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The macroeconomic impact of transportation investment on the Spanish economy

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This paper compares the responses of employment and GDP Spanish growth to a permanent unitary shock in different types of transport capital stock, with those estimated in the literature. The theoretical model used to estimate the step response functions is the multiple equations dynamic model proposed by Flores et al.. (1998) adapted to this particular problem. Results suggest that: (1) The standard single equation static methodology underestimates the elasticity of the capital stock with respect to output, due to the existence of feedback relationships among transport capital stock and output. (2) The exclusion of the remaining net capital stock from the model, when dealing with a particular type of transport capital stock, might lead to biases in the estimation of the responses.

Keywords: *economic growth, labour, capital stock, investment.*

1. Introduction

Since Aschauer's (1989a, b) seminal works, a huge amount of literature estimating the effects produced by public investment on economic activity has been published.

All papers are different because either: (1) they use different type of data (cross section, time series, panel, capital stock series built using different methodologies, investment series) or (2) they use different methodological approaches (single and static production function approach, single and static cost function approach, single and dynamic production function approach, multiple equations static approach, multiple equations dynamic approach) or (3) they take into account or they do not take into account some key statistical properties of data: order of integration, cointegration, stochastic trends, etc.

These differences could explain the variety of results found when estimating the magnitude of the effects of public capital on economic growth.

In this paper it is argued that:

Ignoring key statistical properties of data, as cointegration and/or the likely presence of feedbacks, leads to underestimate the importance of public capital as a powerful engine of growth. In particular the existence of feedback relationships among output, labour and capital

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stock, leads to biases when estimating the effects of capital stock. In such circumstances, a multivariate dynamic framework becomes absolutely necessary.

When studying the effects of Transportation, the exclusion of the remaining components of the capital stock may leads to biases. Capital stock components are not independent from each other, and some play a complementary role to transportation investment. An increase in transportation investment may lead to an increase in output, employment as well as in the investment in other types of capital stock. With time, this first, positive, reaction will lead to further increases in transportation investments. Those later investments will not be taken into account if some components of the full capital stock are omitted from the analysis.

The goal of this paper is to compare two estimations of the contribution of transport infrastructure investment on the Spanish economic growth: (1) The estimation obtained with a static single equation framework, as in Cantos et al. (2005) and (2) the estimation obtained with a general multivariate stochastic dynamic framework, as in Flores et al. (1998). Some others recent papers have used stochastic multivariate models when dealing with the effects of capital stock, that is the case of Pereira (2001) and Pereira and Roca Sagales (2003) for Spain, Pereira and Andraz (2005) for Portugal or Pradhan and Bagchi (2012) for India.

Most papers, dealing with the effects of public capital stock, use different data sets along with different econometric methodologies making their results difficult to compare. Differences can be attributed either to the type of data used (see Sloboda and Yao (2008) comparing between investment and capital stock effects), or to the econometric methodology, or both i.e. panel data in Sloboda and Yao (2008) and Crescenzi and Rodríguez-Pose, (2012). Nevertheless comparisons are appealing and some authors carry them out, see for instance the paper of Melo et al. (2013) where a meta analysis of empirical evidence of output elasticity of transport infrastructure is conducted. Based on a sample of 563 estimates of 33 studies it concludes that output elasticity to roads is higher than other types of transport.

Because the main interest of this paper is to focus on the effects of the methodology used for estimating the contribution of the transportation capital stock on the economic growth, the same data set as in Cantos et al. (2005) will be used. Only the econometric methodology will be different, making our results fully comparable with those in Cantos et al. (2005).

Another contribution of this paper is to pay attention to the full capital stock when studying the effects of just one of its components, as the transportation capital stock. As this component is not the only relevant input in a production function, the omission of other types of capital stock from the model could lead to problems of biases when estimating the responses. In this paper, all models used to estimate the effects of transport capital stock on the economic activity, include the "Complementary Capital Stock", that is, a variable measuring the total capital stock less the particular transportation component.

As pointed out by Pereira and Flores (1997), if there exist feedback relationships among output and the inputs in a production function, to focus on the size of the elasticity of output to public capital, obtained from a single equation methodology, it is not adequate for estimating the effects of this type of capital on output. This is because a single equation framework excludes the likely presence of indirect effects and, in particular, the likely dynamic response of capital stock to movements in output or any other variable of the information set.

For the purpose of this paper, the conceptual framework used in Flores et al. (1998) has been slightly modified, keeping its main features unaltered. These authors showed that when studying the dynamic effects of a variable, say Public Capital (PK) on a set of others, say Private Capital (K), Labour (L) and Output (Y), it is not necessary to build a complete dynamic structural model, as it is done when using the Cholesky decomposition in the structural VAR literature, but only a conveniently orthogonalized reduced form of it. To find this reduced form is possible if the contemporaneous correlations, between the variable whose effects have to be studied (PK) and the rest (*K*, *L* and *Y*) can be interpreted as instant causal relationships going in a particular direction.

Such a procedure has the advantage of imposing just a minimum amount of assumptions on the model structure, avoiding the risk of misspecification when, unnecessarily, the variance-covariance matrix of the model disturbances is fully orthogonalized.

This conceptual framework allows for non-stationary time series, co-integration relationships, and any kind of dynamics, including feedbacks relationships.

The conceptual framework has been adapted in order to be able to identify the structural responses, of output and labour, to a shock in the stock of different types of transport capital stock, when a new variable, the complementary capital stock, is included in the information set. This model has been used in Cosculluela and Flores (2013) to evaluate the effect of housing investment on the Spanish economy, so the methodology has applicability not only in other countries, but also to measure macroeconomic effects of other types of capital stock.

The rest of the paper is organized as follows. Section II shows the theoretical framework. Section III presents the time series used, their statistical properties and the estimation of the theoretical models. Section IV discusses the impulse response functions (IRFs) of output and employment. Finally, Section V provides the concluding remarks.

2. Theoretical framework

The framework used by Flores et al. (1998) is adapted to the present problem in order to consider contemporaneous effects in between complementary capital and the capital that it is been studied. In this research the vector of relevant variables is $\boldsymbol{W_t} = (Y_t, L_t, K_{i_t}, \overline{K}_{i_t})'$, all referring to the Spanish economy**.** Where:

Y_t: is the Gross Domestic Product (GDP)

L_t: Total Net Employment

K_{i_t}: Different Transportation Net Capital Stock types, $i = 2_1$ representing road infrastructures, $i = 2_3$ railway infrastructure, $i = 2_4$ port infrastructure and $i = 2_5$ airport infrastructures, accordingly to BBVA-IVIE second level classification.

$\overline{K}_{i_t}$: Complementary Net Capital Stock, computed as the difference between the Total Capital Stock and the Transportation Capital Stock type in each case.

Each vector of lowercase variables $\boldsymbol{w_t} = (y_t, l_t, \bar{k}_{i_t}, k_{i_t})'$ represents the vector of first-differenced logged variables of $\mathbf{W_t}$. As it is shown later in this paper, w_t it is a vector of integrated variables of order 1, *I(1)* variables. The objective is to estimate the IRFs of y_t and l_t to a permanent unitary shock in k_{i_t}.

Those IRFs can be obtained from the dynamic structural equations set, represented in compact notation, by[3]:

$$\boldsymbol{\Pi^*}_{\boldsymbol{w}}(\boldsymbol{B})\boldsymbol{w_t} = \boldsymbol{a_t^*} \tag{1}$$

where:

$\boldsymbol{\Pi^*}_{\boldsymbol{w}}(\boldsymbol{B})$ is a polynomial matrix[4] in B, the lag operator:

$$\mathbf{\Pi^*}_{\mathbf{w}}(\mathbf{B}) = \mathbf{\Pi^*_{0,w}} - \mathbf{\Pi^*_{1,w}}\mathbf{B} - \mathbf{\Pi^*_{2,w}}\mathbf{B^2} - \ldots$$

Whose elements are (4×4) coefficients matrices.

[3] Detail explanation of the base model in Flores *et al* (1998)
[4] The roots of the determinant of $\Pi^*_{w}(B)$ must lie on or outside the unit circle.

$\boldsymbol{a}_t^*$ is a (4×1) vector of structural shocks, which follows a white-noise vector process, with a diagonal contemporaneous covariance matrix $\boldsymbol{\Sigma}^*$.

For this particular case two types of variables are considered, vector $\mathbf{z_t} = (y_t, l_t)'$ and vector $\mathbf{k_t} = (\mathrm{k}_{\mathrm{i_t}}, \bar{\mathrm{k}}_{\mathrm{i_t}})'$. The vector $\boldsymbol{k_t}$ is made on variables which are more rigid than variables in vector $\boldsymbol{z_t}$; that is, $\boldsymbol{z_t}$ variables responses are faster than responses of $\boldsymbol{k_t}$. It seems reasonable to think that a shock in $\boldsymbol{k_t}$ (in period t) would have both instantaneous and lagged effects on the variables in $\boldsymbol{z_t}$. However, a shock in period t in any variable of $\boldsymbol{z_t}$ would only cause lagged responses of $\boldsymbol{k_t}$ variables. It means that $\boldsymbol{k_t}$ variables need time to react to changes in y_t or l_t.

Thus, $\boldsymbol{k_t}$ levels are determined by past values of $\boldsymbol{z_t}$, while $\boldsymbol{z_t}$ values are determined by past and present values of $\boldsymbol{k_t}$.

Formally, the behaviour of vectors $\boldsymbol{z_t}$ and $\boldsymbol{k_t}$ can be represented as:

$$\boldsymbol{z_t} = \boldsymbol{v_z}(\boldsymbol{B})\boldsymbol{k_t} + \boldsymbol{N_{z_t}}$$
$$\boldsymbol{\Pi_z}(\boldsymbol{B})\boldsymbol{N_{z_t}} = \boldsymbol{\alpha_{z_t}} \tag{2}$$

$$\boldsymbol{k_t} = \boldsymbol{v_k}(\boldsymbol{B})\boldsymbol{z_t} + \boldsymbol{N_{k_t}}$$
$$\boldsymbol{\Pi_k}(\boldsymbol{B})\boldsymbol{N_{k_t}} = \boldsymbol{\alpha_{k_t}} \tag{3}$$

Where $\boldsymbol{v_z}(\boldsymbol{B})$ and $\boldsymbol{v_k}(\boldsymbol{B})$ are (2×2) matrices of stable transfer functions:

$$\boldsymbol{v_z}(\boldsymbol{B}) = \begin{pmatrix} \boldsymbol{v}_{y_{\bar{k}_{i_t}}}(\boldsymbol{B}) & \boldsymbol{v}_{y_{k_{i_t}}}(\boldsymbol{B}) \\ \boldsymbol{v}_{l_{\bar{k}_{i_t}}}(\boldsymbol{B}) & \boldsymbol{v}_{l_{k_{i_t}}}(\boldsymbol{B}) \end{pmatrix} \text{ and } \boldsymbol{v_K}(\boldsymbol{B}) = \begin{pmatrix} \boldsymbol{v}_{\bar{k}_{i_{y_t}}}(\boldsymbol{B}) & \boldsymbol{v}_{\bar{k}_{i_{l_t}}}(\boldsymbol{B}) \\ \boldsymbol{v}_{k_{i_{y_t}}}(\boldsymbol{B}) & \boldsymbol{v}_{k_{i_{l_t}}}(\boldsymbol{B}) \end{pmatrix}$$

Each transfer function in $\mathrm{v_z(B)}$ representing the unidirectional response function of each variable y_t and l_t to shocks in $\mathrm{k_t}$.

At the same time, $\boldsymbol{k_t}$ variables have different yield. It seems reasonable that complementary infrastructures $\bar{k}_{i_t}$ (houses, machinery) take longer to react than the transport capital infrastructure that is being studied (k_{i_t}). The later can react instantaneously and can continue reacting over several periods while complementary infrastructures $\bar{k}_{i_t}$ will only show lagged reactions to changes in the transportation capital stock analysed, i.e. they would not react in the same year.

It is important to note that the empirical analysis will show that no significant contemporaneous correlations between these variables are found in any of the transportation capital types studied, and therefore, this assumption will not be necessary.

This idea can be represented as:

$$\boldsymbol{k_t} = \boldsymbol{v_k}(\boldsymbol{B})\boldsymbol{z_t} + \boldsymbol{N_{k_t}}$$
$$\boldsymbol{\Pi_k}(\boldsymbol{B})\boldsymbol{N_{k_t}} = \boldsymbol{\alpha_{k_t}} \tag{4}$$

with

$$\boldsymbol{E}(\boldsymbol{\alpha_{k_t}}\boldsymbol{\alpha_{k_t}'}) = \boldsymbol{\Sigma_k} = \boldsymbol{P_k^{-1}}\boldsymbol{\Sigma_k^*}\boldsymbol{P_k'^{-1}} \tag{5}$$

where $\boldsymbol{P_K} = \begin{pmatrix} 1 & 0 \\ -\beta & 1 \end{pmatrix}$ is the diagonalization matrix for $\mathbf{\Sigma_k}$ and β is the slope in regression (6).

$$\boldsymbol{\alpha_{k_t}} = \boldsymbol{\beta}\boldsymbol{\alpha_{\bar{k}_t}} + \boldsymbol{\alpha_{k_t}^*} \tag{6}$$

Taking into account this assumption (3) would be:

$$\boldsymbol{P_k\Pi_k}(\boldsymbol{B})\boldsymbol{k_t} = \boldsymbol{P_k\Pi_k}(\boldsymbol{B})\boldsymbol{v_k}(\boldsymbol{B})\boldsymbol{z_t} + \boldsymbol{P_k\alpha_{k_t}} \tag{7}$$

or

$$\boldsymbol{P_k \Pi_k(B) k_t = P_k \Pi_k(B) \nu_k(B) z_t + \alpha^+_{k_t}} \tag{8}$$

with

$$\boldsymbol{E\left(\alpha^+_{k_t}, \alpha^{+\,\prime}_{k_t}\right) = \Sigma^+_k}$$

diagonal.

Equations (2) and (8) in compact notation would be:

$$\begin{bmatrix} \boldsymbol{\Pi_z(B)} & \boldsymbol{-\Pi_z(B)\nu_z(B)} \\ \boldsymbol{-P_k\Pi_k(B)\nu_k(B)} & \boldsymbol{P_k\Pi_k(B)} \end{bmatrix} \times \begin{bmatrix} \boldsymbol{z_t} \\ \boldsymbol{k_t} \end{bmatrix} = \begin{pmatrix} \boldsymbol{\alpha_{z_t}} \\ \boldsymbol{\alpha^+_{k_t}} \end{pmatrix} \tag{9}$$

with

$$\mathbf{E}\left[\begin{pmatrix} \boldsymbol{\alpha}_{\mathbf{z_t}} \\ \boldsymbol{\alpha}^+_{\mathbf{k_t}} \end{pmatrix} \begin{pmatrix} \boldsymbol{\alpha}'_{\mathbf{z_t}} & \boldsymbol{\alpha}^{+\prime}_{\mathbf{k_t}} \end{pmatrix}'\right] = \begin{bmatrix} \mathbf{\Sigma_z} & \mathbf{0} \\ \mathbf{0} & \mathbf{\Sigma^+_k} \end{bmatrix} \tag{10}$$

This model is similar to (1), the difference between them is the dependence of the variables in $\boldsymbol{\alpha_{z_t}}$, that is the non-diagonal character of $\boldsymbol{\Sigma_z}$. However it will be possible to estimate the response functions of each one of the elements of $\boldsymbol{z_t}$ to a shock in $\boldsymbol{k_{i_t}}$.

Model (9)-(10) in compact notation would be:

$$\boldsymbol{\Pi^+(B) w_t = \alpha^+_t} \tag{11}$$

with

$$\boldsymbol{E\left(\alpha^+_t \alpha^{+\prime}_t\right) = \Sigma^+} \tag{12}$$

block diagonal.

Since $\boldsymbol{\Pi^+(0)} = \begin{bmatrix} \boldsymbol{I} & \boldsymbol{-\nu_{z0}} \\ \boldsymbol{0} & \boldsymbol{P_k} \end{bmatrix} \neq \boldsymbol{I}$, the stochastic multivariate model (9) is not normalized in the sense of Alavi (1981). However, it can be normalized by pre-multiplying (11) by $\left[\boldsymbol{\Pi^+_{0,w}}\right]^{-1}$:

$$\left[\boldsymbol{\Pi^+_{0,w}}\right]^{-1} \boldsymbol{\Pi^+(B) w_t} = \left[\boldsymbol{\Pi^+_{0,w}}\right]^{-1} \boldsymbol{\alpha^+_t} \tag{13}$$

where (13) can be written as:

$$\boldsymbol{\Pi_w(B) w_t = a_t} \tag{14}$$

$$\boldsymbol{\Pi(B)} = \left[\boldsymbol{\Pi^+_{0,w}}\right]^{-1} \boldsymbol{\Pi^+(B)}$$

$$\boldsymbol{a_t} = \left[\boldsymbol{\Pi^+_{0,w}}\right]^{-1} \boldsymbol{\alpha^+_t} \tag{15}$$

$$\mathbf{E(a_t, a'_t) = \Sigma} = \left[\mathbf{\Pi^+_{0,w}}\right]^{-1} \mathbf{\Sigma^+} \left\{\left[\mathbf{\Pi^+_{0,w}}\right]^{-1}\right\}' \tag{16}$$

Estimating (14) and its corresponding instant variance-covariance matrix, it allows estimating in a consistent manner all the parameters in (11) and (12)[5], that is, $[\boldsymbol{\Pi^+(B)}]$ and $\mathbf{\Sigma^+}$ which are similar to model (1); and from them, the IRFs. Positions (1,4) and (2,4) of the polynomial elements in (17) will give the response functions of y_t and l_t, respectively.

$$\mathrm{w_t = \Psi^+(B)\alpha^+_t} \tag{17}$$

with

$$\boldsymbol{\Psi^+(B) = [\Pi^+(B)]^{-1} = \Psi^+_0 + \Psi^+_1 B + \Psi^+_2 B^2 + \ldots} \tag{18}$$

The model used considers the different yields in between capital stock and labour and GDP, and in between complementary infrastructures $\bar{k}_{i_t}$ (houses, machinery) and transportation capital stock.

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[5] All mathematical details have been taken to an appendix which is available upon request.

In the following section, expressions (14) and (17) are estimated.

3. Estimation of the theoretical model.

It has been used yearly data of the Spanish economy for the period 1977/2005 (Table 3):

Y_t: Gross Domestic Product (GDP) obtained from the World Bank. Thousands of euros, base year 2000.

L_t: Total employment[6], measured in thousands of workers obtained from the Spanish Labour Survey "Encuesta de Población Activa, EPA" published by the Spanish Statistical Institute (INE, 2006).

K_{i_t}: Net Transportation Capital Stock Data computed by IVIE and published by BBVA foundation (Mas et al., 2007), where $i = 2_1$ represents road infrastructure, $i = 2_3$ railway infrastructure, $i = 2_4$ port infrastructure and $i = 2_5$ airport infrastructure, accordingly to BBVA-IVIE second level classification.

$\overline{K}_{i_t}$: Net Capital Stock Data computed by IVIE and published by BBVA foundation (Mas et al., 2007), excluding the transportation Capital Stock that it is being studied K_{i_t}.

All capital stock series are measured in thousands of Euros with base year 2000.

Univariate Analysis. Table 4 contains the values of the Augmented Dickey-Fuller (ADF) test for a unit root in first and second differenced series, as well as the ARIMA univariate models. No important outliers have been found; therefore no intervention analysis is needed.

Results show that all variables are I(2). The absence of MA terms from univariate models suggest that none of the series seems to be over differenced.

Cointegration. Johansen (1988, 1991) and Granger and Engel (1987) methods were used to study the presence of cointegration relationships among the set of I(1) variables $(y_t, l_t, \overline{k}_{i_t}, k_{i_t})$.

Results suggest that there is a cointegration equation ξ_{1_t}, which involves production and employment growth rates. $\xi_{1_t} = y_t - 0.47_{(0.05)} l_t - 0.02_{(0.001)}$.

Cointegration equation ξ_{1_t} can be interpreted as a stable or equilibrium positive relationship between production and employment growth rates, where the disequilibrium in each period t is measured by ξ_{1_t}.

When airport infrastructure capital stock $\left(k_{2_{4_t}}\right)$ is studied, another cointegration equation ξ_{2_t}, is found. $\xi_{2_t} = l_t - 1.39_{(0.15)} y_t - 0.27_{(0.06)} k_{2_{4_t}} + 0.04_{(0.01)}$

ξ_{2_t} measures the disequilibrium in the stable positive relationship between employment, production and airport infrastructure growth rates.

4. Estimation of the multivariate model

Akaike information criterion (AIC)[7] suggest a VAR(3) process for every type of transportation capital.

Model (14), a VEC(2) on twice differenced variables, has been jointly estimated. All no significant parameters have been constrained to be zero. Its estimated variance-covariance matrix $\widehat{\boldsymbol{\Sigma}}$ and the instant correlation matrix $\widehat{\boldsymbol{\rho}}$ computed from $\widehat{\boldsymbol{\Sigma}}$ are shown in Table 5. AIC applied to the residuals

[6] Ceuta and Melilla employment is not computed. There are missing observations.
[7] Diagnosis of the process is shown in Table 6 to Table 9 and Figure 1 to Figure 4

of the model shows that $\widehat{\boldsymbol{a}}_t$ follow a multivariate white noise process. Tables 6-9 show the cross correlation residual Function values (CCF) and figures below the residual series and their Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions.

No significant correlations between any transportation capital stock type and its complementary capital stock are found $\widehat{\boldsymbol{\rho}}$, $\boldsymbol{P_k} = \boldsymbol{I}$, thus Equation (8) is: $\widehat{\boldsymbol{\Pi}}_{\boldsymbol{k}}(\boldsymbol{B})\boldsymbol{k_t} = \widehat{\boldsymbol{\Pi}}_{\boldsymbol{k}}(\boldsymbol{B})\widehat{\boldsymbol{v}}_{\boldsymbol{k}}(\boldsymbol{B})\boldsymbol{z_t} + \widehat{\boldsymbol{\alpha}}_{\boldsymbol{k_t}}$

From the estimation of $\widehat{\boldsymbol{\Sigma}}$, $\widehat{\boldsymbol{\Pi}}^{+}_{\mathbf{0,w}}$ is estimated (16)[8]. $\widehat{\boldsymbol{\Pi}}^{+}_{\mathbf{0,w}}$ allows calculating (11) from (14).

Pre-multiplying (14) by $\widehat{\boldsymbol{\Pi}}^{+}_{\mathbf{0,w}}$, model (11) will be estimated. Model (11) is similar to (1) with the only difference that $\boldsymbol{\Sigma_z}$ in (11) is not diagonal, variables in α_{z_t} are not independent.

Table 5 presents for each transportation capital stock type (road, railway, airport and port infrastructures): 1) the estimated models (11) in its corresponding VAR(3) representations; 2) the estimated variance-covariance matrix $\widehat{\boldsymbol{\Sigma}}$ together with the instant correlation matrix $\widehat{\boldsymbol{\rho}}$ computed from $\widehat{\boldsymbol{\Sigma}}$ of the estimation of the VEC(2) process (14); 3) $\widehat{\boldsymbol{\Pi}}^{+}_{\mathbf{0,w}}$ estimated matrix (Equation 16). Those estimated models (11) have been computed pre-multiplying the estimated model (14) in its VAR representation by their estimated $\widehat{\boldsymbol{\Pi}}^{+}_{\mathbf{0,w}}$.

No significant contemporaneous correlations, between any transportation capital variables and the corresponding complementary capital stock, are found in any of the transportation capital types studied. $\widehat{\boldsymbol{\rho}}$ Matrix positions (3, 4) have been considered not significant compared with the standard criteria.

Orthogonalized reduced forms (Equation 11) are presented in Table 5 in the following way:

$$\widehat{\boldsymbol{\Pi}}^{+}_{w}(\boldsymbol{B})\boldsymbol{w_t} = \widehat{\boldsymbol{a}}^{+}_{t}$$

$\widehat{\boldsymbol{\Pi}}^{+}_{w}(\boldsymbol{B})$	$\boldsymbol{w_t}$	$\widehat{\boldsymbol{a}}^{+}_{t}$
$\begin{bmatrix}\widehat{\boldsymbol{\Pi}}^{+}_{w_{11}}(\boldsymbol{B}) & \widehat{\boldsymbol{\Pi}}^{+}_{w_{12}}(\boldsymbol{B})\\ \widehat{\boldsymbol{\Pi}}^{+}_{w_{21}}(\boldsymbol{B}) & \widehat{\boldsymbol{\Pi}}^{+}_{w_{22}}(\boldsymbol{B})\end{bmatrix}$	$\begin{pmatrix}y_t\\ l_t\\ \bar{k}_{i_t}\\ k_{i_t}\end{pmatrix} + \begin{pmatrix}\widehat{u}_{1_t}\\ \widehat{u}_{2_t}\\ \widehat{u}_{3_t}\\ \widehat{u}_{4_t}\end{pmatrix}$	$\begin{pmatrix}\widehat{a}^{+}_{y_t}\\ \widehat{a}^{+}_{l_t}\\ \widehat{a}^{+}_{\bar{k}_{i_t}}\\ \widehat{a}^{+}_{k_{i_t}}\end{pmatrix}$

Table 5 shows dynamic relations among all the variables studying any type of transportation capital.

As it has been explained in Section II, IRFs (Equation 17) can be obtained from the reduced form of model (11) in Table 5, $\boldsymbol{\Psi}^{+}(\boldsymbol{B}) = [\boldsymbol{\Pi}^{+}(\boldsymbol{B})]^{-\mathbf{1}}$.

By adding up the IRFs, the corresponding Step Response Functions (SRFs) are computed and showed in Figure 6.

5. SRFs from the orthogonalized reduced form.

Figure 6 shows the responses, in percentage points, of output, labour, complementary capital stock and capital stock, for each of the following 20 periods, to a permanent, one percentage point increase in the level of each capital transportation stock type (roads, railways, airports and ports). Those responses were computed adding up the IRFs until the corresponding period.

Results can be summarized as follows:

[8] All mathematical details have been taken to an appendix which is available upon request

A permanent increase in the level of road, railway, and airport infrastructure capital stock, leads to a permanent increase in the level of output and labour (both achieved approximately in six years). Thus, output and labour respond positively to a shock in road, railway, and airport infrastructure capital stock. Port infrastructures do not seem to cause effects on output or labour. All these general results are similar to those found in the literature, even the lack of effects of Port infrastructures, also found in Cantos et al. (2005).

The differences come from the feedbacks found among the variables considered, and in particular from the capital stock to the rest of variables. In that case the output elasticity it is not constant anymore. The same happens with the labour elasticity which varies with the term considered. Figure 6 shows the responses of output, labour and rest of capital stock to a permanent unitary shock in roads, railways and ports infrastructures. The output elasticity, for each term, can be computed by dividing the output SRF (ln Y) by the capital stock feedback effect for each capital stock (road, railway, airport and port) ($\ln K_i$, for $i = 2_1, 2_3, 2_4$ and 2_5). The same applies to labour and complementary capital elasticity.

A shock in any type of transportation capital stock takes one period to be productive, while it affects labour in the same period.

One period after the shock, the highest elasticity of output is produced by a shock in railway infrastructure capital stock (.13), followed by airports (.04) and roads (.03). After six years all responses get stabilized and estimated long run elasticity show a change in the ranking of importance: Now airports elasticity rises up to .43, railways rises up to .19 and roads keeps almost constant around .04.

The instant labour elasticity to a shock in railway, roads and airport infrastructure are (.44), (.16) and (.06), respectively. Five years later (long run) are (.39), (.08) and (.86). While railways and roads almost keep constant, airports long run elasticity rises exponentially.

No effects on complementary capital stock have been detected. According to this finding transport infrastructure capital stock seems to move independently from other capital stock types. The huge amount of aids for transportation investment coming from the European Union to encourage the Spanish convergence could be behind this strange result.

These results are quite different from those obtained in Cantos et al. (2005). The table below shows the differences on long run output elasticity:

Table 1. Long Run Output Elasticity

	Cantos et al. (2005)	Cosculluela and Flores (2011)
Roads	.090	.040=0.08/1.95
Airports	.008	.430=0.03/0.07
Railways	.000	.194=0.21/1.08
Ports	.000	.000

Only the output elasticity of Ports is the same in both papers. For any other capital stock, the differences are big and caused by implicitly assuming that feedbacks are not present in this data set.

The static single equation analysis prevents to estimate the effects of transportation capital stock on employment, implicitly assuming independence, which is not true as can be seen in the following table:

Table 2. Long Run Employment Elasticity

	Cosculluela and Flores (2011)
Roads	.08=0.16/1.95
Airports	.86=0.06/0.07
Railways	.39=0.42/1.08
Ports	.00

Excluding Ports, the long run employment elasticity of any type of transportation capital stock is positive.

Finally, it is important to note that the instantaneous response of output to shocks in either Roads or Airports or Railways or Ports is zero, i.e., very close to the long run output elasticity estimated in Cantos et al. (2005). This is not strange because when dynamics are not allowed in a production function, the long run elasticity coincides with the instantaneous elasticity. That is, what Cantos et al. (2005) estimated with their static single equation production function was the instantaneous elasticity of output.

6. Summary and concluding remarks

Disaggregated econometric estimations of the economic effects produced by transportation infrastructure capital stock, by means of different types of infrastructures are difficult to find. Aggregated analysis estimating transportation contribution on output, in different countries, even in Spain, are difficult to compare, because they use different data sources and methodologies.

Cantos et al. (2005) studied the impact of transportation infrastructures on the Spanish economic growth distinguishing among transportation infrastructure types (road, railway, airport and port). These authors used an accounting approach on the basis of a regression on total factor productivity (TFP) indices, and a single Cobb-Douglas production function to estimate the elasticity of output to roads, ports, airports and railways.

The present paper deals with the same problem and uses the same capital stock data source than Cantos et al. (2005), but unlike those authors, it uses a multivariate dynamic approach, where feedback relationships from capital stock play an important role. The objective is to be able to compare the results of both papers and evaluate the importance of feedbacks from capital stock, when estimating its contribution to economic growth.

Our results prove that feedbacks are present in the data set and its omission causes important biases when estimating the contribution of infrastructure capital stock to GDP growth. In the best of cases, Cantos et al. (2005) estimate instantaneous responses instead of long run ones. That could be the reason why they find such small responses of output to shocks in all types of capital stock considered.

Further, labour and capital stocks far from being independent each other, it is found that the increase of capital encourages the use of labour.

It is concluded that for studying the effects of capital stock on output and / or employment, it is necessary to use a multivariate dynamic framework.

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Appendix A.

Table 3. Data.

Year	GDP	Net Employment	Total Capital Stock	2_1. Road infrastructures	2_3. Railway infrastructures	2_4. Airport infrastructures	2_5. Port infrastructures
1977	345 224 904.70	12 594.38	1 088 822 267	36 368 128.96	17 984 834.47	3 013 483.93	6 135 721.13
1978	350 275 502.08	12 398.28	1 136 945 841	37 968 062.88	18 177 947.77	3 087 523.06	6 331 904.94
1979	350 421 090.30	12 227.50	1 180 460 634	38 863 181.78	18 653 281.64	3 097 087.49	6 471 191.87
1980	358 160 891.90	11 894.90	1 222 594 208	39 714 424.66	18 903 434.47	3 150 928.43	6 649 900.70
1981	357 686 509.57	11 588.38	1 262 288 977	40 734 804.65	19 051 061.09	3 245 449.36	6 812 909.87
1982	362 144 890.88	11 481.38	1 301 460 454	42 578 660.77	19 313 086.90	3 401 305.46	6 962 461.29
1983	368 555 294.72	11 421.70	1 338 247 528	44 451 816.75	19 921 279.27	3 448 672.09	7 152 909.73
1984	375 132 815.36	11 118.90	1 370 253 267	45 860 902.11	20 353 014.79	3 610 827.80	7 317 259.75
1985	383 841 304.58	11 004.05	1 404 863 421	47 465 315.33	20 700 221.40	3 690 720.79	7 530 336.49
1986	396 328 894.46	11 208.80	1 444 999 566	49 323 535.04	21 067 972.88	3 790 908.83	7 759 446.21
1987	418 313 699.33	11 749.08	1 492 914 843	51 680 185.12	21 729 192.60	3 900 709.88	7 942 846.95
1988	439 624 007.68	12 178.80	1 550 232 290	54 952 627.96	22 501 568.47	4 014 143.42	8 174 941.37
1989	460 844 793.86	12 602.55	1 617 434 219	59 351 118.39	23 311 871.65	4 215 481.38	8 465 756.90
1990	478 271 111.17	12 922.25	1 689 823 644	65 521 396.29	24 544 740.34	4 518 774.07	8 913 395.91
1991	490 447 896.58	13 025.98	1 761 930 594	72 184 642.61	25 928 296.66	4 770 923.43	9 270 627.15
1992	495 005 204.48	12 788.80	1 827 833 648	78 335 965.65	26 977 901.89	4 910 867.63	9 685 444.52
1993	489 899 294.72	12 259.28	1 882 300 510	84 256 686.31	27 926 951.25	5 007 714.96	10 126 012.25
1994	501 574 598.66	12 174.13	1 937 081 749	90 009 524.67	28 636 288.90	5 272 905.80	10 574 568.31
1995	515 405 414.40	12 478.00	1 998 114 494	95 571 482.17	29 156 419.86	5 729 350.08	10 961 376.47
1996	527 829 401.60	12 835.03	2 060 344 847	99 597 602.15	29 854 690.77	6 068 834.78	11 246 748.79
1997	548 234 002.43	13 307.28	2 126 970 493	104 397 980.30	30 703 041.40	6 502 576.27	11 582 527.19
1998	572 809 478.14	13 864.85	2 205 363 875	109 500 247.27	31 915 035.53	6 928 531.68	11 916 343.98
1999	600 008 228.86	14 648.88	2 295 656 762	114 131 968.75	33 218 471.78	7 313 865.34	12 257 618.60
2000	630 262 988.80	15 461.83	2 393 286 747	118 507 793.47	35 158 880.66	7 702 000.36	12 588 174.54
2001	652 600 999.94	16 100.20	2 494 650 236	123 193 698.02	37 744 155.49	8 474 044.56	13 010 999.80
2002	670 092 886.02	16 584.08	2 597 450 307	128 517 223.89	40 901 052.36	9 554 921.31	13 520 105.36
2003	690 183 995.39	17 248.50	2 705 711 149	134 248 452.17	43 934 492.67	11 288 715.34	14 102 090.05
2004	711 542 571.01	17 923.15	2 818 378 849	139 180 269.64	47 122 718.57	12 749 345.42	14 646 997.38
2005	735 924 322.30	18 925.18	2 943 208 569	144 202 404.51	50 373 443.41	14 235 182.27	15 204 542.32

Labour in thousands of employees and Capital Stock and GDP in thousands of 2000 Euro

Appendix B.

Table 4. Univariate analysis

ADF	*Lags (*)*					*Univarite models (**)*					
	0	**1**	**2**	**3**	**4**		Φ_1	Φ_2	Φ_3	σ_{a_t}	**Q(5)**
y_t	-0.87	-0.60	-0.77	-0.64	-0.46	∇y_t				1.33%	2.49
∇y_t	-5.91	-3.44	-2.69	-2.71	-2.62						
l_t	-0.92	-1.56	-1.00	-0.90	-0.90	∇l_t	0.43	-0.35		1.75%	1.36
∇l_t	-3.54	-3.99	-2.91	-2.30	-2.76		(-0.20)	(0.20)			
$k_{2_{1t}}$	-0.59	-0.51	-0.45	-0.42	-0.72	$\nabla k_{2_{1t}}$	0.37			0.99%	1.06
$\nabla k_{2_{1t}}$	-3.71	-3.26	-2.71	-2.11	-1.95		(0.17)				
$\bar{k}_{2_{1t}}$	-0.20	0.17	0.12	0.45	0.52	$\nabla \bar{k}_{2_{1t}}$	0.93	-0.36		0.32%	5.02
$\nabla \bar{k}_{2_{1t}}$	-2.46	-2.84	-2.73	-2.91	-3.02		(0.20)	(0.19)			
$k_{2_{3t}}$	0.42	0.03	0.38	0.37	0.01	$\nabla k_{2_{3t}}$				0.97%	3.99
$\nabla k_{2_{3t}}$	-4.35	-3.47	-2.61	-1.81	-2.69						
$\bar{k}_{2_{3t}}$	-0.30	0.18	0.06	0.38	0.39	$\nabla \bar{k}_{2_{3t}}$	0.88	-0.33		0.32%	5.41
$\nabla \bar{k}_{2_{3t}}$	-2.67	-2.81	-2.77	-2.85	-3.15		(0.20)	(0.19)			
$k_{2_{4t}}$	-0.23	0.01	0.29	1.37	1.78	$\nabla k_{2_{4t}}$				2.41%	2.20
$\nabla k_{2_{4t}}$	-5.59	-3.70	-4.28	-3.27	-2.84						
$\bar{k}_{2_{4t}}$	-0.26	0.16	0.09	0.40	0.41	$\nabla \bar{k}_{2_{4t}}$	0.92	-0.36		0.32%	5.18
$\nabla \bar{k}_{2_{4t}}$	-2.55	-2.86	-2.78	-2.91	-3.06		(0.20)	(0.19)			
$k_{2_{5t}}$	-0.30	0.12	0.02	0.16	0.23	$\nabla k_{2_{5t}}$				0.64%	2.47
$\nabla k_{2_{5t}}$	-6.39	-3.72	-3.11	-2.40	-1.51						
$\bar{k}_{2_{5t}}$	-0.23	0.17	0.11	0.41	0.43	$\nabla \bar{k}_{2_{5t}}$	0.92	-0.36		0.33%	5.16
$\nabla \bar{k}_{2_{5t}}$	-2.56	-2.87	-2.76	-2.87	-3.07		(0.20)	(0.19)			

Notes: First differences of natural logarithm of the variables in lowercase letters.
(*): ρ=1 in $\nabla z_t = \mu + \rho z_{t-1} + \sum_{j=1}^{p} \gamma_j \nabla z_{t-j} + \mu_t$. Critical value at 95% is -1.96 with μ=0 (MacKinnon)
(**): $\left(1 - \sum_{i=1}^{n} \Phi_i B^i\right)[\nabla^2 \ln X_t - \mu_t] = a_t$ is the univariate model specification. SD in parenthesis. (σ_{a_t}) represents the residual standard deviation and Q(5) is the Ljung-Box statistic.

Appendix C.

Table 5. Orthogonalized Reduced Forms

$$\widehat{\Pi}^+_w(B) w_t = \hat{a}^+_t \ (*)$$

$\widehat{\Pi}^+_w(B)$	w_t	$\hat{a}^+_t$
$\begin{bmatrix} \widehat{\Pi}^+_{w_{11}}(B) & \widehat{\Pi}^+_{w_{12}}(B) \\ \widehat{\Pi}^+_{w_{21}}(B) & \widehat{\Pi}^+_{w_{22}}(B) \end{bmatrix}$	$\begin{pmatrix} y_t \\ l_t \\ \bar{k}_{i_t} \\ k_{i_t} \end{pmatrix} + \begin{pmatrix} -0.01 \\ 0 \\ 0 \\ 0 \end{pmatrix}$	$\begin{pmatrix} \hat{a}^+_{y_t} \\ \hat{a}^+_{l_t} \\ \hat{a}^+_{\bar{k}_{i_t}} \\ \hat{a}^+_{k_{i_t}} \end{pmatrix}$

Road infrastructures $\left(k_{2_{1_t}}\right)$

$\widehat{\Pi}^+_{w_{11}}(B)$	$\widehat{\Pi}^+_{w_{12}}(B)$
$\begin{bmatrix} 1-0.37B & -0.30B \\ 0 & 1-1.23B+0.49B^2-0.27B^3 \end{bmatrix}$	$\begin{bmatrix} 6.43B-2.68B^2+0.04B^3-3.79 & 0 \\ 8.98B-3.74B^2+0.05B^3-5.29 & 0.25B-0.08B^2 - \end{bmatrix}$
$\widehat{\Pi}^+_{w_{21}}(B)$	$\widehat{\Pi}^+_{w_{22}}(B)$
$\emptyset$	$\begin{bmatrix} 1-1.70B+0.71B^2-0.01B^3 & 0 \\ 0 & 1-1.49B+0.49B^2 \end{bmatrix}$

$\widehat{\Pi}^+_{0,w}$	$\hat{\rho}$	$\hat{\Sigma}$
$\begin{pmatrix} 1 & 0 & -3.79 & 0 \\ & 1 & -5.29 & -0.16 \\ & & 1 & 0 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0.81 & 0.80 & 0.30 \\ & 1 & 0.83 & 0.33 \\ & & 1 & 0.29 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1.30E-04 & 1.47E-04 & 2.16E-05 & 3.06E-05 \\ & 2.54E-04 & 3.12E-05 & 4.76E-05 \\ & & 5.61E-06 & 6.25E-06 \\ & & & 8.22E-05 \end{pmatrix}$

Railway infrastructures $\left(k_{2_{3_t}}\right)$

$\widehat{\Pi}^+_{w_{11}}(B)$	$\widehat{\Pi}^+_{w_{12}}(B)$
$\begin{bmatrix} 1-0.35B & -0.31B \\ 0 & 1-1.12B+0.37B^2-0.25B^3 \end{bmatrix}$	$\begin{bmatrix} 5.91B-2.10B^2-0.22B^3-3.60 & 0 \\ 8.74B-2.43B^2-0.99B^3-5.32 & 0.44B-0.44 \end{bmatrix}$
$\widehat{\Pi}^+_{w_{21}}(B)$	$\widehat{\Pi}^+_{w_{22}}(B)$
$\begin{bmatrix} 0 & 0 \\ 0 & -0.21B+0.21B^2 \end{bmatrix}$	$\begin{bmatrix} 1-1.64B+0.58B^2+0.06B^3 & 0 \\ -1.54B^2+1.54B^3 & \nabla \end{bmatrix}$

$\widehat{\Pi}^+_{0,w}$	$\hat{\rho}$	$\hat{\Sigma}$
$\begin{pmatrix} 1 & 0 & -3.60 & 0 \\ & 1 & -5.32 & -0.44 \\ & & 1 & 0 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0.81 & 0.79 & 0.14 \\ & 1 & 0.83 & 0.21 \\ & & 1 & 0.01 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1.30E-04 & 1.47E-04 & 2.25E-05 & 1.14E-05 \\ & 2.55E-04 & 3.32E-05 & 2.44E-05 \\ & & 6.22E-06 & 2.17E-07 \\ & & & 5.31E-05 \end{pmatrix}$

Airport infrastructures $\left(k_{2_{4_t}}\right)$

$\widehat{\Pi}^+_{w_{11}}(B)$	$\widehat{\Pi}^+_{w_{12}}(B)$
$\begin{bmatrix} 1-0.35B & -0.31B \\ -0.01B & 1-1.17B+0.44B^2-0.23B^3 \end{bmatrix}$	$\begin{bmatrix} 6.05B-2.22B^2-0.19B^3-3.64 & 0 \\ 8.57B-3.02B^2-0.27B^3-5.28 & 0.03B-0.06 \end{bmatrix}$
$\widehat{\Pi}^+_{w_{21}}(B)$	$\widehat{\Pi}^+_{w_{22}}(B)$
$\begin{bmatrix} 0 & 0 \\ 0.23B & -0.74B \end{bmatrix}$	$\begin{bmatrix} 1-1.66B+0.61B^2+0.05B^3 & 0 \\ 3.63B-3.63B^2 & 1-0.51B \end{bmatrix}$

$\widehat{\Pi}^+_{0,w}$	$\hat{\rho}$	$\hat{\Sigma}$
$\begin{pmatrix} 1 & 0 & -3.64 & 0 \\ & 1 & -5.28 & -0.06 \\ & & 1 & 0 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0.81 & 0.80 & 0.12 \\ & 1 & 0.84 & 0.28 \\ & & 1 & 0.24 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1.30E-04 & 1.48E-04 & 2.23E-05 & 2.99E-05 \\ & 2.57E-04 & 3.32E-05 & 9.53E-05 \\ & & 6.01E-06 & 1.28E-05 \\ & & & 4.64E-04 \end{pmatrix}$

Port infrastructures $\left(k_{25_t}\right)$

$\widehat{\Pi}^{+}_{w_{11}}(B)$	$\widehat{\Pi}^{+}_{w_{12}}(B)$
$\begin{bmatrix} 1-0.35B & -0.31B \\ 0 & 1-1.24B+0.51B^2-0.27B^3 \end{bmatrix}$	$\begin{bmatrix} 6.45B-2.66B^2-3.79 & 0 \\ 9.43B-3.88B^2-5.54 & 0 \end{bmatrix}$
$\widehat{\Pi}^{+}_{w_{21}}(B)$	$\widehat{\Pi}^{+}_{w_{22}}(B)$
$\begin{bmatrix} 0 & 0 \\ 0.14B^2-0.14B^3 & 0.26B-0.26B^2 \end{bmatrix}$	$\begin{bmatrix} 1-1.70B+0.70B^2 & 0 \\ -1.27B+1.27B^2 & 1-0.59B-0.41B^2 \end{bmatrix}$

$\widehat{\Pi}^{+}_{0,w}$	$\hat{\rho}$	$\hat{\Sigma}$
$\begin{pmatrix} 1 & 0 & -3.79 & 0 \\ & 1 & -5.54 & 0 \\ & & 1 & 0 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0.80 & 0.80 & 0.17 \\ & 1 & 0.84 & 0.03 \\ & & 1 & 0.15 \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1.30E-04 & 1.46E-04 & 2.20E-05 & 9.17E-06 \\ & 2.53E-04 & 3.22E-05 & 2.36E-06 \\ & & 5.83E-06 & 1.65E-06 \\ & & & 2.14E-05 \end{pmatrix}$

Note: (*) The orthogonalized reduced forms (Equation 11) for each capital stock type has been computed from GLS VEC(2), on twice differenced variables estimation in its VAR representation (13), its estimated variance-covariance matrix $\hat{\Sigma}$ and the instant correlation matrix $\hat{\rho}$ computed from $\hat{\Sigma}$ (Equation 16). As there are no significant correlations between any transportation capital stock type and the its complementary capital stock, $P_k = I$, Equation (8) is $\widehat{\Pi}_k(B)k_t = \widehat{\Pi}_k(B)\hat{v}_k(B)z_t + \hat{\alpha}_{k_t}$. $\widehat{\Pi}^{+}_{0,w}$ is calculated from the estimation of $\hat{\Sigma}$ in (13) (Equation16, details in appendix upon request). Pre-multiplying (13) by $\widehat{\Pi}^{+}_{0,w}$ model (11) is computed.

Diagnosis of the process is shown in Table 6 to Table 9 and Figure 1 to Figure 4. All no significant parameters have been constrained to be zero. AIC applied to the residuals of the model shows that $\hat{a}_t$ follows a multivariate white-noise process.

Appendix D.

Table 6. Cross Correlation residual Function values (CCF). Road Infrastructure Capital Stock

lags	1,1	1,2	1,3	1,4	2,1	2,2	2,3	2,4	3,1	3,2	3,3	3,4	4,1	4,2	4,3	4,4
1	0.21	0.29	0.23	0.16	0.07	0.17	0.26	0.03	0.21	0.20	0.25	0.13	-0.01	0.08	0.00	0.02
2	-0.03	-0.01	0.02	-0.17	-0.07	0.00	0.00	-0.33	-0.17	-0.08	-0.18	-0.41	0.16	0.05	0.22	-0.21
3	0.02	-0.05	-0.15	-0.46	-0.13	-0.22	-0.29	-0.56	-0.07	-0.08	-0.10	-0.44	0.63	0.50	0.45	0.02
4	-0.18	-0.11	-0.32	-0.09	-0.37	-0.18	-0.37	-0.07	-0.16	-0.08	-0.23	-0.07	-0.13	0.03	-0.07	0.02
5	-0.19	-0.10	-0.20	0.13	-0.25	-0.21	-0.26	0.06	-0.30	-0.26	-0.36	0.01	-0.23	-0.20	-0.16	-0.05
SD (σ)=0.2																

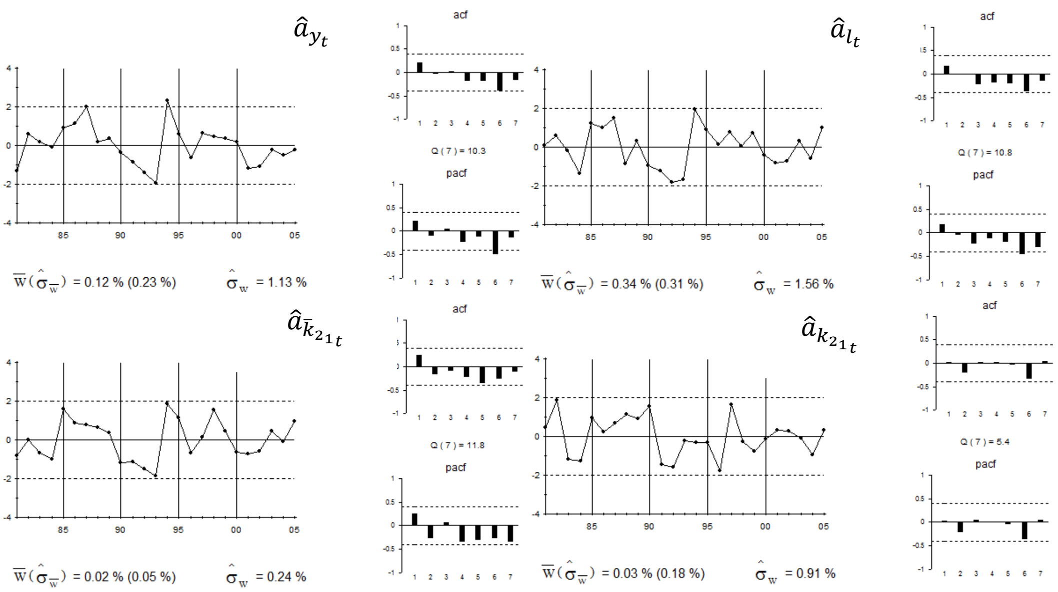


Figure 1. Residual series and their Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions.

Table 7. Cross Correlation residual Function values (CCF). Railway Infrastructure Capital Stock

lags	1,1	1,2	1,3	1,4	2,1	2,2	2,3	2,4	3,1	3,2	3,3	3,4	4,1	4,2	4,3	4,4
1	0.22	0.29	0.27	0.15	0.07	0.18	0.28	0.00	0.21	0.21	0.27	0.00	-0.03	0.12	0.04	-0.01
2	-0.03	-0.01	0.03	-0.15	-0.09	-0.02	-0.03	-0.21	-0.16	-0.08	-0.18	-0.11	-0.15	-0.05	-0.03	-0.11
3	0.02	-0.05	-0.17	-0.15	-0.14	-0.22	-0.35	-0.06	-0.02	-0.01	-0.10	-0.02	0.21	0.12	0.11	0.02
4	-0.18	-0.09	-0.32	0.45	-0.37	-0.17	-0.37	0.41	-0.20	-0.09	-0.24	0.35	0.14	0.30	0.13	0.30
5	-0.19	-0.09	-0.17	0.10	-0.24	-0.21	-0.24	0.01	-0.32	-0.28	-0.37	0.22	-0.27	-0.03	-0.01	-0.20
SD (σ)=0.2																

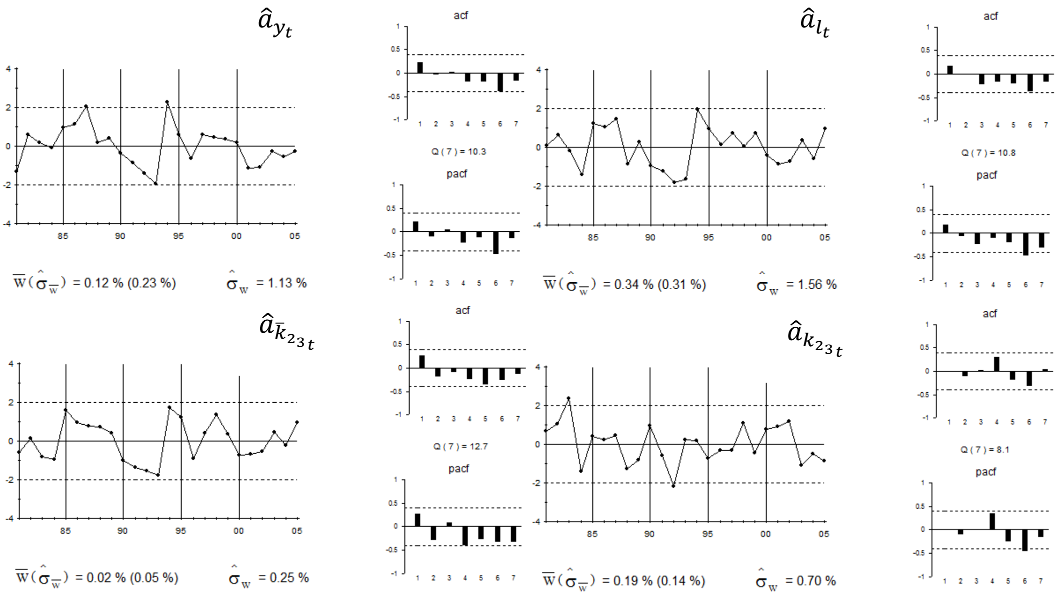


Figure 2. Residual series and their Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions.

Table 8. Cross Correlation residual Function values (CCF). Airport Infrastructure Capital Stock

lags	1,1	1,2	1,3	1,4	2,1	2,2	2,3	2,4	3,1	3,2	3,3	3,4	4,1	4,2	4,3	4,4
1	0.22	0.29	0.28	-0.11	0.07	0.18	0.29	0.03	0.21	0.22	0.28	-0.01	-0.09	0.01	0.07	0.07
2	-0.03	-0.01	0.03	-0.29	-0.11	-0.04	-0.05	-0.15	-0.17	-0.08	-0.18	-0.21	-0.21	-0.27	-0.19	-0.13
3	0.02	-0.04	-0.18	-0.08	-0.15	-0.23	-0.37	-0.11	-0.02	-0.01	-0.10	-0.01	-0.03	-0.09	-0.16	-0.33
4	-0.18	-0.08	-0.30	0.09	-0.36	-0.16	-0.35	0.11	-0.21	-0.08	-0.25	0.23	0.06	0.12	0.08	-0.02
5	-0.19	-0.09	-0.18	0.27	-0.24	-0.20	-0.24	0.24	-0.34	-0.28	-0.37	0.06	-0.11	-0.08	0.05	0.05
SD (σ)=0.2																

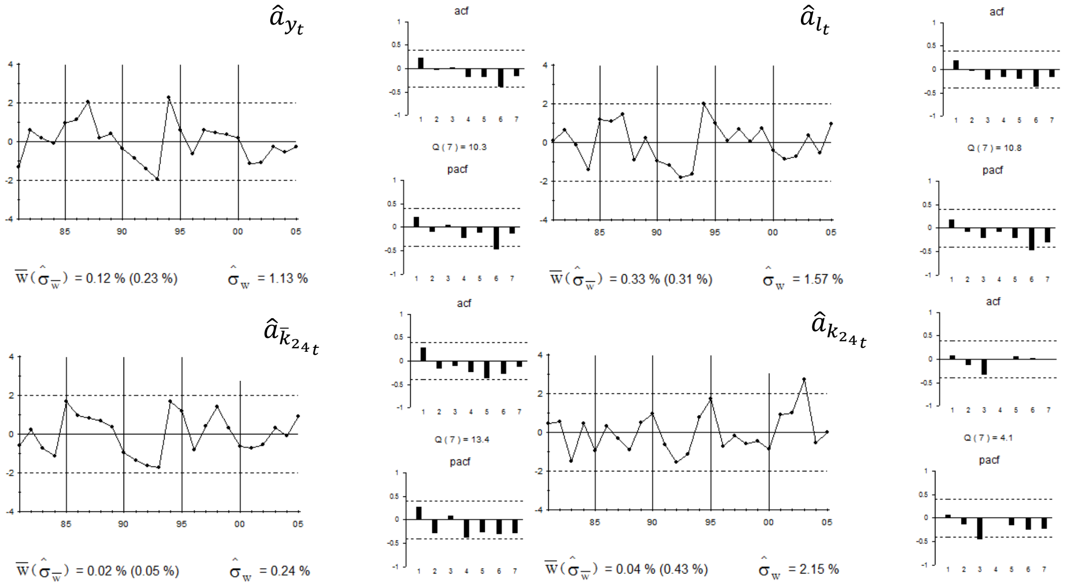


Figure 3. Residual series and their Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions.

Table 9. Cross Correlation residual Function values (CCF). Port Infrastructure Capital Stock

lags	1,1	1,2	1,3	1,4	2,1	2,2	2,3	2,4	3,1	3,2	3,3	3,4	4,1	4,2	4,3	4,4
1	0.22	0.29	0.27	0.25	0.06	0.16	0.26	0.14	0.18	0.19	0.24	0.12	0.11	0.13	0.06	0.04
2	-0.03	-0.01	0.02	0.08	-0.08	-0.01	-0.03	-0.05	-0.16	-0.08	-0.19	0.03	-0.06	-0.16	-0.14	-0.02
3	0.02	-0.05	-0.18	-0.30	-0.13	-0.22	-0.34	-0.26	0.01	-0.02	-0.08	-0.23	0.41	0.48	0.25	-0.12
4	-0.18	-0.10	-0.31	0.24	-0.37	-0.18	-0.36	0.08	-0.20	-0.08	-0.23	0.08	0.02	0.11	0.14	0.23
5	-0.19	-0.09	-0.17	0.12	-0.24	-0.21	-0.23	-0.06	-0.33	-0.28	-0.35	0.12	-0.24	-0.08	-0.05	0.09
SD (σ)=0.2																

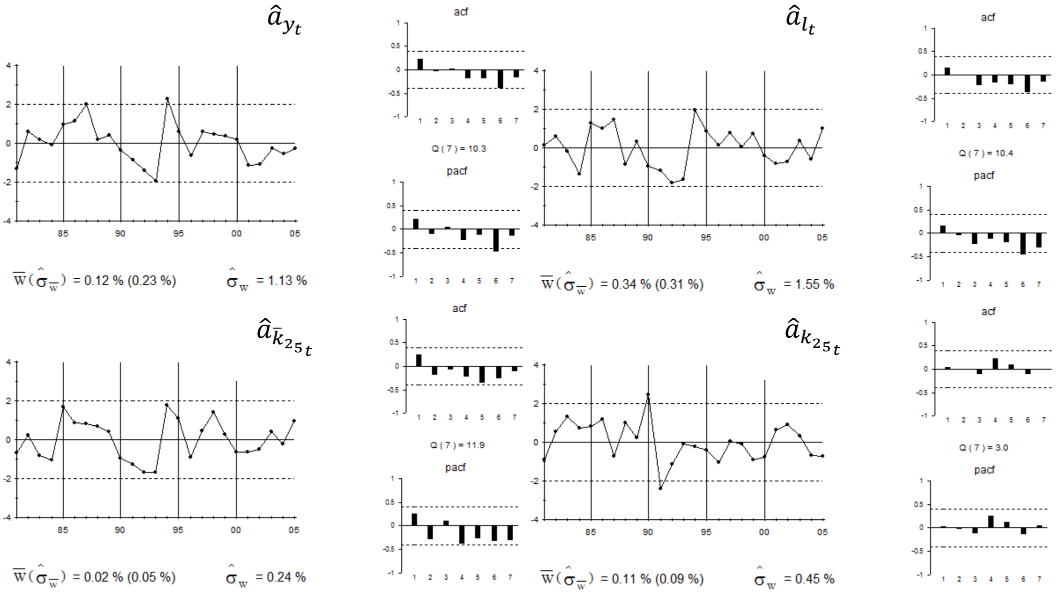
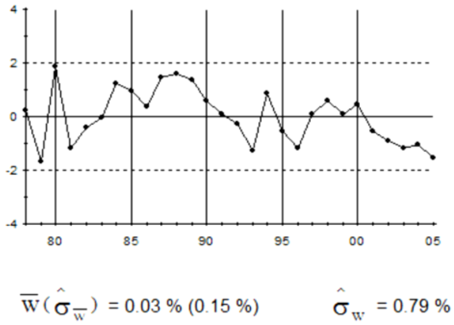
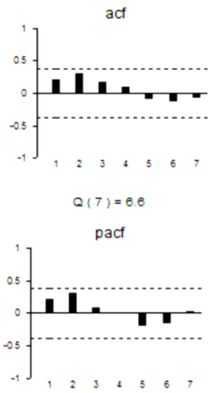


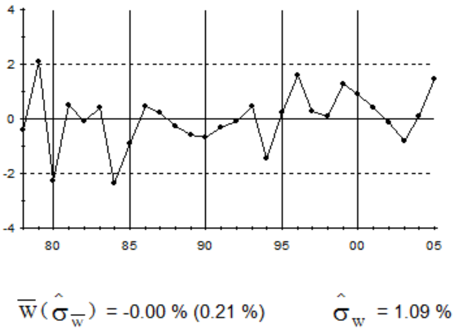
Figure 4. Residual series and their Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions.

$$\xi_{1_t} = y_t - 0.47_{(0.05)} l_t - 0.02_{(0.001)}$$





$$\xi_{2_t} = l_t - 1.39_{(0.15)} y_t - 0.27_{(0.06)} k_{2_{4_t}}$$



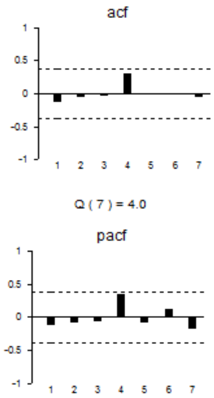


Figure 5. Cointegration Equations

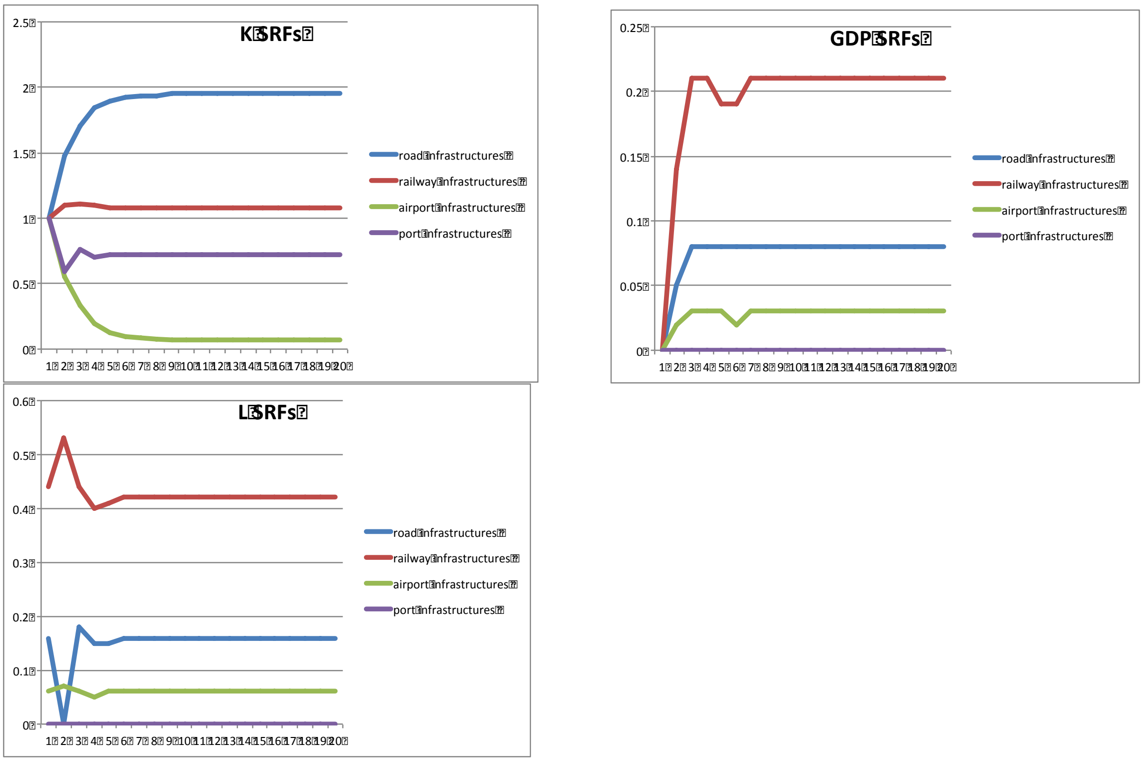


Figure 6. SRF (%) of each variable level to a permanent unitary shock in transportation infrastructures capital stock (road, railways, airport, and port) on GDP, Labor and feedback effects. Notes: SRFs of natural logarithms of each variable. SRFs has been computed adding up IRFs obtained form of model (11) showed in Table 5, as $\Psi^{+}(B) = [\Pi^{+}(B)]^{-1}$(Equation 17) until the referenced period. No effects on complementary capital of any of the transportation infrastructures have been found.