Environmental Impact in Andalusia of the Mediterranean Rail Corridor: An Estimation with a Dynamic CGE.

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Abstract:
Sector of transport is one the most important ones in the economy, but it also implies some cost, as it is responsible for an important amount of gas emissions, which favours the greenhouse effect (GHE) and the climate change. In Spain, the sector of transport produced 25% of total greenhouse sources. Carbon Dioxide (CO₂) is the main responsible of GHE as it represents the 80% of all greenhouse gasses (GHG) emitted, and the sector of transport accounted for the 35% of total CO₂ emitted. In Andalusia, the environmental impact is similar, accounting for 23% of the GHG emissions. From this perspective, the impact of transport is important not only from an economic perspective but also in terms of its environmental impact, but there are differences among them. Therefore, substitution of modes of transport is important to tackle the level of emissions, moreover when there are different modes of transport competing. The transport of cargo is also responsible for an important amount of these emissions, as it
represents more than 30% of all modes of transport’s GHG emissions. This paper measures the long-term environmental impact in Andalusia of the new rail infrastructure known as Mediterranean corridor, that should absorb an important part of the transport of cargo by road from the Port of Algeciras, which is one of the most important ones in Spain. The effect is simulated through the use of a Computational General Equilibrium (CGE) model with a dynamic component and the vector of GHG emissions, and calibrated with the Social Accounting Matrix (SAM) of 2010 of Andalusia with the modes of transport disaggregated. The results show how there is a positive economic impact, but that environmental benefits overcome economical ones, arising the need of assessing also environmental impacts and not only the economical ones.

**Keywords:** Computed General Equilibrium, Transport, Andalusia, Rail, Environmental Impact

**JEL codes:** R11, R40, L92, C68, H54
1. Introduction

One of the relevant sectors in any economy is the sector of transports, due to their weight in the economy, and how it interacts with the rest of sectors. Transport makes also possible the movement of people, what ease the commercial activity of companies beyond the limits of their geographical area of activity. The European Union is therefore favouring the improvement of communications all around Europe, in order to promote the economical development. These infrastructures will have a positive impact in the economy, and will increase incomes due to more affordable transport and reduction of transport cost.

There are some other effects that has also to be considered. One of the is the environmental impact. Better transport infrastructures are likely increase CO₂ emissions, that is the gas that contributes the most to the greenhouse effect (GHE), due to a higher demand of transport. But the operation of modern rail transport infrastructures will likely substitute other transport means with higher emissions rate, what will also help to mitigate greenhouse gasses (GHG) emissions. It is important, therefore, to assess if the aggregate emission levels will be reduced or not.

This study analyses the environment effect of the new Mediterranean Rail Corridor that improves the transport from the Port of Algeciras. It is classified as a primary rail hub for both, the Mediterranean and the Atlantic TEN-T rail corridors of the European Core Network, and it is among Mediterranean and Spanish more important ports.

But not all means of transport have the same impact. Rail is usually the most efficient and less costly ground mean of transport; hence, the improvement of access by train to the center of Spain and the rest of Europe will have an impact in the port’s activity. In addition, this infrastructure can also promote a shift from transport by road to transport by rail. In 2014 roughly 138.000 tons were transported by rail versus 9.500.000 tons by road in the port of Algeciras. The starting up of operations is intended for year 2020. Building works started in 2015, and the cost is partially financed by the European Union through FEDER funds.

This paper is organized as follows. Section two is a short literature review and section three reviews the methodology used in this analysis. In the fourth, the main
characteristics of the dynamic model are explained. Fifth section describes how the impact has been modeled. In section six results are shown and commented. Finally, section seven concludes and summarizes.

2. Literature Review.

The impact of transport infrastructures, and more in detail those related to rail transport, have been widely analysed by scholars and practitioners. It has been assessed very often its impact in the economy, although environmental analysis is also relevant.

Over the last years there has been a predominance of works related to High Speed Train (HST), due to the investment that it requires and its substantial growth in some European countries, such as Spain, and in China.

The economical aspect of transport’s infrastructures is usually studied through different approaches. The most obvious is the cost-benefit, as it is the most widely used when huge investments are required. In this line, De Rus and Nombela (2007) and Carrera-Gómez et al (2006) value the effectiveness of High Speed Train (HST) in Spain, There are also some examples that make use of logit models to compare the impact on demand of new HST lines as those from González-Savignat (2004), Martín and Nombela (2007), Roman et al (2007) and Pagliara et al (2012). In a different line, Castillo-Manzano et al (2015) propose the use of a Dynamic Linear Regression to estimate the substitution effect due to the expansion of the HST network in Spain. But these approached do not take into account the impact in the economic aggregates, due to the interaction between the agents in the economy.

The impact of sector of rail transport in GHG emissions is very important, because it emits less and is more energy efficient than other modes of transport with which it competes, as air transport or transport by road. Hence, environmental impact of transport by rail has been also widely analysed, however, is less common in the literature that economic impact. Nevertheless, there are some good examples that shed light about the positive impact of rail transport. Wee et al (2005) concluded that the average emission of CO₂ from road transport was three times higher than rail transport and Janic (2011) assessed the reduction of GHG when substituting short-haul passengers from aviation to HST.
Both aspects, economic and environmental, have been also analysed with CGE models. These models have been widely used in impact analysis because they take into account intersectoral links, shedding as result the aggregate impact in the economy. For instance, Chen et al (2016) analyses the economic and environmental impact of high-speed train in China on the 2002-2013 period, concluding that rail investment has had an important effect on economic growth and a substantial positive impact in terms of CO$_2$ emissions when demand of road transport is substituted by rail, but minimised by new added emissions due to the induced demand. Bröcker et al (2010) made use of a multi-regional CGE model to analyse the economic impact of the Trans European Network (TEN) and found that welfare impact was modest.

As described before, a significant part of these works is referred to the rail in Spain, but they do not make use of CGE models and do not check the environment aspect. Our approach is different as we make comparisons in terms of impact in main economic aggregates, instead of a Cost-Benefit or a demand split approach. In addition, this work also introduces long term effects with a dynamic model.

3. One Applied General Equilibrium Model

The concept of general equilibrium in the economy was developed at the end of the 19th century by Walras (1874), and later completed by Arrow and Debrew (1954), although CGE models finally gathered momentum with the development of computers at the end of the 20th century. CGE provides a modelling approach that overcomes some of the limitations of lineal models, since it takes into account price effects, elasticities of demand and substitution of products and factors. CGE can furthermore make use of different production functions for each sector, and different utility function for utility-maximizing consumers. The evaluation of the parameters that reflect the behavior of the economic agents is done through data from a Social Accounting Matrix (SAM). A SAM includes data of transactions between the different agents in the economy, and it represents the equilibrium of reference that the CGE model aims to reproduce.

Most of the CGE models developed over the years are static. They are useful to compare the equilibrium ex-ante with the one reached after the simulation of a shock or an economic policy. However, in certain cases it could be useful to have a growth path for the endogenous variables. This is the goal of dynamic CGE models. The most
A popular approach is the growth model of Ramsey (1928) with a representative consumer with infinite lifetime. Ramsey’s model was later on improved by Cass (1965) and Koopmans (1965). However, there are also models based on overlapping generations. Scarf and Hansen (1973) started the use of dynamic CGE models, although Johansen (1974) was the first one to develop a dynamic CGE to depict the Norwegian economy. Harberger (1962) was another early user of dynamic CGE models to show the impact of taxation in an economy with two sectors.

Since the nineties, dynamic CGE models have become more common in the literature. These models have been used to analyze policy issues in disciplines such as taxation, international trade or climate change. A good review of the literature about dynamic-CGE models, including recent applications, can be found in Cardente and Delgado (2015), which is also the most recent application of this family of models to the Andalusian economy.

This work appraises the environmental effect of the Mediterranean Rail Corridor in Andalusian through a CGE model with a dynamic component, to evaluate the effect along several periods of time. A more detailed explanation about the fundamentals are shown in works as those from Srinivision and Whalley (2005), Hosoe, Gasawa and Hashomoto (2010), Burfisher (2011) and Cardenete, Guerra y Sancho (2012).

### 3.1 Static Model

A static general equilibrium model is the basis for the within period equilibrium. This model includes the following actors and markets:

#### 3.1.1. Producers

The production technology is given by a nested production function. In the first level, the overall input $y_i$ is obtained combining domestic $q_i$ and imported $m_i$ outputs according to the Armington (1969) hypothesis, with a Constant Elasticity of Substitution (CES) aggregator:

$$y_j = \left( \mu_{ij} q_j \right)^{\alpha_j} + \left( \mu_{mj} m_j \right)^{\alpha_j} y_j^{1-\alpha_j}$$

(1)
In the second level of the nested technology, the domestic output of a sector is obtained by combining, through a Leontief technology, inputs from the rest of sectors and value-added, with fixed coefficients $a_{ij}$ and $v_i$:

$$q_j = \min \left( \frac{y_{1j}}{a_{1j}}, \frac{y_{2j}}{a_{2j}}, \ldots, \frac{y_{33j}}{a_{33j}}, \frac{V A_j}{v_j} \right) \quad j = 1, 2, \ldots, 33 \tag{2}$$

Where $y_{ij}$ are the quantities of good $i$ available for the manufacturing of domestic good $j$; $a_{ij}$ are the technical coefficients that represent the quantity of goods from sector $i$ that are required for one unit of domestic product $j$. $V A_j$ is the added value, and $v_j$ is the amount of $V A_j$ that is required for the manufacturing of one unit of domestic good $j$.

In the third level, the quantity of value-added for sector $j$ is determined by the aggregation of primary factors labor ($L_j$) and capital ($K_j$) by a CES technology:

$$V A_j = \left[ (\gamma_{Lj} \cdot L_j)^{\theta_L} + (\gamma_{Kj} \cdot K_j)^{\theta_K} \right]^{\frac{1}{\theta_L}} \tag{3}$$

Elasticities have been set to 0.5. It represents a low elasticity but within the range of values usually found in the literature.

All agents, consumers and firms, behave rationally as utility and profit maximizers, and as far as constant returns of scale are assumed for firms, to maximize profits for them is the same than to minimize cost.

3.1.2. Consumers

On the demand side, there is one representative consumer $h$ that demands final consumption $C_j$ of each good $j$, and saving, $S_v$. The objective of the consumer is to maximize a Cobb-Douglas utility aggregator subject to a disposable income constraint, $YDISP_h$, and a price vector $p(p_1, \ldots, p_n)$ for goods and $w(w, r)$ for primary factors, where $w$ and $r$ are the prices of labor and capital.

$$\text{Max } U_h(C_{jh}, S_h) = \left( \prod_{j=1}^{n} C_{jh}^{\frac{\phi}{\theta}} \right)^{\frac{\theta}{\phi}} S_h^\phi \quad j = 1, 2, \ldots, 33 \tag{4}$$

$$s.t. \ YDISP_h = \sum_{j=1}^{n} p_j C_{jh} + pinvS_h$$
\( \chi \) and \( \kappa \) are the coefficients of participation in the consumption of goods and saving and they represent the substitution elasticities. \( p_j \) is the price of good \( j \) and \( p_{inv} \) is the price of the good of investment for consumer \( h \).

Total disposable income is financed by the sale of the primary inputs, labor and capital. The customer also pays taxes; \( ID \) is the tax rate on consumer’s income and \( CO \) is the employee’s contribution to the social security. He receives lump transfers from the government, consumes public goods \( TSM \) and also receives transferences from the rest of the world \( TRM \). Disposable income for consumption is gross income minus taxes,

\[
Y_{DISP} = wL + rK + ipcTSP + TRM - ID(rK + ipcTSP + TRM + wL) - CO \cdot wL \tag{5}
\]

Whereas \( w \) and \( r \) are the prices of the primary factors, labor and capital, and \( ipc \) is the consumer price index.

Rearranging:

\[
Y_{DISP} = (1 - ID)(rK + ipcTSP + TRM) + (1 - ID - CO)wL \tag{6}
\]

### 3.1.3. Government

The government is a special agent in the economy that taxes exchanges between the rest of agents to get resources. With them, the government finances its activity. On the other hand, it also transfers resources to the private sector through consumption of goods and services. The difference between income and expenses will determine the deficit.

\( RIP \) is the collection of indirect taxation to the productive activity, including VAT, where \( \tau \) denotes the tax rate on production of sector \( j \)

\[
RIP = \sum_{j=1}^{n} \frac{\tau_j}{1 + \tau_j} \cdot y_j p_j \tag{7}
\]

The government taxes labor in two different ways. One way is through the employer’s contribution to the social security, denoted as \( RP \), where \( CP_j \) is the rate of employer’s contribution to the social security in sector \( j \).

\[
RP = \sum_{j=1}^{n} CP_j w \cdot l_j \tag{8}
\]
Second one is the employee’s contribution denoted as $RO$. As there is only one representative consumer, $RO$ is defined as follows:

$$RO = CO \cdot w \cdot L$$ \hfill (9)

Tariff for imports has not been considered because most of them come from the rest of Spain and the UE.

The government also obtains resources from the direct taxation on consumer’s income.

$$RD = ID(w \cdot L + r \cdot K + ipc \cdot TSP + TRM )$$ \hfill (10)

The total collection of taxes by the government is thus:

$$R = RIP + RO + RP + RD$$ \hfill (11)

In our model, the demand of the public sector is kept as steady, and denoted as $DC_j$. The government deficit $D$ is consequently endogenously determined as follows:

$$D = -R + TSP \cdot ipc + \sum_{j=1}^{n} DC_j \cdot p_j$$ \hfill (12)

### 3.1.4 External Sector

The Andalusian economy is very small compared with the rest of the world, therefore, the demand level of the foreign sector is assumed to be exogenously given, not being influenced by domestic variables. Additionally, imports are considered as imperfect substitutes for domestic production, following the Armington hypothesis (1969). As a result, imports are endogenously determined, and external deficit $F$ is consequently endogenously determined also.

$$F = prm \sum_{j=1}^{33} m_j - TRM - prm \sum_{j=1}^{33} EXP \quad j = 1, 2, ..., 33$$ \hfill (13)

Where $prm$ is the weighed averaged price of the international market, $EXP_j$ is the external demand of goods from sector $j$, and $m_j$ the imported goods of sector $j$.

### 3.1.5 Saving and Investment

This is a savings driven model, so the level of investment is endogenously determined by savings, which is also endogenously defined by the preferences of consumers and the deficits of public and external sectors, according to the following equation where $INV_j$ is the level of investment.
\[ pinv \sum_{j=1}^{n} INV_j = S \quad pinv - D + F \]  

(14)

3.1.6. Prices

Prices are endogenous in the model and they are made up taking into account production and prices of goods and primary factors. There is an internal price \( p_i \) of the locally produced good \( i \) as defined in expression (15) where \( p\text{val}_i \) denotes the price index for added value used in sector \( i \), under zero-profit condition. There is also a final price \( p_i \) that also take into account the participation of imported goods in the production of final products and indirect taxation \( \tau \) to production, as we can see in Equation (16). In this expression \( \xi_i \) and \( \zeta_i \) represent, respectively, the participation of locally produced and imported good in the final product.

\[ p_i = p\text{val}_i \cdot \nu_i + \sum_{j=1}^{n} p_j \cdot a_{ij} \]  

(15)

\[ p_i = \left( 1 + \tau_i \right) \left( \xi_i \cdot p_i + \zeta_i \cdot prm \right) \]  

(16)

3.1.7. Labor Market

Labor market behavior is imposed by assuming that the real wage is sensitive to the unemployment rate. It is related to the power of unions, or any other socioeconomic factors inducing frictions and rigidities in the labor market. The idea behind the proposed formulation is that of a wage curve (Blanchflower and Oswald, 1990, 1994) that captures the relationship between the real wage \( (w_i / (p \cdot \gamma)) \) and the unemployment rate \( u \) through a parameter \( \beta \).

This model follows the implementation of Kehoe et al. (1995), based on the use of the elasticity of the real wage relative to the unemployment rate:

\[ \bar{w} = \left( \frac{1 - u}{1 - \bar{u}} \right)^{\frac{1}{\beta}} \]  

(17)

where \( \bar{w} \) is the real wage rate and \( \bar{u} \) is the benchmark unemployment rate. Salaries are rigid when \( \beta \) is large, and salaries are more flexible when \( \beta \) is decreasing.
3.1.8. Model Resolution

Due to the Walras’ law, one equation is redundant. For this reason, one of the prices has to be chosen as numéraire and results are referred to it. In this case, the net price of labor has been chosen as numéraire.

The economic structure of the model is translated to a nonlinear system of equations. The equilibrium is reached when the consumers maximize their utility and firms their benefits. In addition, the government redistributes among the different actors in the economy. All markets also reach their equilibrium; at each market of factors and goods demand equals supply.

GAMS software module computes the benchmark equilibrium and uses it as an internal basis for subsequent simulation. This guarantees very fast compilation and execution time and, in practice, yields convergence in all cases.

3.1.9. The Database

SAM is an extension of IO tables (Leontief, 1941, 1951), first developed by Stone (1964), and it gives a detailed account of interindustry transactions in an equilibrium setup in which total supply matches the sum of intermediate and final demand. Once the model is established, all parameters in the model need to be calibrated to reproduce such equilibrium. This model uses as reference the SAM of the Andalusian economy for 2010 assembled by Cardenet, Fuentes, Mainar and Delgado (2011) with the sectors of transport disaggregated (Cardenete and López, 2014). It includes 33 productive sectors: the 25 original ones where the sector of transport has been split in 8 sectors of transport plus the annexed services to the transport. It also includes two primary factors (labor and capital), a capital account (savings and investment), a private consumption account, a foreign sector, a government account that collects the taxation, one indirect tax to production, a direct taxation to the next income, and taxation to the labor. The matrix structure is such that for each sector the sum by columns equals the sum by rows.

3.2. Dynamic Model. The growth model of Ramsey

There are different approaches to develop a Dynamic-CGE. The growth model of Ramsey (1928), later improved by Cass (1965) and Koopmans (1965), is the most
widely used in the literature. The model behaves in a different way depending on whether the economy is in a steady state or not. The steady state is the one where the economic aggregates such as capital, Gross Domestic Product (GDP) or investment grow at a constant rate. The analysis of Ramsey’s model starts with the data of the base period of an economy in a steady state. The representative consumer maximizes the present value of their utility along his lifetime.

\[
Max \sum_{t=0}^{T} \left( \frac{1}{1+\rho} \right)^t U(C_t)
\]

(18)

t represents the periods of time. The lifetime of the consumer is \( T \) periods. \( \rho \) is the discount factor between periods, \( U \) is the utility function and \( C_t \) is the consumption in period \( t \). The total production in the economy is dedicated to investment \( I_t \) and consumption \( C_t \). There is also a capital depreciation rate denoted as \( \delta \). Finally, the investment cannot be negative. These restrictions are written as follows:

\[
C_t \leq F(K_t, L_t) - I_t,
\]

(19)
\[
K_{t+1} = K_t(1-\delta) + I_t,
\]

(20)
\[
I_t \geq 0
\]

(21)

\( K \) is the capital and \( F \) is the function of production. The solution to the maximization problem subject to these restrictions is gathered in the following equations:

\[
P_t = \left( \frac{1}{1+\rho} \right)^{t} \frac{\partial U(C_t)}{\partial C_t}
\]

(22)
\[
PK_t = (1-\delta)PK_{t+1} + P_t \frac{\partial F(K_t, L_t)}{\partial K_t}
\]

(23)
\[
P_t = PK_{t+1}
\]

(24)

\( P_t, PK_t \) and \( PK_{t+1} \) are the Lagrange multipliers of the maximization problem. These can be interpreted as the price of the product, the price of today’s capital and the price of tomorrow’s capital.

One of the objectives is to determine the value of investment in the steady state, but capital and labor have to be established first. We assume that growth rate is \( g \).
depreciation rate is \( \delta \) and interest rate is \( r \), and all them are known. Initial labor force \( L_0 \) is also known, therefore labor force at any time \( t \) is as follows:

\[
L_t = (1 + g)L_{t-1} \tag{25}
\]

\[
L_t = (1 + g)L_0 \tag{26}
\]

In a steady state economy, all the quantities of capital, output, labor and consumption grow at the same steady rate \( g \). Therefore, the growth path of capital follows the next rule:

\[
K_{t+1} = (1 + g)K_t \tag{27}
\]

Interest rate \( r \) is fixed. If future prices are represented in present value, then:

\[
P_{t+1} = \frac{P_t}{1 + r} \tag{28}
\]

Capital can be rented or purchased. There are therefore two prices of capital, purchase price, \( PK \), and rental price, \( RK \). If \( VK \) is the total return of capital, rental price can be written as follows:

\[
VK_t = K_tRK_t \tag{29}
\]

First order conditions from the maximization problem can be used to define the growing path of investment and capital levels in the steady state economy. These conditions can be re-written:

\[
PK_t = (1 - \delta)PK_{t+1} + RK_t \tag{30}
\]

\[
PK_{t+1} = P \Rightarrow PK_t = (1 + r)P \tag{31}
\]

Equation (31) can be used to substitute \( PK_{t+1} \) and \( PK_t \) in equation (30). It can be thus rewritten as:

\[
(1 + r)P_t = (1 - \delta)P_t + RK_t \tag{32}
\]

Renting price of capital is:

\[
RK_t = (r + \delta)P_t \tag{33}
\]

Investment is obtained from the second restriction of the maximization problem (20) and the growing path of capital. Investment is consequently given by the following equation:
\[ I_t = (\delta + g)K_t \]  

(34)

This expression is the base for the investment rule in the steady state growth model, but in Ramsey’s model, investment can be also referred to initial capital attending to the grow path:

\[ I_t = (\delta + g)(1 + t)K_0 \]  

(35)

CGE models are calibrated with the information in IO tables or SAM. Data available will be then total return of capital in the base period, VK0. Equations (29), (33) and (34) referred to the basic period give us the relation between investment and return of capital in the base period:

\[ I_0 = \frac{g + \delta}{\delta + r}VK_0 \]  

(36)

From Equations (20) and (27) the investment rule is:

\[ I_t = (\delta + g_{t+1})K_t \]  

(37)

Growth rule for capital stock is Equation (27):

\[ K_t = (1 + g_t)K_{t-1} \]  

(38)

And capital stock in the basis period is obtained from Equations (29) and (33):

\[ K_0 = \frac{VK_0}{\delta + r_0} \]  

(39)

Ramsey’s model has been introduced in the dynamic CGE model through Equations (37), (38) and (39)

In the static model, investment (I) is calculated as the sum of household saving (S_h), government (D) and external (F)deficit, therefore I is well established once S_h, D and F are also defined. All these variables are endogenously determined in the model, so an additional degree of freedom has to be added to the model. Household saving (S_h) is defined through the utility function of the consumers. Government deficit (D) is the difference between government income obtained through taxes, that is endogenously determined in the model, and government expenditure, that is an exogenous variable. External deficit (F) is the variation between imports (M), that are endogenously determined in the model, and exports, that are exogenously defined. Government
expenditure and imports are the only variables that can be added as new degrees of freedom. Government expenditures are quasi-fix, as a consequence, if a level of investment is required and household savings and government deficit are not enough, external sector will fulfill the required level of investment through external deficit. As imports are endogenously defined, exports will be also; they are thus endogenously determined in the dynamic CGE model, in contrast to the static CGE.

3.3 Environmental Impact in the Model.

The valuation of the of the environmental impact of the new Mediterranean Rail Corridor is done with the CO₂ emissions factor by output level. CO₂ emission factor is defined as follows:

\[ YE_i = \frac{E_i}{Y_i} \]  

(40)

Where \( E_i \) denotes CO₂ emissions of sector \( i \) and \( Y_i \) represents the total output of sector \( i \). \( YE_i \) has been estimated with data of year 2010 from the Spanish Institute of Statistics (INE)\(^1\) and from the Andalusian Institute of Statistics (IGEA)\(^2\) when possible. Due to the level of disaggregation of the sectorial accounts, data for transport of cargo by road and by train has been estimated with data from previous works (Monzón et al, 2010), that establishes emission levels of 136,3 gCO₂/Ton-Km for transport of cargo by road and 28,8 gCO₂/Ton-Km by rail. The aggregation of GHG emissions from all sectors matched with the total emissions of productive sectors in Andalusia in 2010, that is taken as the year of reference.

4 Shaping the Shock and Alternative Scenarios

4.1. Shock in the Model

Transport is one of the main sources of GHG. In Andalucía it represents the 24% of total emissions. CO₂ represent the main part of these emissions, up to an 80% in 2010\(^2\). One of the advantages of rail transport is that it more energy-efficient than transport by road; if there is substitution effect, we expect that there are also a reduction

\(^1\) Spanish Institute of Statistics (INE) Accounts of emission to the atmosphere by branches of activity, 2010
\(^2\) Andalusian Institute of Statistics (IGEA) Pollutant emission to the atmosphere in Andalusia for sectors of activity, 2010
on emissions. Rail is also more efficient in the use of resources, and has better multiplier effect than transport by road, there is thus a second effect that leads to an increase on emissions due to an additional growth of the economy, even if there is not a net increase on the transport demand.

To have a better view about these two effects, the shock is modeled in two ways. First, as an increase of exports in the sector of transport of cargo by train, and hence as a decrease in exports of sector of transport of cargo by road. In this case, the shock is neutral from the point of view of the quantity of transported goods. There is only a shift from a mode of transport to another. The second way of modeling the shock is through an increase of the transport by train, but without reducing the amount transported by road. The shock assumes an increase on goods transported by ground.

This effect has been modeled in equations of production. The expressions that define the total output have been modified to change external demand in different periods of time. It has been defined a new parameter that defines the change of the demand of the external sector. For each sector, this change has been defined in terms of total output of the previous period.

\[ \Delta D_{ex, t} = y_j \cdot \delta_t \] (41)

For each sector \( \delta_t \) is the parameter that defines the increase (or decrease) of external demand in terms of total output in the previous period of time. This parameter is null except for the sectors of transport of cargo by train and by road. The values of these parameters are defined afterwards. This change on the external demand is included in the equation of the total output as an increase of exports.

\[ Y_j = INV_j + DC_j + \sum_n C_{jk} + \sum_i a_{ij} \cdot q_i + EXP_j + \Delta D_{ex, j} \] (42)

4.2. Modelling the Impact of the Rail Infrastructure

In year 2014, the share of load carried by train was negligible, but in Europe the weight of rail transport in the entry/exit of cargo to/from ports is around 20%. Where this weight is not reached, is due to the relative importance of inner waterway, such as Rotterdam or Antwerp, or the lack of appropriate infrastructure, such as Valencia that is also pushing for an European rail corridor (Enrico Pastori, 2015). We assume a 20% weight of rail transport in the port of Algeciras. It will be reached after three two-years
periods of time (six years), from the entry into service of the rail infrastructure. It is supposed that the rail infrastructure starts to operate in year 2016.

First simulation assumes the substitution of trucks by rail transport, without any increase of traffic due to the more efficient connections of the port with its hinterland. Second simulation is based on a net increase of transport by train, keeping steady the amount transported by road.

Transport services rendered by non-residents fall on the imported goods exclusively (MIOAN-2010\(^3\)). In the same way, the transport services linked to exports are provided by resident transport units. Following this criterion and also in line with the valuation criteria of Eurostat, transport of goods “in transit” carried out by resident units is considered as export of services.

To define the dynamic model based on Ramsey’s growth model it is necessary a growth path. Table 1 shows this data for basis year 2010, up to year 2014. Table 2 shows estimations and projections (2015 and onwards). Finally, table 3 summarizes the parameters used to simulate the growth path in the six two-years periods of time.

Table 1. Economic data for Andalusia (2010-2014)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP deflator</td>
<td>BdE</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.7%</td>
<td>-0.5%</td>
</tr>
<tr>
<td>Real GDP</td>
<td>IGEA</td>
<td>-3.5%</td>
<td>-1.0%</td>
<td>-1.3%</td>
<td>-3.0%</td>
<td>-1.6%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Rate of capital depreciation</td>
<td>Literature*</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>10 year bond’s yield</td>
<td>INE</td>
<td>3.8%</td>
<td>5.4%</td>
<td>5.5%</td>
<td>5.3%</td>
<td>4.1%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>Estimated</td>
<td>3.5%</td>
<td>5.2%</td>
<td>5.4%</td>
<td>5.1%</td>
<td>3.4%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>various**</td>
<td>3.2%</td>
<td>2.7%</td>
<td>2.4%</td>
<td>2.4%</td>
<td>2.4%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Rate of capital depreciation</td>
<td>Literature*</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>Various***</td>
<td>1.3%</td>
<td>1.4%</td>
<td>1.1%</td>
<td>1.1%</td>
<td>1.1%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Bde: Bank of Spain. GDP deflators, consumer and industrial prices
IGEA: Andalusian Institute of Statistics. Yearly Regional Accounting of Andalusia
INE: Spanish Institute of Statistics. Long term interest rates (Bonds 10 Yr)
*Denia, Gallego and Mauleón. 1996

Table 2. Economic data for Andalusia. Estimations 2015-2020

Various**: BdE (Feb 2016) and UE Winter 2016 Economic Forecast
Various***: BdE. Stability Plan 2015-2018
*Denia, Gallego and Mauleón. 1996

\(^3\) Andalusian Institute of Statistics (IGEA), 2010 Input-Output Methodology
Table 3. Parameters defining the growing path of Ramsey’s model.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>-4,3%</td>
<td>-0,2%</td>
<td>6,0%</td>
<td>4,9%</td>
<td>4,9%</td>
<td>4,9%</td>
</tr>
<tr>
<td>Rate of capital depreciation</td>
<td>10,3%</td>
<td>10,3%</td>
<td>10,3%</td>
<td>10,3%</td>
<td>10,3%</td>
<td>10,3%</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>10,8%</td>
<td>5,8%</td>
<td>2,7%</td>
<td>2,2%</td>
<td>2,2%</td>
<td>2,2%</td>
</tr>
</tbody>
</table>

Source: Own Elaboration.

4.3. Simulation Without Traffic Increase.

20% of rail transport in the port of Algeciras means 1.908.562 tons transported by train (Port of Algeciras, 2015). Roughly half of this quantity is entry and the other half is exit. The hypothesis is that cargo in transit is considered as export if it exits from the region; therefore, exports of the sector of transport by train increase in 954.281 tons. In terms of tons, it represents about a 106% increase of the final demand of transport of cargo by train in Andalusia, that is accounted as exports4. Cargo shifts from transport by truck to transport by train, consequently, the demand of transport by truck decreases, and it is calculated in terms of tons-kilometer. The increase of demand of transport by train means about a 2,34% decrease of demand of transport by truck. Table 4 summarizes the values that will be introduced in the model for each scenario.

Table 4. Modal split forecast in the port of Algeciras.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of transported loads by train over the total</td>
<td>6,3%</td>
<td>12,9%</td>
<td>20,0%</td>
</tr>
<tr>
<td>Increase over the total transported loads by train (As exports)</td>
<td>27,2%</td>
<td>61,9%</td>
<td>106,0%</td>
</tr>
<tr>
<td>Decrease over the total transported loads by road (As exports)</td>
<td>-0,8%</td>
<td>-1,6%</td>
<td>-2,3%</td>
</tr>
</tbody>
</table>

Source: Own Elaboration.

4.4. Simulation with Traffic Increase.

Due to the high amount of transshipment in the port of Algeciras, there is room

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Observatorio del Transporte y la Logística en España (OTLE), *Annual Report* 2015.
for increasing transport by train, not only as a shift from transport by road, but as a net increase. This increase can be originated by a shift from transshipment or also by an increase on the overall traffic in the port.

In this case, the share is reached without any reduction on the amount of cargo transported by road. A share of 20%, keeping steady the amount transported by road, means a 116% increase in the overall transported goods by train. This increase will be managed as exports. Table 5 shows the parameters that define the shock for each of the simulations and each of the three scenarios.

Table 5. Change of ground traffic by road and by rail. Andalusia.

| Share of transported loads by train over the total | 6.3% | 12.9% | 20.0% |
| Increase over the total transported loads by train (As exports) | 27.2% | 61.9% | 106.0% |
| Decrease over the total transported loads by road (As exports) | -0.8% | -1.6% | -2.3% |

Source: Own Elaboration.

5 Simulations and Main Results

5.1. Impact of The Rail Infrastructure Without Traffic Increase

The model has been also used to draw up the results previous to the shock. Results with and without the sock are used to compare the effect of the new rail infrastructure. First shock is designed to be neutral on the quantity of transported goods from the port of Algeciras, as ton-kilometer. Results are shown in table 6, and shows how the shift from road to train increases production in Andalusia, even if there is not an increase in the traffic of ground transport from the port of Algeciras.

Table 6. Impact of rail infrastructure on GHG emissions in Andalusia.

<table>
<thead>
<tr>
<th>In Equivalent Tons of CO₂</th>
<th>In % relative to Base Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Economy</td>
<td>1525</td>
</tr>
<tr>
<td>Road</td>
<td>-33922</td>
</tr>
<tr>
<td>Rail</td>
<td>7953</td>
</tr>
<tr>
<td>Ground Transport</td>
<td>-25969</td>
</tr>
<tr>
<td>Total Output</td>
<td>0.006%</td>
</tr>
<tr>
<td>GDP</td>
<td>-0.0003%</td>
</tr>
</tbody>
</table>

Source: Own Elaboration.
Environmental impact is measured in terms of equivalent tons of CO₂ emitted, and just as expected, the substitution of transport by road decreases GHG emission as rail transport is less emission intensive. The reduction in emissions accounts for 78,000 equivalent tons of CO₂ at the end of the period, equivalent to more than two times the increase due to transport by rail from the port of Algeciras. But, although there is an increase of productive activity due to the shift of transport by road to transport by rail due to the higher multiplier effect, the total GHG emitted is also reduced. It is a consequence of the weight of sector of transport in total GHG emissions. They are reduced in more than 50,000 equivalent tons of CO₂, less than the reduction in ground transport as a consequence of the increase of other sectors. An 1.5% reduction in GHG of ground transport has an effect of a 0.1% reduction in the whole economy.

We conclude that the shift of transport by road to transport by rail that the Mediterranean Corridor enables has a positive environmental impact in Andalusia, even with an increase in the total output.

### 5.2. Impact of The Rail Infrastructure with Traffic Increase

Here after Table 7 shows results when the growth of transport by train is reached through an increase on traffic by train, but not impacting traffic by road.

<table>
<thead>
<tr>
<th></th>
<th>In Equivalent Tons of CO₂</th>
<th>In % relative to Base Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 4</td>
<td>Period 5</td>
</tr>
<tr>
<td>Whole Economy</td>
<td>8398</td>
<td>20274</td>
</tr>
<tr>
<td>Road</td>
<td>-253</td>
<td>-616</td>
</tr>
<tr>
<td>Rail</td>
<td>8569</td>
<td>20781</td>
</tr>
<tr>
<td>Ground Transport</td>
<td>8316</td>
<td>20165</td>
</tr>
<tr>
<td>Total Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Own Elaboration.*

In this simulation there is reduction in total output, as a consequence of the additional resources required by rail transport that are taken from other sectors that adapt their production to the new equilibrium. However, there is an increase in GDP, as it avoids double accounting of intermediate consumption. GHG emissions increase due to the additional activity of rail transport that is not compensated by a reduction in
transport by road. This increase is the main contribution to total increase in Andalusia, although there is a GDP increase.

6 Conclusions

This paper assesses the environmental impact in Andalusia of the Mediterranean Rail corridor that impacts the transport of cargo from the Port of Algeciras. The impact is assessed in terms of GHG emitted through a dynamic-CGE. The results are based on the assumption that rail transport reaches a share of 20% in the ground transport from the Port of Algeciras.

The effect appraised does not take into account the impact of the construction of the infrastructure (short term impact), but the operation of the new infrastructure (long term effects). This study investigates the environmental implications of the substitution of two ground modes of transport, that is not very common in the literature but has huge implications.

The new rail corridor offers a case of study to apply CGE to deep dive into the environmental impact of this infrastructure and to give an answer to the question about the environmental impact of rail.

Any change in the modes of transport will likely impact GHG emissions, as sector of transport is the source of 25% of them (MAPAMA, 2017). One case that is very attractive is when rail transport competed with transport by road, as its emissions are much lower than transport by road. This study also appraises the global effect of all sectors, as it takes into account the intersectoral linkages, that are very important as the impact of different modes in the economy is not the same. This work also analyses the impact when rail transport substitutes transport by road.

This analysis concludes that the impact of the Mediterranean rail corridor has a positive environmental impact in Andalusia. The impact in emissions from sector of transport of cargo is about 78,000 equivalent tons of CO\textsubscript{2}, but this amount is minimized by the increase in the productive activity. The impact in total emissions when rail substitutes transport by road in more than 50,000 equivalent tons of CO\textsubscript{2}, although the is an increase in the productive activity. This amount means an 0.1% reduction.
When the 20% share is reached only by increasing rail transport, emissions are thus increased in the amount emitted by it.

But this analysis has some room for improvement. The model can be improved with better estimation of the parameters that define the behavior of the agents in the economy. Data of emission can be also defined more in detail, as some sectors in Andalusia have not components with the same weight in the aggregation than in Spain.

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