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Gdyn-E: a dynamic CGE model for the economic assessment of long run climate policy alternatives.

(DRAFT version – do not quote)

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1. Introduction

During last years, although models for ex-ante economic analysis have been strongly developed, the changes in the political economy issues and regulation have determined the need for a wider analytical framework. The globalization has increased the impact of capital accumulation on the effects and "wideness" of country policies. The impact of such policies has became less and less bounded. The Kyoto protocol, for example, even if it can be considered as an environmental regulatory issue, has a strong impact on international trade and competitiveness.

Therefore, to assist policy makers in defining useful scenarios, a long run approach including both dynamic and multi sectoral aspects, needs to be included in the modelling strategy. Most of existing contributions have addressed these issues without accounting for a crucial aspect of the forecasting scenario, related to the dynamics in economic patterns. This is mainly due to the lack of specific analytical tools able to tackle with long run horizons, with capital accumulation and timing effects. The purpose of this work goes in the direction of filling this methodological gap by developing a new dynamic Computable General Equilibrium (CGE) model which includes a specific treatment of CO_2 emissions associated to long run policy scenarios.

A large amount of the international literature as well as policy debate have expressed increasing interest in measures that mitigate the negative externalities of climate change policies. As a matter of fact, the imposition of stringent climate policies may produce substantial effects in terms of GDP reductions, trade displacement and re-allocation production processes. However, the extent of economic impacts of "green" policies is controversial and there is considerable debate over the design of an effective energy policy strategy.

In this respect, we will elaborate on the existing studies providing further evidence of the extent of the economic and trade impacts of climate policies, and their connection with sectoral productivity, in particular relative to land transport sector. Our goal is to assess the increase in productivity needed to compensate the economic impacts of CO2 emission reduction policies, in particular when measured on GDP and the trade balance. This research question provide us with the case study needed to test our newly developed dynamic CGE. It allows the effectiveness and efficiency of climate policies in achieving their goals to be evaluated together with their side-effects on the economic system.

The rest of the paper is structured as follows. In Section 2 we describe the computable general equilibrium
model, the sectoral and regional aggregation, as well as the baseline and the policy scenario, in Section 3 we present the main simulation results and Section4 provides some final remarks.

2. Model

The dynamic CGE model here proposed, called Gdyn-E, is built up by merging the standard dynamic version of GTAP with the last improved version of the static GTAP-Energy model, particularly to analyse the impacts of long-term energy and climate policies.

The new model GTAPDyn-E uses the last version 8 of the GTAP-Database, together with the last version of the additional GTAP-Energy data, which contains data on CO2 emissions along with the arrays in standard GTAP Data Base 8, in a format that can be readily used with the GTAPDyn-E model. Moreover, since the GTAP Database 8 is characterized by different possibilities with respect to base year, namely 2004 and 2007, we used the latest to build the long-run baseline, updating the 2007 to 2010 by historical macroeconomic and emissions data.

The Dynamic GTAP (GTAP-Dyn) is a recursive- dynamic extension of the standard GTAP (Hertel, 1997), which preserves all the standard features of the GTAP model – perfect competition, Armington trade flows, disaggregated import usage by activity, non-homothetic consumer demands and explicit modelling of international trade and transport – while enhancing the investment theory to incorporate international capital mobility and ownership (Ianchovichina and McDougall 2001).

An adaptive expectations theory of investments introduces a disequilibrium approach to model endogenously international capital mobility. It allows a recursive solution procedure, and having time as a variable, not as an index, allows an easy implementation of the dynamic into the standard GTAP model with minimum modifications. The GTAP-Dyn model uses the standard GTAP data base supplemented with foreign income data form IMF Balance of Payments statistics in order to track international capital mobility and foreign wealth and a new parameters file necessary for the dynamic theory.

On the other hand, the computable general equilibrium GTAP-E model is an energy-environmental version of the standard GTAP model (Burniaux and Truong, 2002; McDougall and Golub, 2007), specifically designed to simulate CO2emission mitigation policies[1]. It includes an explicit treatment of energy demand, the possibility of inter-factor and inter-fuel substitution, data on carbon dioxide emission accounting and the possibility of introducing market-based policy instruments such as carbon taxes or emission trading).

The last revised version of the GTAP-E model for the GTAP database 8, introduces a refined energy nest in private and government consumption with new parameters and an additional variable representing government share of carbon tax payments/permits revenue.

2.1 New features

In order to better evaluate not only the impact of long-run energy and climate policies but also technological improvements in the different regions further modifications to the model have been added.

Since the literature agrees on the crucial role of substitution elasticities in the quantification of policies impacts such as the geographical distribution of leakage rates, first of all, some substitution elasticities - namely the substitution elasticity between the capital–energy composite and the other endowments, and the substitution elasticity between capital and energy in all the nests related to the energy composite - were replaced with those proposed by Beckman and Hertel (2010).

In particular, modified values of substitution elasticities between capital and energy have been inserted basing on econometric estimations of the production function of energy intensive manufacturing industries.

In the GTAP-E model, substitution elasticity values between energy and capital are crucial when determining the aggregate output related to energy price changes since technology (energy-efficiency, capital turnover) has significant economic implications on production input choices. Moreover, it also affects carbon emission volume, carbon permit prices, and welfare. In particular, the mechanism of changes in relative prices is what strongly influences the decision to substitute inputs in the

[1] For technical details on GTAP-E settings, see Antimiani et al. (2012).

production function, thus affecting relative convenience for non-abating countries to increase energy consumption despite other production inputs where abatement targets are implemented by regulated countries. In order to better evaluate the changes in elasticity between capital and energy due to technical change, an additional coefficient has been inserted to allow specific changes in the elasticity in each region.

The Armington elasticities for energy commodity were also changed as suggested in Hertel et al. (2007), in order to improve the coherency of the geographical distribution of emission patterns rate when unilateral climate policies were simulated2.

The elasticity of substitution in household energy sub-consumption has been modified as well, based on the energy mix consumption at the country level. In particular, the elasticity has been increased for countries having a relatively highly differentiated consumption mix, and decreased otherwise.

Regarding the extra parameters used in the dynamic theory, the parameters which represent the rigidity of allocation of wealth by regional household and the rigidity of source of funding of enterprises have been modified. These changes have been done maintaining the original differentiation of the GTAP Database, but modifying the values in order to improve the capacity of the model to find a convergence solution.

Moreover, in order to model not only climate policies with emission reductions objectives, but also economy's carbon intensity targets (China), as well to take into account the national carbon intensity due to technical change, a specific additional Coefficient has been inserted showing the relationship between CO2 emission and national gross domestic production. An additional variable for augmenting technical change in each sector and in each region has been also included to evaluate the productivity.

Finally, since in the Gtap Database 8 are included energy volume data in Mtoe we have derived the total national consumption of energy commodities in Mtoe, allowing the representation of national energy balances, and the national energy production of energy commodities. Both variables are updated after each year of the simulation and they provide useful information to evaluate the impacts of climate policies on national patterns in the consumption and production of energy commodities .

2.2 Regional and sectoral aggregation

With regard to regional aggregation, we disaggregated Italy and major European countries, and we singled out the major emerging economies, including the BRIC Countries (Brazil, Russia, India and China).

As far as sectoral aggregation is concerned, in addition to the energy sectors such as coal, crude oil, gas, refined oil products and electricity, we singled out land, air and water transport since we aim at investigating the impact of climate policies on trade relationships, in the wave of the existing and increasing literature addressing potential negative effects associated to large scale environmental policy.

[2] For a comprehensive discussion on substitution elasticities in the energy sector, see Koetse et al. (2008), Okagawa and Ban (2008), while Panagarya et al. (2001) and Welsch (2008) discuss the role of import demand elasticities in international trade.

Table 1 - Regional-sectoral aggregation

Regions	Sectors
Italy	Coal
France	Oil
Germany	Gas
Spain	Refined oil products
United Kingdom	Electricity
Rest of Europe	Energy Intensive Industry
United States	Other Industry
Japan	**Land Transport**
China	**Air Transport**
India	**Water Transport**
Brasil	
Rest of the World	

In this case the value added of Gdyn-E could be to provide an optimal policy mix scenario where either environmental goals or minimization of negative economic impacts could drive policy tools. As a narrower sectoral issue, we will investigate how trade impacts produced by climate policies could be compensated by changes in sectoral productivity. To this purpose, we will focus on the transport sector, as it is highly pervasive in the whole production value chain for a large portion of the economic system, and as such it is higly relevant for shaping import and export patterns. At the same time it is responsible for a huge amount of CO2 emissions.

In other words, we want to introduce a "trade equivalent measure" of productivity giving a specific environmental target in terms of emission reduction. Moreover, we will be able to analyze the impacts of trade policies on the main categories of goods - agricultural, energy-intensive and manufactured - as well as the productivity of different transport typologies.

2.3 Baseline construction

In order to build medium-run baseline scenario, reaching up to year 2020, first of all, a 2010 baseline scenario has been built with two calibrations to historical data, applied to macroeconomic variables, namely GDP, population, skilled and unskilled labour, using mainly World Bank data, and carbon emissions, using 2010 IEA CO2 data3. In this way the GTAPDyn-E model reflects as closely as possible the changes occurred in the world economy until 2010.

In a second step, we have used growth projections for population, labour force, productivity and GDP by international organisations (United Nations, IMF, World Bank and ILO). As far as emissions projections are concerned, for EU member countries baselined projections have been obtained from the Energy Roadmap 2050[4] and for other countries from the World Energy Outlook (WEO)2012) by International Energy Agency, in both cases referring to the reference scenario.

The calibration, then, has been done using the emissions projections as benchmark and adjusting some variables, like capital accumulation (since energy and capital are substitutes, ndr), technological efficiency of energy input and the output productivity (to have also a price effect for the energy products). By this way we ensure that the model "answer" coherently with respect to the energy structure and then, we can simulate policy scenarios.

2.4. Climate policy scenario

In order to build our policy scenarios in terms of emission reductions, two different sources have been used. For EU member countries, the Energy Roadmap 2050 has been used, and in particular the Current policies initiatives scenario, whereas for other countries the Current policies scenario from WEO 2012.

The scenarios modeled in the Energy Roadmap 2050 reflect the decarbonisation initiative Resource efficient Europe, and are coherent with the Roadmap for moving to a competitive low carbon economy in 2050, as well as with the Communication Europe 2020 and Energy 2020, and with the energy policy planned in the Lisbon Treaty.

Four main decarbonisation routes are modeled for the energy sector – energy efficiency impacting mostly on the demand side and RES, nuclear and CCS predominantly on the supply side. All decarbonisation scenarios use the same assumptions about GDP development as the Reference scenario.

The Reference scenario is based on current trends and long-term projections for GDP, and it includes only energy policies adopted by March 2010. All decarbonisation scenarios are built on Current Policy Initiatives scenario, which differ from the Reference scenario since it reflects energy policy measures adopted up to 2020. The decarbonisation scenarios allow to reach 85% energy related CO2 reductions by 2050 (40% by 2030). Transport measures - such as energy efficiency standards and low carbon fuels, as reflected in the Transport White Paper - are included in all scenarios. In particular, we refer to the High Energy Efficiency scenario, which includes very high primary energy savings by 2050 and includes a very stringent implementation of the Energy Efficiency plan.

In the Current Policy Initiatives scenario the CO2 emission reduction for the EU as whole in 2020 equals -20.3% with respect to 1990 level, and -6.7% with respect to the reference case. On the other hand, in the High Energy Efficiency scenario the CO2 emission reduction is -24% with respect to 1990 level, and -11% with respect to the reference case.

3. Policy scenarios and results

Emission reduction targets affects the economic system of a country by different ways. GDP, high energy intensive sectors and trade competitiveness could be affected. Our policy scenarios are aimed to test the newly developed Gdyn-E model and answer to a political economy research question. In particular, the issue is represented by evaluating the change in productivity needed to compensate the

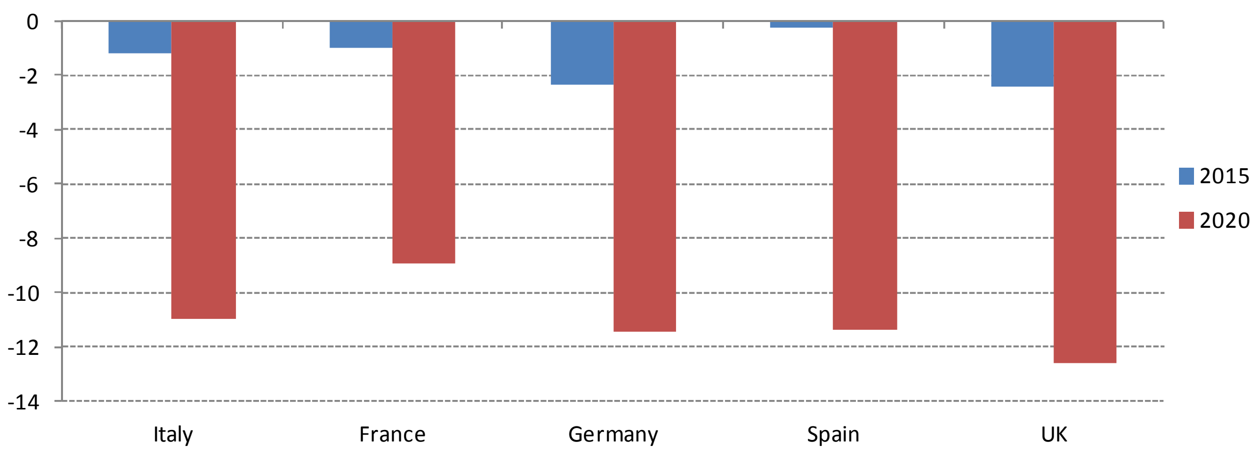
[4] European Commission, 2001; http://ec.europa.eu/energy/energy2020/roadmap/doc/roadmap2050_ia_20120430_en.pdf

impact of the climate policy scenario on selected key economic variables. If we want to "reduce" the impact of the climate policy simulated we should evaluate the policy order to choose "which impact" we want to reduce and, since resource are scarce, "how much it costs". In a "second best" world we could decide that a feasible political intervention is more effective even if the objective is not the first best one.

Gdyn-E - where CO_2 emissions and economic variables are both explicit – is well suited to answer our political economy research question. Reducing CO_2 could impact GDP, and energy intensive sectors, among which transport sectors (land, water and air). We focus on the transport sector as a case studio since, beyond providing a good representation of the situation described above, it is a very peculiar sector, key both for climate and economic policies. In fact, at the same time it is highly affected by the climate policy as it is one among the major polluting sectors and it has a relevant impact on imports and exports, which are both strongly based on transport services.

The model features allow us to focus on EU energy strategy, evaluating the impact of the CO_2 emission reduction policy described in the Energy Roadmap 2050 as "Energy efficiency scenario". In Figure 1, the impact of the CO_2 policy scenario described in the previous section are outlined for the countries investigated.

Figure 1 - Cumulated % reduction on total emission



In 2020, with the emission reduction modeled, we have a negative impact on GDP, shown in Figure 2. This impact is highly differentiated for each of the EU countries investigated, due to the carbon intensity of their economy, which for example is very low for France, and to other specific features, i.e. the relative weight of energy-intensive industrial sectors.

Figure 2 - Cumulated % reduction GDP: differences between baseline and policy

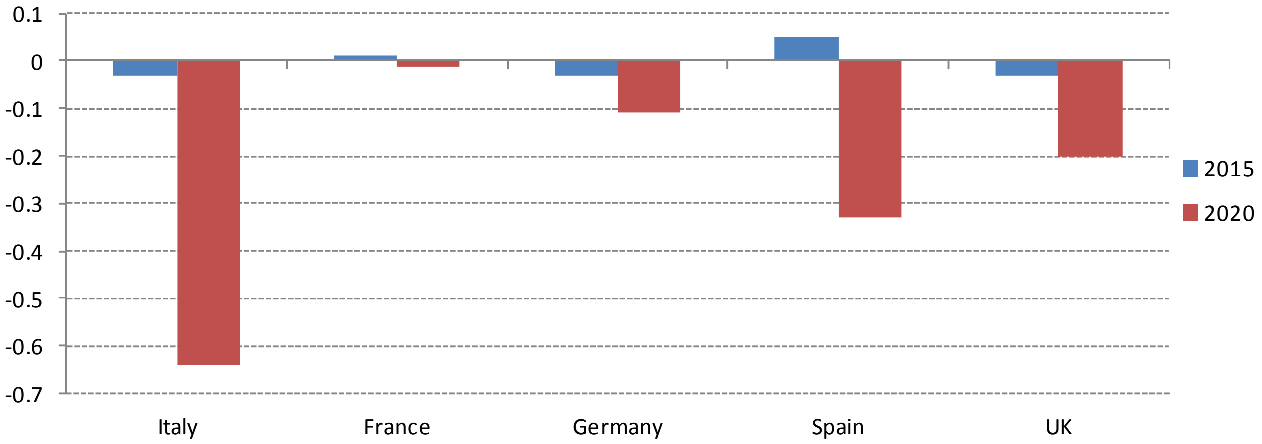
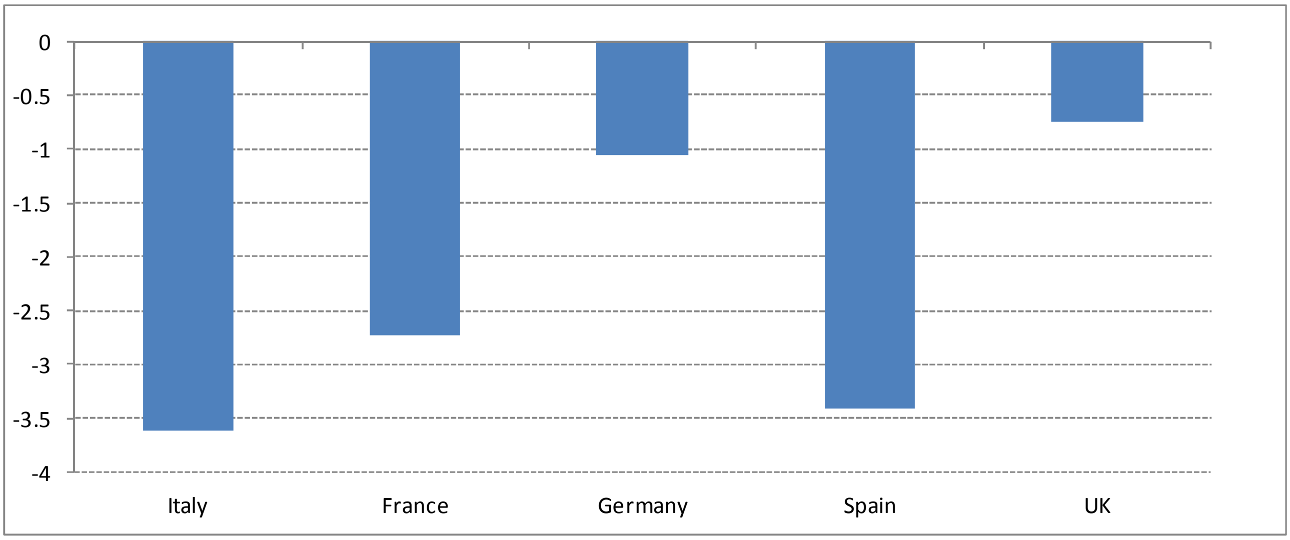


Figure 3 shows the impact on the production of land transport, the transport sector on which we concentrated for our policy scenarios. Our focus is due to the prevailing role this transport mode plays for freight transport in the EU countries examined, and then its strong link with their economies. In all cases the CO_2 policy decreases sectoral output, in a differentiated way for each country.

Figure 3 - Cumulated % reduction on land transport sector output at 2020: differences between baseline and policy



However, even if the impact on GDP is univocal, and negative (figure 2), the impact of the CO_2 reduction policy on the trade balance is differentiated having a positive or negative effect. This pattern is shown in Table 1, including the values of GDP and Trade balance. Also the effect on Output of land transport sector is always negative as the one on GDP (Table 1).

While for Italy the impact on trade balance is negative, for France it is positive and almost neutral on UK, Germany and Spain.

Table 2 - Impact on trade balance, US million: baseline and policy and 2020

	Baseline	Policy
France	-3,261	5,914
Italy	-78,723	-94,094
UK	113,227	115,421
Germany	415,263	416,249
Spain	-314,541	-317,845

Having highlighted the economic impacts of the emission reduction policy, we use the model for a counterfactual analysis which seeks to capture, in a single figure, the productivity growth we should reach in the land transport, uniform among production sectors, given a specific target the political economy intervention would like to reach:

- Preserving the output of the land transport sector at the baseline level

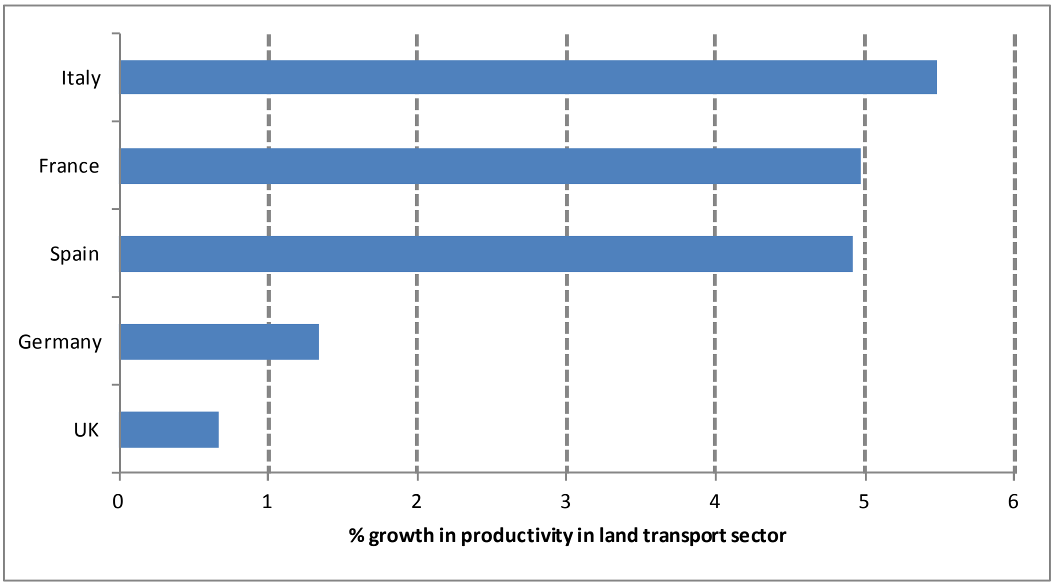
or

- Maintaining the trade balance at the baseline level.

In other worlds, in these counterfactual experiments we "ask" to the model to "give back" the "level" of productivity growth we should achieve when, given the emission reduction policy, we would like to preserve at the baseline level first of all for the value of output in the land transport sector and in a second experiment if we want instead to maintain the trade balance of the main European countries at the baseline level.

In the first case, if we want to preserve the output of the land transport sector, we can see that the political intervention is almost feasible for all countries, going from a "required" productivity growth by 0,7% in UK to 5.5% in Italy (figure 4).

Figure 4 - "Need" in terms of productivity to take the land transport output at baseline level



However ,for all countries, focusing on policy aimed at increasing land transport productivity implies not only a decrease in GDP (table 2) but also a higher national carbon tax (table 3).

On trade balance instead the policy is almost neutral in Germany and UK, has a positive effect in France and a slight positive effect in Spain and Italy (table 4.).

Table 3 - Impact on carbon tax ($), baseline and policies (2020)

	CO2 policy	**CO2 + Policy_1**
Italy	118	**126**
France	84	**87**
Germany	53	**54**
Spain	121	**128**
UK	75	**76**

Table 4 - Impact on GDP growth (%), difference between baseline and policies (2020)

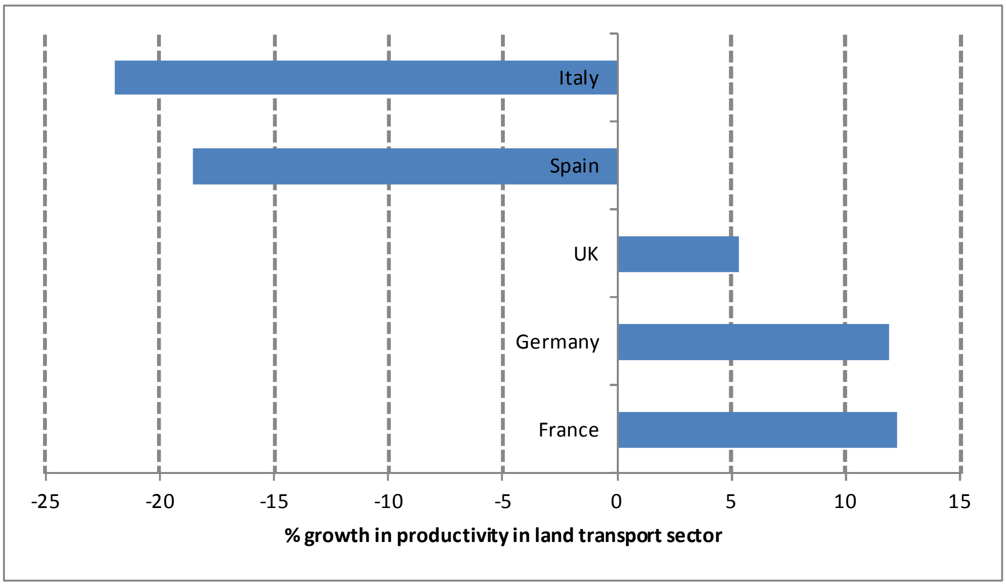
	CO2 policy	**CO2 + Policy_1**
Italy	-0.64	**-1.08**
France	-0.01	**-0.29**
Germany	-0.11	**-0.19**
Spain	-0.33	**-0.73**
UK	-0.20	**-0.24**

Table 5 - Impact on trade balance (US million): baseline and policies (2020)

	Baseline	**CO2 policy**	**CO2 + Policy_1**
Italy	-99,961	-78,723	**-71,288**
France	5,115	**-3,261**	**-804**
Germany	414,540	415,263	415,654
Spain	-317,024	-314,541	**-311,924**
UK	115,623	113,227	113,364

In the second case, if we want to maintain the trade balance at the baseline level, we can see that the political intervention is almost feasible just for UK (growth rate by 5,4%) while the investment in productivity for Germany and France seems to be too high. On the opposite side, Spain and Italy, given the different way in which land transport would impact the economy, could "disinvest" in the land transport efficiency if the objective is keeping unchanged the trade balance (figure 5).

Figure 5 - "Need" in terms of productivity to take trade balance at baseline level



For all countries, focusing on policy for preserving the trade balance implies a significant impact on the output of land transport (Table 5). Carbon tax remains more or less similar (table 6), while for Italy and Spain this policy option improves the GDP growth rate (table 7).

Table 6 - Land transport output (%): difference between baseline and policies (2020)

	CO2 policy	CO2 + Policy_2
Italy	**-3.34**	**-9.79**
France	**-2.50**	3.16
Germany	**-0.88**	0.05
Spain	**-3.45**	**-9.19**
UK	**-0.64**	3.70

Table 7 - Impact on carbon tax ($), baseline and and policies (2020)

	CO2 policy	CO2 + Policy_2
Italy	118	103
France	84	**91**
Germany	53	52
Spain	121	116
UK	75	75

Table 8 - Impact on GDP growth (%), difference between baseline and policies (2020)

	CO2 policy	CO2 + Policy_2
Italy	-0.64	**0.24**
France	-0.01	-0.71
Germany	-0.11	-0.23
Spain	-0.33	**0.28**
UK	-0.20	-0.56

4. Some conclusions

The Gdyn –E model, characterized with the inclusion of CO2 emissions and elements of the Gtap-dyn model (Ianchovichina and McDougall 2001), allows to evaluate not only the economic impacts of the long-term emission reduction policy but also the pattern of emissions reduction needed to reach the target. Calibration and parameters adjustments are fundamental to have a model right for the purpose we want.

Moreover, two counterfactual scenarios have been presented to assess the impacts of the climate policy avoiding fist of all the impacts on the output of the land transport sector and in a second experiment the effects on the trade balance. In both cases has been possible to evaluate, among others results, the impacts on GDP, the carbon tax and the needs in terms of productivity of the land transport sector to maintain the selected elements (output of land transport and trade balance) at the baseline level.

The focus on the land transport and on the main European countries permitted to confirm the relevance of the sector in this countries. On other hand, however, it also show how the policy options, if we want to mitigate, under a competitiveness point of view, the impact of emissions reduction, it is not straightforward in which direction should be put the effort. We show that a support to the land sector, both with the objective of trade balance or sectoral output, could have trivial effects on the GDP and trade balance too (when sectoral output is the target). By this way, CGE mode, with explicit representation of emission, is a needed tool for better describe policy intervention.

Regarding further research, under methodological point of view we plan to introduce an uniform variable for the productivity for all transport sectors (air, water and land), in order to make more comparable the two policies analyzed, trade balance versus sectoral output (for transport sectors).

Introducing the no-Co2 emissions, biofuels and partial endogenous technological change will be also part of the project research in order to produce more consistent output.

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