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Economic and environmental impact of the new Mediterranean Rail Corridor in Andalusia: A dynamic CGE approach

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A B S T R A C T

Transport is one the most important sectors 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 climate change. In Spain, the sector of transport represents the 25% of total greenhouse sources. From this perspective, the impact of transport is important not only from an economic perspective but also in terms of its environmental impact. 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. The objective of this paper is to apprise the long-term environmental and economic impact in Andalusia of the new rail infrastructure known as Mediterranean Corridor. It will absorb an important part of the transport of cargo by road from the Port of Algeciras, which is one of the most important in Spain and an important node of this rail corridor. The effect is simulated through the use of a Computational General Equilibrium (CGE) model with a dynamic component, the vector of GHG emissions and calibrated with the Social Accounting Matrix (SAM) of 2013 of Andalusia with the modes of transport disaggregated. The results show how positive is the economic impact of this infrastructure, but also how environmental benefits outweigh economic ones, arising the need of assessing also environmental impacts and not only the economic ones.

1. Introduction

One of the relevant sectors in the economy is the transport, due to its weight, and how it interacts with the rest of sectors. Transport makes also possible the movement of people and goods, what eases the commercial activity of companies beyond the limits of their geographical area of activity. From this perspective, the European Union is favouring the improvement of communications all around Europe, and in this network the port of Algeciras is an important node. 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. European Union (EU) White Paper 2011 moreover set as objective a 30% mode shift from road to others, such as rail and waterborne transport, for distances over 300 Km.

Due to the high investment that this infrastructure requires, it is of the highest interest to policy makers to have a rational basis for decision making, which provides them with qualitative valuation of its impact in the economy. However, there are some other effects that need also to be considered. One of them is the environmental impact. Better transport infrastructures might increase CO_2 emissions, due to a higher demand of transport. But the operation of modern rail infrastructures will likely substitute other transport means with higher emissions, helping to reduce greenhouse gasses (GHG) emissions.

In the literature there are examples of papers assessing the market share that rail can secure in competition with road. EU in one of its published documents (Freight on Road: Why EU Shippers Prefer Truck to Train, 2015) collects several studies assessing and quantifying the opportunities for rail transport to secure market share in competition with road. It goes without saying that the shift will depend largely on shipper's preferences like punctuality and speed, let alone the cost, although it is out of question that the potential for a shift is higher above a threshold of 300 Km where rail is more competitive than road. This EU document also includes data from a survey carried out by the Zaragoza Chamber of Commerce (2010) in Spain, which may show evidence of how Spanish shippers would prefer rail over road if the rail infrastructure would be more widely accessible (among some others).

This paper apprises the impact of a modal shift from road to rail, as a consequence of the new Mediterranean Rail Corridor. To this end, the

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port of Algeciras has been considered as the main source feeding this rail corridor in Andalusia. The expected share of goods transported by rail in the port of Algeciras have been assessed with data from comparable ports in Europe. Thanks to this new rail infrastructure, the port of Algeciras will compete against akin ports in Europe, like Rotterdam, Bremen or Hamburg. Enrico Pastori (2015) offer a clear view about the participation of this mode in transport at European ports, pointing out its relevant weight at major European ports, ranging from 10% to 40%, with a mean value of about 20%. This information has been also taken into account to define the scenarios in the sensibility analysis (see chapter 5.3).

It is also important to highlight that by nature, the vast majority of goods to be transported will be for large distance well above 300 Km to other European destinations, what eases the shift from road to rail according to the specialized literature.

For long distances, rail is more efficient and the less costly than transport by road or by air. In 2017 in Spain the cost of transport by road was above 5,0 cents per ton-km (Transport by Road Cost Observatory, 2018) versus less than 2,7 of rail transport (Transport and Logistic Observatory, 2019); hence, the improvement of the access by train to the rest of Spain and Europe will impact the port's activity, and it is expected that this infrastructure will promote a shift of freighting from road to rail. In the port of Algeciras, roughly 87.000 tons were transported by rail versus 11.900.000 tons by road in 2016 (Port of Algeciras (Port Authority), 2017.). Building works started in 2015 and the start up of operations is intended for year 2020, although the infrastructure will not be fully operative up to year 2025. The cost is partially financed by the European Union through FEDER funds.

This paper is organized as follows. Section two reviews the literature about economic and environmental impact of rail infrastructures. Section 3 explains the main characteristics of the dynamic model. Section 4 describes how the impact has been modelled. Results are set out and commented in section 5. Finally, section 6 concludes and summarizes.

2. Literature review

The impact of transport's infrastructures, and more particularly 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.

The economic 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 a huge investment is 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 approaches 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 has lower emissions and is more energy efficient than other modes of transport with which it competes, as transport by air or by road. Hence, environmental impact of transport by rail has been also widely analysed, however, it is less common than 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 CO_2 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 because they take into account intersectoral links, shedding as result the aggregate impact in the economy.

Main CGE characteristic is that they simulate the entire economy by depicting with mathematical expressions the supply and demand of every market, as functions of all processes across the economy. CGE models also simulate the behavior of main actors in the economy, households that are utility maximisers, and firms which are profit maximisers.

We can find in the literature good examples of papers that try to tackle similar issues about transport with CGE models. Robson et al. (2018) presents a detailed description of the different types of CGEs that have been developed to assess the economic impact of transport.

There are Urban CGE models that study the impact of transport in urban areas, such as the economic impact of speed limits in an "average" German city (Nitzsche and Tscharaktschiew, 2013) or to model issues such as fuel prices increase or rail investment growth (Anas, 2013). These models try to reproduce the microeconomic behaviour of markets and agents which are relevant for the urban area, and dismiss some others such as the government or the external markets.

Another group of models is comprised of those reproducing a set of areas larger than urban agglomerations. These models dismiss the urban issues that are less significant at regional scale, and they place more emphasis on macroeconomics behaviour. These areas can be as large as an entire country, and interregional trade flows are typically modelled with gravity equations. Some models adopt the Armington (1969) assumption that stablishes that commodities produced in one region can be treated as imperfect substitutes of those produced in other region. Now these models link the transport cost to the physical movement of goods. In this line Dakila and Mizokami (2007) determined the best modes to invest in Philippines, by applying a shock to the sector of transport, and Bröcker et al. (2010) made use of a multi-regional CGE model to analyze the economic impact of the Trans European Network (TEN) and found that welfare impact was modest. In some cases the practitioners are focused on the externalities of transport, such as congestion, therefore some additional constrains should be added to the production and utility functions, like a congestion index or household time constrains. In this line Mayers (2000) assessed the impact in congestion, among other externalities, of different tax alternatives through a time allocation constrain, concluding that peak road pricing is more preferred than fuel tax to tackle congestion. Finally, there are also non-spatial models which have been also applied to transport issues. For instance, Chen et al. (2016) analyses the economic and environmental impact of HST in China over the 2002–2013 period with a non-spatial CGE, concluding that rail investment 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, although minimized by new added emissions due to the induced demand.

The model used in this paper belongs to the non-spatial type, although it has somehow a spatial component since it adopts the Armington assumption, with an external sector that supplies goods and services from abroad. A spatial CGE has not been rendered as necessary since the impact of this new rail infrastructure is heavily concentrated in the port of Algeciras. Therefore, it is not necessary to draw up a complex Spatial Economic CGE that eventually will not reproduce the impact better than assuming a modal shift at the port of Algeciras, based on the evidence of other ports that already enjoy comparable infrastructures.

As described before, a significant part of works is about rail impact 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, and it also takes into account its environmental impact.

3. Setting the model: a dynamic CGE

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. Furthermore, CGE can make use of different production functions for each sector, and different utility function for utility-maximizing consumers. A more detailed explanation about the fundamentals are shown in works as those from Kehoe et al. (2005), Hosoe et al. (2010), Burfisher (2011) and Cardenete, Guerra y Sancho (2012).

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 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 economic and environmental effect of the Mediterranean Rail Corridor in Andalusian through a CGE model with a dynamic component, to evaluate its effect along several periods of time.

3.1. The static part of the model

A static general equilibrium model is the basis for the within period equilibrium. It follows the classical CGE formulation, with a set of equations that represents the interactions among the different actors in the economy: producers, households and the government. All agents, consumers and firms, behave rationally as utility and profit maximisers, and as far as constant returns of scale are assumed for firms, to maximize profits for them is the same than to minimize cost. The model includes 27 productive sectors, two factors (labour and capital), one household type and an investment/saving account. The model has been enlarged by including a government that collet taxes (payroll, income and indirect taxes) and demands products and services, and foreign activities through one account representing the rest of the world (ROW).

3.1.1. Producers

The production technology is given by a nested production function. In the first level, the quantity of value-added for sector j is the result of combining primary factors labor L_j and capital K_j with a Constant Elasticity of Substitution (CES) aggregator, where elasticities β_j have been set to 0,5 that is a mean value in the literature (Lichter et al., 2013), meanwhile γ_{Lj} and γ_{Kj} are parameters estimated during the calibration of the model.

$$VA_j = \left[(\gamma_{Lj} \cdot L_j)^{\beta_j} + (\gamma_{Kj} \cdot K_j)^{\beta_j}\right]^{\frac{1}{\beta_j}} \tag{1}$$

Afterwards, the domestic output of a sector is produced with inputs from the rest of sectors and value-added in fixed proportions through a Leontief technology (zero substitution elasticity):

$$q_j = \min\left(\frac{y_{1j}}{a_{1j}}, \frac{y_{2j}}{a_{2j}}, \dots, \frac{y_{27j}}{a_{27j}}, \frac{VA_j}{\nu_j}\right) j = 1, 2 \dots, 27 \tag{2}$$

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. VA_j is the added value, and ν_j is the amount of VA_j that is required for the manufacturing of one unit of domestic good j. Both set of parameters a_{ij} and ν_j are estimated with data from the Social Accounting Matrix (SAM) used to calibrate the model.

Finally, the overall input y_j is obtained combining domestic q_j and imported m_j outputs according to the Armington (1969) hypothesis, with a CES aggregator:

$$y_j = \left[(\mu_{qj} \cdot q_j)^{\alpha_j} + (\mu_{mj} \cdot m_j)^{\alpha_j}\right]^{\frac{1}{\alpha_j}} \tag{3}$$

This aggregator is specified in the same way than added value's CES (see equation (1)), elasticities α_j have been set to 0,5 and μ_{qj} and μ_{mj} are estimated in the course of the calibration of the model with data from the SAM.

3.1.2. Consumers

On the demand side, there is one representative consumer h that demands final consumption C_{hj} of each good j, and saving S_h (tomorrow consumption). He is assumed to maximize a Cobb-Douglas utility aggregator $\mathrm{U_h}$ subject to a disposable income constraint $YDISP_h$, and a price vector $\mathbf{p}(\mathrm{p}_1, \dots \mathrm{p}_j, \dots)$ for goods and $pinv$ for the good of investment S_h.

$$MaxU_h(C_{hj}, S_h) = \left(\prod_{j=1}^{n} C_{hj}^{\chi_{hj}}\right) S_h^{\kappa_h} \quad j = 1, 2, \dots, 27$$

$$s.t.YDISP_h = \sum_{j=1}^{n} p_j C_{hj} + pinvS_h \tag{4}$$

Here, χ_{hj} and κ_{h} are the coefficients of participation in the consumption of goods and saving (substitution elasticities), which are set from the SAM when the model is calibrated.

On the other hand, household income is financed by the sale of the primary inputs, labour and capital, and lump transfers from the government TSP (e.g. consumption of public goods), and from the rest of the world TRM. Household pays income taxes with a tax rate ID, and also a contribution to the social security CO. Disposable income for consumption $YDISP$ is thus gross income minus taxes,

$$YDISP = wL + rK + TSP + TRM - ID(rK + TSP + TRM + wL) - CO \cdot wL \tag{5}$$

Where w symbolizes the price of labour and L is the total amount of work, as aggregation of the labour L_j demanded by each sector j. Similarly, r is the price of capital and K the aggregation of capital K_j demanded by each sector j. CO is the contribution rate of employees to the social security.

3.1.3. Government

The government is a special agent in the economy that taxes exchanges between the rest of agents to get resources. Government collects an indirect tax on transactions RIP (productive activity, including VAT) with a tax rate τ_j on production of sector j

$$RIP = \sum_{j=1}^{n} \frac{\tau_j}{1 + \tau_j} \cdot y_j p_j \tag{6}$$

The government also taxes labour in two different ways. One is through the employer's contribution to the social security RP, with a rate CP_j of employer's contribution to the social security in sector j.

$$RP = \sum_{j=1}^{n} CP_j \cdot w \cdot L_j \tag{7}$$

Second one is the employee's contribution to the social security denoted as RO. As there is only one representative consumer, RO is defined as follows:

$$RO = CO \cdot w \cdot L \tag{8}$$

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

$$RD = ID(w \cdot L + r \cdot K + TSP + TRM) \tag{9}$$

The total collection of taxes by the government is thus:

$$R = RIP + RO + RP + RD \tag{10}$$

With these recipes, the government finances its activity; it transfers resources to the private sector through consumption of goods and services, and to households through lump transfers. The difference between expenses and income will determine the deficit.

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

$$D = -R + TSP + \sum_{j=1}^{n} DC_j p_j \tag{11}$$

All the tax rates are parameters estimated with data from the SAM, as well as lump transfers from the government TSM (as consumption of public goods) and from the rest of the world TRM.

3.1.4. External sector

Tariff for imports has not been considered because most of them come from the rest of Spain and the EU. In our model, the demand from the public sector is kept as steady. As a consequence, the deficit of the government is endogenously determined.

The Andalusian economy is negligible when compared with the rest of the world, therefore, the demand from 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), in such a way that imports are endogenously determined, consequently external deficit F is endogenously determined also.

$$F = prm \sum_{j=1}^{n} m_j - TRM - prm \sum_{j=1}^{n} EXP_j \quad j = 1, 2, ..., 33 \tag{12}$$

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 closure rule stablishes the level of investment. Savings are the aggregation of private savings, endogenously determined by the maximization problem of the representative consumer, and public and external deficit.

Therefore, the level of investment INV_j at each of the sectors j is defined according to the following equation:

$$pinv \cdot \sum_{j=1}^{n} INV_j = S_h \cdot pinv - D + F \tag{13}$$

3.1.6. Prices

Prices are endogenous in the model and they are made up taking into account production and the prices of goods and primary factors. There is an internal price pi_i of the locally produced good i as defined in expression (14) where pva_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 τ_i to production, as we can see in Equation (15). In this expression ξ_i and ζ_i represent, respectively, the participation of locally produced and imported good in the final product.

$$pi_i = pva_i \cdot \nu_i + \sum_{j=1}^{n} p_j \cdot a_{ij} \tag{14}$$

$$p_i = (1 + \tau_i)(\xi_i \cdot pi_i + \zeta_i \cdot prm) \tag{15}$$

3.1.7. Labour market

This model also introduces a labour market, 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 labour 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 and through a parameter λ. Salaries are rigid when λ is large, and salaries are more flexible when λ turns down.

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:

$$\overline{w} = \left(\frac{1-u}{1-\overline{u}}\right)^{\frac{1}{\lambda}} \tag{16}$$

Where $\overline{w}$ is the real wage rate, u is the unemployment rate and $\overline{u}$ is the benchmark unemployment rate. Parameter λ has been estimated with wage unemployment elasticities apparaised in previous works for Spanish regions (Bande et al., 2012).

3.1.8. Good and services clearance closure condition

The model is closed by an additional condition. Market of goods and services are cleared at the equilibrium. For each sector, the production equals the demand from the government, households, intermediate demand, investment and the external sector.

$$y_j = INV_j + DC_j + EXP_j + q_j + C_{hj} \tag{17}$$

In addition, the distribution of the demand from investment and the demand from external sector among the different sectors in the economy, is kept steady and calibrated with data form the SAM.

3.2. Model resolution for the within period equilibrium

The model includes the same number of equations and unknowns. However, 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.

In the economy consumers maximize their utility and firms their benefits; the government redistributes among the different actors in the economy. The economy reaches its equilibrium when, at each market of factors and goods, demand equals supply.

Prices and production of sectors are endogenously computed by the model. Prices rule the demand and supply of goods and services, in such a way that the economy meet the equilibrium when prices and products and services clear all markets, and at each market demand equals supply also. Labour market is the only one that does not clear, as there are idle resources counted as unemployment.

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.

3.3. Calibration of the model. SAM as database

SAMs are an extension of IO tables (Leontief, 1941, 1951), first developed by Stone (1962), and it gives a detailed account of interindustry transactions in an equilibrium setup in which total supply

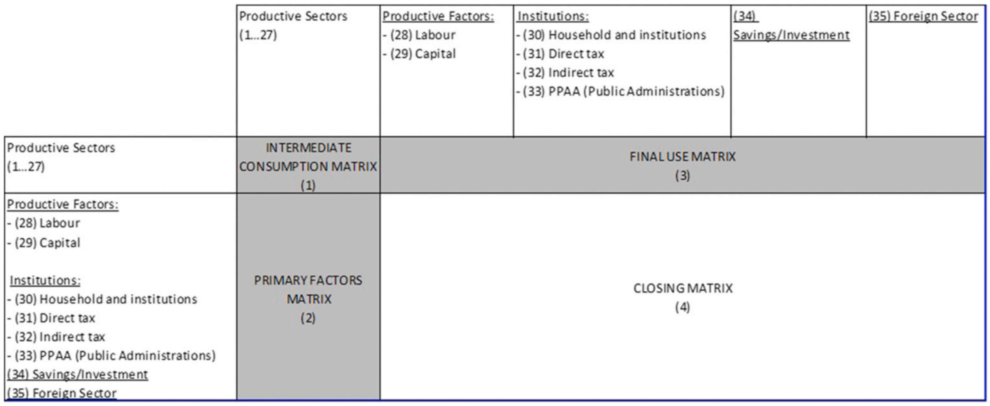

Fig. 1. Brief structure of SAMAND2013 with sectors of transport by rail and road disaggregated.

matches the sum of intermediate and final demand. The matrix structure is such that for each sector the sum by columns equals the sum by rows. The evaluation of the parameters that reflects the behaviour of the economic agents is done through data from a SAM. It includes data of transactions between the offering agents in the economy, and it represents the equilibrium of reference that the CGE aims to reproduce. The benchmark that calibrates this model is the SAM of the Andalusian economy for 2013, with the sectors of rail and road transport disaggregated. This SAM has been drawn up with official data (Andalusian Institute of Statistics, IGEA), and the sectors of transport have been also disaggregated with data from official sources (Andalusian Institute of Statistics, IGEA and the Spanish Institute of Statistics, INE). Fig. 1 presents the SAM structure of accounts.

The process of calibration ensures that the model replicates the benchmark equilibrium. In addition, in this equilibrium all the prices relative to the *numerarie* are equal to unity, assuring the consistency of the model. However, the elasticities ruling the behaviour of CES aggregators have been gathered from different sources in the literature. It is assumed that this is one of the weakness of this models as well as for any CGE model: these elasticities borrowed from the literature usually do not belong to the region under analysis. For this reason, one of the sensitivity analysis carried out are about the effect of changes on these elasticities (see chapter 5.3).

3.4. 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. In addition, the representative consumer maximizes the present value of his utility along his lifetime.

As a consequence, Ramsey's model is introduced in the dynamic CGE model through the following equations, which stablish the rules for investment (18), the accumulation of capital (19), as well as the stock of capital at the basis period (20).

$$I_t = (\delta + g_{t+1})K_t \tag{18}$$

$$K_t = (1 + g_t)K_{t-1} \tag{19}$$

$$K_0 = \frac{VK_0}{\delta + r_0} \tag{20}$$

Where δ represents the capital depreciation (a constant value over the time), g_t is the growth, r_t is the interest rate and VK_0 the capital earnings at the base period. Subscript refers to the period.

In the static model, investment is calculated as the sum of household saving, government and external deficits; investment is thus well established once savings and deficits 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. Government expenditure and imports are the only variables that can be added as new degrees of freedom. Government expenditures are quasi-fix, therefore, if a level of investment is required and household savings and government deficit are not enough, the external sector will be who fulfils the required level of investment through external deficit. As imports are endogenously defined, the aggregate amount of exports is also laid down in the dynamic CGE model, in contrast to the static CGE.

3.5. Environmental impact in the model

The valuation of the of the environmental impact of the new Mediterranean Rail Corridor is done with the CO_2 emissions per output level. CO_2 emission factor is defined as follows:

$$YE_i = \frac{E_i}{Y_i} \tag{21}$$

Where E_i denotes CO_2 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 (Spanish Institute of Statistics (INE), 2010)[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 (Spanish Ministery of Transportation, 2011), that stablishes emission levels of 136,3 gCO_2/Ton-Km for transport of cargo by road and 28,8 gCO_2/Ton-Km by rail. The aggregation of GHG emissions from all sectors matched with the total emissions of productive sectors in Andalusia in 2010.

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. CO_2 represents the main part of these

[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

Table 1
Modal split forecast in the port of Algeciras.

Share of transported loads by train over the total			Increase over the total transported loads by train (As exports)			Decrease over the total transported loads by road (As exports)		
Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025
6%	13%	20%	33,1%	77,3%	136,0%	−0,76%	−1,51%	−2,26%

Source: Own Elaboration.

emissions, up to an 80% in 2010.[2] As it was quoted in chapter 1, one of the upsides of rail transport is that it is more energy-efficient than transport by road; if there is a substitution effect, we expect also a reduction on emissions.

The shock will be modelled as a substitution effect, by increasing exports of the sector of transport of cargo by train, and hence, decreasing exports from sector of transport of cargo by road, keeping the shock neutral from the point of view of the quantity of transported goods. It is a shift from a mode of transport to another.

The expressions that define the total output have been modified to change external demand in different periods of time.

4.2. Modelling the impact of the rail infrastructure

In year 2016, the share of freight carried by train from the port of Algeciras was negligible, but in Europe the participation of rail transport in amount of cargo coming into and out of their ports is around a 20%. Where this share is not reached, it is due to the relative importance of inland waterway, such as in Rotterdam or Antwerp, or due to the lack of appropriate infrastructure, such as Valencia that is also pushing for the Mediterranean Rail Corridor (Enrico Pastori, 2015).

Based on these data, the most likely scenario is to reach this share of load transported by rail. We also assume that this relative weight will be reached in 2025, after three two-years periods of time (six years) from the entry into service of the rail infrastructure.

According to the agreed criteria for the MIOAN-2010[3] transport services rendered by non-residents fall on the imported goods exclusively. 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.

4.3. Simulating the shift of transport of load from road to rail

Based on the figures of year2016,[4] a 20% of transport by rail means 1.299.330. 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 by 649.665 tons. It represents about a 136% increase of the final demand of transport of cargo by train in Andalusia, that is accounted as exports.[5] Cargo shifts from road to train, and consequently, the demand of transport by road decreases. This drop is measured in tons-kilometre. The increase of the demand of transport by train means a 2,26% decrease of the demand of transport by road. Table 1 summarizes the values that will be introduced in the model.

In addition, to design the dynamic model based on Ramsey’s growth model it is necessary to set out the growth path. Table 2 shows real figures from years 2013–2017, meanwhile Table 3 shows estimations and projections from 2018 onwards.

[3] Andalusian Institute of Statistics (IGEA), 2010 *Input-Output Methodology*.
[4] Port of Algeciras Bay (2017).
[5] Sp1nish Ministry of Transportation, Statistics of Rail Transport, 2016. Spanish Ministry of Transportation, *Yearly Road Freight Transport Survey. Year 2016,* IGEA, Infrastructures and Rail Transport Statistics.

Table 2
Economic data for Andalusia (2013–2017).

Parameter	Source	Historical data				
		2013	2014	2015	2016	2017
GDP deflactor	BdE	0,7%	−0,2%	0,6%	0,3%	1,0%
Real GDP	IGEA	−1,7%	1,4%	3,6%	2,8%	2,9%
Rate of capital depreciation	Literature[a]	5,0%	5,0%	5,0%	5,0%	5,0%
10 year bond’s yield	INE	4,1%	1,8%	1,7%	1,4%	1,6%
Real interest rate	Estimated	3,4%	2,0%	1,1%	1,1%	0,6%

Bde: Banco de España (Bank of Spain).
IGEA: (Andalusian Institute of Statistics IGEA, 2010) Instituto de Estadística y Cartografía de Andalucía (Andalusian Institute of Statistics).
INE: Instituto Nacional de Estadística (Spanish Statistical Institute).
[a] Denia (1996).

Finally, Table 4 summarizes the parameters that rule in the model to simulate the growth path in the six two-years periods of time.

5. Simulations and main results

The model has been used to drawn up different magnitudes. The results with and without the sock will be used to compare the effect of the new rail infrastructure fed by the port of Algeciras.

5.1. Economic impact of the rail infrastructure

The economic impact is measured in terms of GDP and employment. The shock is designed to be neutral on the quantity of transported goods, measured as ton-kilometre. The impact of the new infrastructure is illustrated hereafter in Table 5 in terms of Andalusia’s GDP, for the three periods after the rail infrastructure starts to operate in year 2019.

The modal shift from road to train has a positive impact in the economy, although it is not significative. This impact has been valued at around 3 million of euros.

This result is in line with others that has been carried out to quantify economic impact of rail transport as the one from Bröcker et al. (2010) who highlighted modest impact in welfare of the Trans European rail Network (TEN) by using a multiregional CGE.

The impact on employment has been also calculated and it is displayed at Table 6.

The impact on employment is slightly negative. The transport by road is more labour intensive than the transport by train. The drop in labour demand from the sector of transport by road cannot be compensated by the rise from the transport by train. In fact, the labour increase in transport by train only covers the 60% of the decrease in transport by road.

However, there are positive indirect and induced effects that shorten the negative impact of the labour demand reduction. As a result, the whole effect is still negative although negligible.

In short, the substitution of road transport by rail transport has not a significant impact in employment, even if the road transport is more labour intensive, due to the positive indirect and induce effects of rail transport.

For all the results outlined before, we come to the conclusion that

Table 3
Economic data for Andalusia. Estimations 2018–2025.

Parameter	Source	Forecast							
		2018	2019	2020	2021	2022	2023	2024	2025
Real GDP	BdE*	2,7%	2,4%	2,1%	2,1%	2,1%	2,1%	2,1%	2,1%
Rate of capital depreciation	Literature**	5%	5%	5%	5%	5%	5%	5%	5%
Real interest rate	BdE*	0,1%	0,2%	0,3%	0,3%	0,3%	0,3%	0,3%	0,3%

BdE*: Banco de España (Bank of Spain), Macroeconomic projections for the Spanish Economy (2018–2020) and INE (Spanish Statistical Institute) *Denia (1996).

Table 4
Parameters defining the growing path of Ramsey's model.

Parameter	Period 1 2014–2015	Period 2 2016–2017	Period 3 2018–2019	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025
Real GDP	5,1%	5,8%	5,2%	4,2%	4,2%	4,2%
Rate of capital depreciation	10,3%	10,3%	10,3%	10,3%	10,3%	10,3%
Real interest rate	3,1%	1,7%	0,3%	0,6%	0,6%	0,6%

Source: Own Elaboration.

Table 5
Impact of rail infrastructure on GDP (million €) in Andalusia.

GDP Variation (Million €) from Baseline	Period 4 2020–2021	Period 5 2022–2023	Period 5 2022–2023
GDP Variation from Baseline	0,1	0,9	2,7
GDP Variation from Baseline	0,0001%	0,0005%	0,0014%

Source: Own Elaboration.

Table 6
Impact of rail infrastructure on employment in Andalusia.

Labor Variation (Jobs) from Baseline	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025
Labor Variation from Baseline	−22	−38	−48
Labor variation from Baseline	−0,0007%	−0,0012%	−0,0015%
Labor variation on Freight Transport by Train	106	251	449
Variation on Freight Transport by Road	−832	−1268	−1288

Source: Own Elaboration.

there is not a negative impact of the Mediterranean Rail Corridor. There are job losses in transport by road, which is a very labour intensive, and therefore in household's consumption. This drop cannot be compensated by jobs increase in the sector of transport by rail, although the gap, in terms of economic activity and employment, is closed by indirect effects of the transport by rail. These better indirect and induced effects in Andalusia of rail transport over road transport has been already highlighted and quantified in previous studies, as the one from Cardenete and López (2018).

5.2. Environmental impact of the rail infrastructure

The model has been also used to assess the environmental impact of the substitution of road transport by rail transport, due to the Mediterranean Corridor that is fed with loads coming into and out of the port of Algeciras. Table 7 shows the equivalent tons of CO_2 saved, and also as percentage relative to base scenario (without impact)

Environmental impact is measured in terms of equivalent tons of CO_2 emitted, and as expected, the substitution of transport by road decreases GHG emission as rail transport is less emission intensive. The net reduction in emissions accounts for 83.000 equivalent tons of CO_2 by year at the end of the period. But, although there is an increase of productive activity due to the shift of transport by road to transport by rail, that induces higher multiplier effects, the total amount GHG emitted is also reduced. In the economy, there is a reduction of more than 50.000 equivalent tons of CO_2, less than the reduction in ground transport (rail and road transport) as a consequence of the increase in the economy activity. The relative effect is a reduction of 1.6% in GHG emissions, which represents a 0.1% reduction in the whole economy.

Table 7
Impact of rail infrastructure on GHG emissions in Andalusia.

Change GHG emissions in Equivalent Tons of CO2			
	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025
Whole Economy	−19270	−38067	−55841
Road	−32866	−68724	−108179
Rail	5701	14000	25876
Gound Transport	−27165	−54724	−82303
Change in GHG emissions in % relative to Base Scenario			
	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025
Whole Economy	−0,04%	−0,07%	−0,10%
Road	−0,72%	−1,43%	−2,14%
Rail	38,28%	87,05%	150,02%
Gound Transport	−0,59%	−1,13%	−1,62%
Total Output	0,00%	0,01%	0,01%
GDP	0,0000%	0,0000%	0,0000%

Source: Own Elaboration.

We conclude that the modal shift of freight from road to rail, of those loads coming into and out of the port of Algeciras thanks Mediterranean Corridor, will have a positive environmental impact in Andalusia, even with an increase in the total output of the economy. The substitution effects could decrease GHG emissions in around 1,6% of total emissions of freight transport by ground. It is not a negligible value for a sector that accounts for an important amount of all GHG emissions. From a qualitative point of view, this result is in line with others, like the one from Chen et al. (2016) which also concludes the positive impact of substitution effect of road by rail transport, although minimized by positive indirect and induced effect. However, in this work the effect has been quantified for the Andalusian economy.

5.3. Sensitivity analysis

The results presented in section 5.1 and 5.2 are dependent upon the specification of the model as well as the calibration and the chosen elasticities. To gather the sensitivity of the results with regard to the specification of the model and the elasticities, three sensibility analysis have been carried out.

The first sensitivity analysis captures the effect of the substitution elasticities (see chapter 3.1.1) in the results of the model at the end of the period, when they are twice or half of those used in the model. These results are shown in Table 8.

It can be observed that the effect of changing the elasticities in CES

Table 8
Sensitivity analysis with regard to elasticities used in the model.

% change with respect to results with standard elasticities α_i & β_i = 0,5	α_i & β_i x 0,5	α_i & β_i x 2
Δ Labor	5,0%	−8,6%
Δ GDP	−16%	17%
CO2 in Economy	0,8%	−1,4%
CO2 in Road	0,5%	−0,8%
CO2 in Ferr	0,5%	−0,8%
CO2 in Ground Transport	0,4%	−0,8%

Source: Own Elaboration

Table 9
Sensitivity analysis with regard to the shock (20% Shift).

% change with respect to results with the baseline: 20% shift	10% Shift	30% Shift
Δ Labor	−50,0%	50,1%
Δ GDP	−72%	43%
CO2 in Economy	−50,0%	50,0%
CO2 in Road	−50,0%	50,0%
CO2 in Ferr	−50,0%	50,0%
CO2 in Ground Transport	−50,0%	50,0%

Source: Own Elaboration

Table 10
Sensitivity analysis with respect to wage elasticity to unemployment.

% change with respect to results with standard elasticity λ	ζ x 2	ζ x 0,5
Δ Labor	5,7%	−9,7%
Δ GDP	−56%	84%
CO2 in Economy	1,0%	−2%
CO2 in Road	0,6%	−1%
CO2 in Ferr	0,6%	−1,1%
CO2 in Ground Transport	0,6%	−1,1%

Source: Own Elaboration

aggregators does not impact appreciably the results in terms of emissions. Higher elasticities reduce the negative impact in terms of employment, and the opposite happens with lower elasticities. Nonetheless the impact in employment is low in any case. On the other hand, the impact in the increase of GDP is higher, but still negligible.

The second sensitivity analysis gathers the effect of the size of the shock in the results. It has been done with three different scenarios, the base line is based on a 20% shift from road to rail of the freighter getting in or out of the port of Algeciras. In addition, the results based on this scenario have been compared with other two alternatives: a conservative scenario based on a shift of a 10% and an optimistic scenario of a 30%. These scenarios are based on the weight of rail transport in the principal ports in Europe with comparable rail infrastructures (Enrico, 2015). Results are shown in Table 9.

According with these results, we conclude that there is a mostly linear relationship between changes in the shock and the results, as a consequence of the relatively small impact of the shock when compared with the whole Andalusian economy. Therefore, the results could be easily extrapolated to any scenario based on a different value of modal shift.

The third sensitivity analysis, is about the effect of the wage elasticity to unemployment rate. The results are given in Table 10.

When the economy grows thanks to an accumulation of capital, the demand of labour also increases, leading to a decrease in the unemployment rate, and an increase in salaries. If wages are more rigid (higher values of λ) their growth due to a lower unemployment rate is smaller than with more flexible salaries, leading to less consumption and a lower increase of GDP. As a consequence, more rigid salaries lead to lower activity increases, and higher CO_2 reductions, lower increase in GDP and less unemployment reduction. Nevertheless, the impact is very low, as changes in the wage elasticity to unemployment rate leads to changes below the 2% in the reduction of CO2 emissions. The impact in unemployment and GDP is higher in percentage, but still very small in volume.

In addition, the consistency of the dynamic behaviour of the model has been also checked. It has been done by comparison of the growth path that rules the dynamic part of the model (see chapter 3.4) with the GDP growth that the model reproduces. The unemployment rate has been also compared with the real data and the results are in Table 11.

As can be seen, the dynamic part of the model reproduces the behaviour of the economy, in terms of growth and unemployment rates. Nonetheless the model has some momentum, and it is not fast enough to mimic the changes in the real economy. This can be attributed to several factors. First and foremost, the year 2013, which has been the one used for calibrating the model, is a very unique year as it was when the recession that started in year 2008 reached one of its lowest points (−1,7% of GDP growth and 36% of unemployment rate). The following periods were marked by years with exceptional growth rates and unemployment rate reduction (the resiliency of the economy). Second, the simulation takes two years periods, it means that there are less loops in the simulation to capture sharp changes than if there are yearly periods. Finally, there is also an impact of the elasticities in the CES aggregators, the elasticity of wages to unemployment rate and rates of capital depreciation, which have been set to standard values that could not be the ones applicable to the Andalusian economy at this period of time.

6. Conclusion

This paper assesses the quantitative effect in Andalusia of the new rail infrastructure in the Port of Algeciras as part of the Mediterranean Rail Corridor, in terms of GDP, employment and GHG emissions, through a dynamic-CGE.

The impact has been modelled as a 20% substitution of road transport by rail, in line with the other European ports with rail connection.

The new rail infrastructure has a positive economic impact of nearly 3 M€, what might be deemed as negligible. In any case, it is an important result, as it means that rail transport overcomes the negative impact of labour income drop from ground transport. The effect on employment reveals this effect, which is slightly negative. The loss of employment due to the fall of transport by road, which is more labour intensive than rail transport, it is not fully compensated by direct effects from the growth of transport by train, although strongly minimized as a consequence of its better indirect and induced effects of rail transport than transport by road.

Table 11
Comparison of real GDP and unemployment rate with model results.

	Period 1 2014–2015	Period 2 2016–2017	Period 3 2018–2019	Period 4 2020–2021	Period 5 2022–2023	Period 6 2024–2025
2025Growth Path (GDP Increase)[a]	5,1%	5,8%	5,2%	4,2%	4,2%	4,2%
GDP Increase (model)	5,6%	5,0%	4,3%	3,8%	3,8%	3,8%
Unemployment Rate (Real)	32%	26%	21%	19%[b]		
Unemployment Rate (Model)	33%	30%	27%	25%	23%	20%

[a] See Table 4.
[b] Estimation from the Statistics Institute of Andalusia.
Source: Own Elaboration

This work also assesses the environmental impact due to the substitution of road transport by rail transport, thanks to the new rail infrastructure. Any change in the modes of transport will likely impact total GHG emissions, as sector of transport is the source of 25% of them. Substitution of road by rail transport is very interesting, as rail 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 in the economy difers among modes of transport.

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 83.000 equivalent tons of CO_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 56.000 equivalent tons of CO_2, in spite of the increase in the productive activity. This amount means an 0.1% reduction.

Whereas the economic and labour impact of substituting road by rail transport might be considered as negligible, the environmental impact is of utmost importance. Substitution effects deliver an important reduction of GHG emissions, reaching a net reduction of 1,6% in total GHG emissions in Andalusia.

Author statement

1 All authors of this research paper have directly participated in the planning, execution, and analysis of this study.
2 All authors of this paper have read and approved the final version submitted.
3 The contents of this manuscript have not been copyrighted or published previously.
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5 The contents of this manuscript will not be copyrighted, submitted, or published elsewhere, while acceptance by the Journal is under consideration.
6 There are no directly related manuscripts or abstracts, published or unpublished, by any authors of this paper.

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