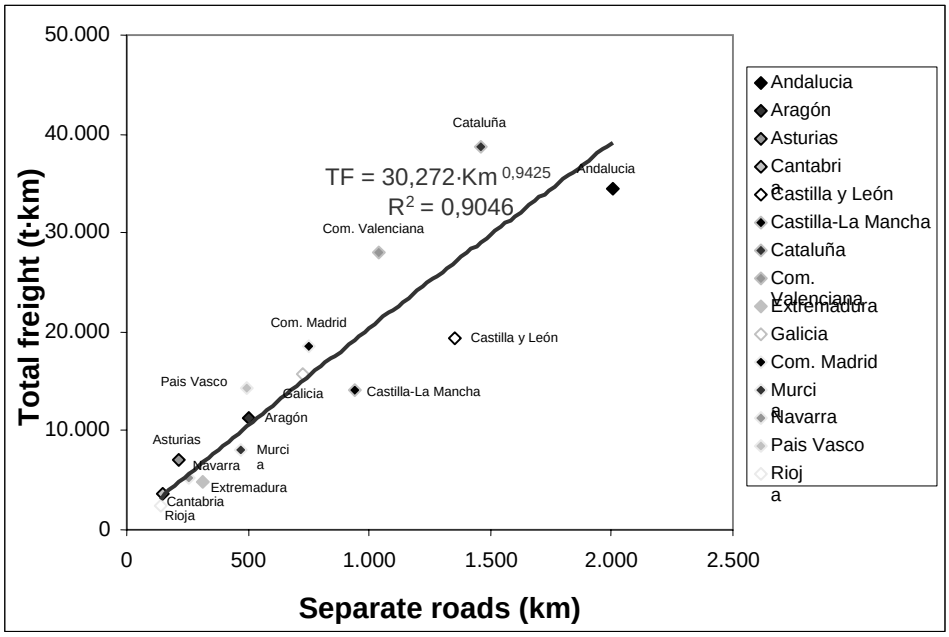

Figure 3: Relation between large-capacity road network and national road freight traffic

In the final part of this paper we will examine some of the results of what was the second line of investigation whose objective was to make a comparison over a period of time (1996-2001) of the freight transport demand behaviour in autonomous communities as socio-economically different as Andalusia and Catalonia. Although it is a series which is not excessively long, in some cases conclusions can be reached with regard to current and future trends. It was initially planned to start the historical series in 1991, however, the fact that up to 1995 the data on roads referred to the old State Road Network (85,000 Km.) and as from this year onwards the information concerning road traffic referred to that managed by the State, the Autonomous Communities and Regional Councils, the values given were distorted since they did not have the same measurement basis.

Possibly the variable that has maintained greater relation with national road traffic over these years (variable chosen as already mentioned on various occasions in order to represent freight traffic) has been the GDP. In Fig.4 the models which relate the variables already mentioned for both autonomous communities over the six years spanning the study are shown. Next to each of the functions is their mathematical formula and the correlation coefficients which are very high in both cases.

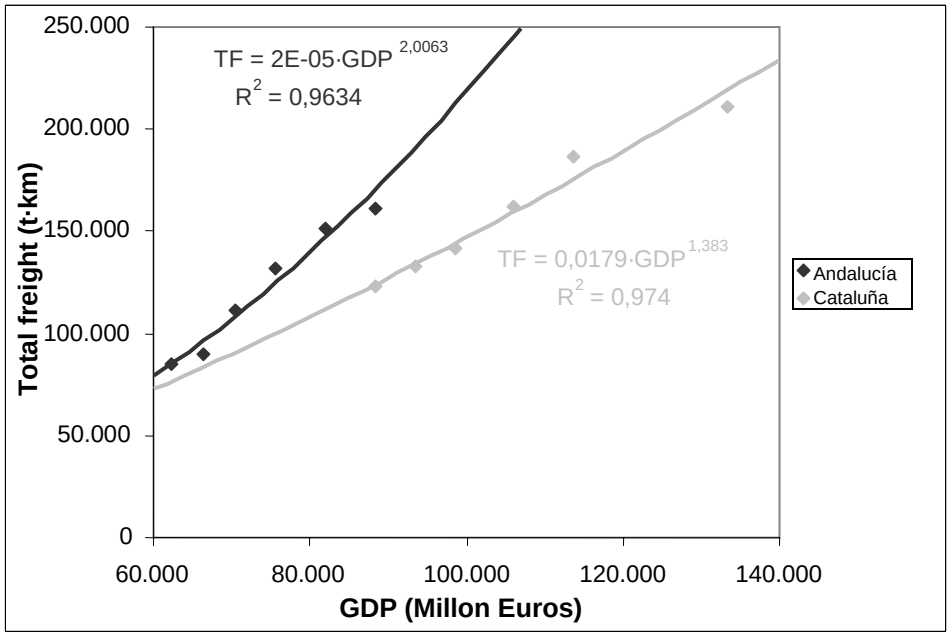

Figure 4. Relation between the GDP (current prices) and national road traffic in Andalusia and Catalonia (1996-2001)

DISCUSSION

In the graph that relates the GDP to the national road freight traffic we can observe, in the light of the elasticity of the model, that Spain has reached an important degree of industrial development. At the same time, it is possible to observe that some communities (those placed over the graph, as Castilla-León, Castilla-La Mancha or the Valencian Community) have a degree of industrial development quite higher than their service activities or their office activities. On the contrary, those communities that are placed below the graph have a higher level of service sector in relation to their industrial level (the community of Madrid is especially significant, because there are a high quantity of goods passing through any other place in the Peninsula).

It can be said also about the second graph, which relates the number of inhabitants to the national road freight traffic. This happens because there is a relation between the GDP and the population of every Autonomous Region (it is not a linear relation, but there is an interrelation certainly).

Therefore, it is possible to deduce that in those communities placed over the graphs there might be a higher development of the infrastructures of transport.

Concerning the graph that relates the national road freight traffic to the kilometres of large-capacity road network, it is observed that the communities placed over the graph (as Catalonia and the Valencian Community) have a movement of goods higher than the national average, which means that should exist a higher investment in public infrastructures. On the other hand, those communities placed below the graph have made higher investments in their road network than it had been necessary according to their current needs, trying to attract higher freight movement (if investments increase equally in transport centres and in industries).

That is, in the most developed communities, generally the movement of goods generates the need to construct new transport infrastructures, whereas in the least developed communities infrastructures of transport are constructed with the intention of attracting higher freight transport.

In the graph that relates national road freight traffic to GDP in the communities of Catalonia and Andalusia, looking at the demand elasticity, it can be said that Andalusia is in a fewer degree of industrial development than Catalonia, although Catalonia has not reached his biggest degree of development yet. If we compare it with the first graph, this conclusion is confirmed.

CONCLUSION

If the results of applying this simple model are analysed, interesting conclusions can be reached with regard to the values taken by exponent *b*, the parameter representing the elasticity of demand with regard to GDP.

When the territory is in his first stages of industrial development, the exponent reaches values lightly over the unit, whereas if the territory has a deeply placed development, the exponent frequently is equal to one or even lower. In both cases, the values are above the unit which makes us think that the development process has still not settled in either of the two cases. In the case of Andalusia, the growth forecast by the function is far quicker than in Catalonia, very probably because the latter is currently in a state of far more advanced development than the former. Moreover, in both cases, given that they are temporary series they could carry out a freight transport demand prognosis, not recommendable (at least if we do not want to be significantly inaccurate), with the models discussed in the first part of the paper regarding a specific period of time as was 2001.

Although not commented upon in this paper, the relations established between freight traffic and the population or the provision of infrastructures by road follow very similar criteria to those established with the GDP both for Andalusia and Catalonia.

Finally, it is necessary to emphasize that the line of investigation continues using multiple regressions with both GDP and population.

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