

Green budgeting and the evaluation of mitigation policies in Italy¹

Paolo Di Caro (University of Catania; Department of Finance, Ministry of Economy and Finance, Italy)

Carlo Orecchia (University of Essex, United Kingdom)

Abstract: *Environmental goals play an increasingly important role in the European and Italian policy agenda. This is timely and relevant to recalibrate the recovery from the COVID-19 pandemic crisis towards a green transition. To achieve climate objectives, however, there is a need for internal support (from citizens and firms) and external cooperation (among countries/continents). In this contribution, we participate in the current discussion on the appropriateness of climate change policies in the EU and Italy in two main directions. First, we provide a review of the main contents of the Union-wide and national climate change strategies in order to shed new light on the most recent measures, such as the European Green Deal and the Fit for 55 package at the EU level and the Italian recovery and resilience plan. Second, we present and discuss some results related to the application of the Fit for 55 package in terms of economic effects. Our impact assessment, based on a CGE-environmental model, shows heterogeneous effects of EU climate change policies on production, competitiveness, consumption and carbon leakage. The main policy message deriving from our empirical application, therefore, is that the support of climate change policies, both at national and Union-wide level, necessarily implies the understanding of the overall consequences of climate change policies.*

Contents: 1. Introduction - 2. Green budgeting in the EU and Italy - 2.1. Environmental fiscal reforms in the EU - 2.2. The Italian green budgeting process - 3. An evaluation of mitigation policies in Italy - 3.1. Policy framework - 3.2 Methodology and data - 4. Empirical results - 4.1 Calibration and Scenarios - 4.2 Main findings - 5. Concluding remarks – References.

1. Introduction

There is now growing consensus among policymakers, practitioners and citizens about the need of considering climate change issues as priorities of intervention in current days, when the make-or-break decade has already

¹ The views expressed in the paper do not reflect those of the institutions of affiliation. The usual disclaimer applies.

started. The opportunities to prioritise green policy reforms that help promote environmental objectives and speed up structural change towards a low-carbon transition are particularly relevant at the time of the COVID-19 pandemic, when concerted policy actions are required to sustain social and economic recovery (OECD, 2021). At the time of writing this contribution, world leaders are meeting for the United Nations Climate Change Conference of the Parties (COP26) in Glasgow, where the goal of limiting global warming to 1.5°C until 2100 is expected to be formally defined in an international agreement². In July 2021, the G20 Environment Ministers met in Naples under the Italian presidency and committed to continue and increase efforts to address, among others, the interconnected challenges of climate change, biodiversity loss, and pollution in order to work for a healthy planet, improve human well-being, and achieve inclusive and sustainable production and consumption (G20, 2021). In this context, the European Union (EU) aims at leading the international climate change agenda with the recalibration of Union-wide policies for achieving environmental goals, the most important of which is becoming the first climate-neutral continent by 2050, by the adoption of important actions like the European Green Deal and the recent Fit for 55 package (EU Commission, 2021). Similarly, Italy is expected to achieve ambitious targets on climate change in the coming years: in the national Recovery and Resilience Plan (RRP), about €191.5 billion (37% of total) has been allocated to green transition (Presidenza del Consiglio dei Ministri, 2021)³.

Despite the surge of information and ideas regarding environmental issues, the economics of climate change, that is, the application of economic analysis tools in this area of policymaking, is complicated and requires attention, given the presence of very long-run forecasts and the difficulty to separate the signal from the noise (Weder di Mauro, 2021). Moreover, climate change policies like carbon pricing and/or emission trading schemes (ETS) rarely produce effects on individual countries/continents alone, but they have cross-border consequences and impact competitiveness among trading partners (Eunomia, 2016). Therefore, the understanding of the overall impact of environmentally-related policies is crucial to mobilising a broad policy consensus both within and across countries for sustaining particular reforms (World Bank, 2005; Furceri et al., 2021) and, most importantly, to sustaining

² For more information, see <https://ukcop26.org/it/gli-obiettivi-della-cop26/>.

³ For more information, see

<https://www.governo.it/sites/governo.it/files/PNRR.pdf>

the relevance of specific policy actions with grounded evidence (Parry et al., 2012). Knowing the effects of climate change policies more in depth is also important from a redistributive perspective, given the climate-inequality nexus that can be observed when looking at the consequences of environmental policies on individual/household social and economic conditions (Chancel and Piketty, 2015). Cruz and Rossi-Hansberg (2021), for instance, show that the geography of global warming is quite unequal across continents, with major welfare losses registered in countries located in Africa and Latin America.

The main objective of this contribution is twofold. First, we provide an updated review of the main policy actions in the area of climate change that have been undertaken in the EU and Italy in recent years, by adopting a public economics perspective. In detail, we organise recent, selected EU and Italian environmental reforms that can be considered part of the green budgeting process in line with recent evidence for selected EU Member States (MS) (Bova, 2021)⁴. We analyse EU and Italian regulations and laws on climate change in order to provide an economic rationale for such reforms, disentangle the specific policy tool under investigation, and try to understand the potential impact of the different European and national policies on public revenues⁵. This is timely and relevant, at least from our point of view, given the plethora of official documents on climate change policies that can be observed at the EU and Italian level (Weder di Mauro, 2021). Selecting the nature and effects of environmental fiscal reforms can be also useful to promote their implementation: for instance, the recent International Monetary Fund (IMF) proposal on setting an International Carbon Price Floor received support after the gains of such policy had been carefully evaluated in a comprehensive report (PwC and the World Economic Forum, 2021).

⁴ The Green Budgeting Process can be defined as «using the tools of budgetary policy-making to help achieve environmental goals. This includes evaluating environmental impact of budgetary or fiscal policies and assessing their coherence towards the delivery of national and international commitments. Green budgeting can also contribute to informed, evidence-based debate and discussion on sustainable growth» (OECD, 2017).

⁵ In this contribution, we do not explicitly look at green finance for climate-related investment, for which there is mixed evidence at present date, mostly because we are directly interested in analysing environmentally-related tax policies (CEPR, 2021). According to the IMF's Global Financial Stability Report, the world's \$50 trillion investment fund industry, especially funds with a sustainability focus, can play an important role financing the transition to a greener economy and helping to avoid some of the most perilous effects of climate change (IMF, 2021).

Specifically, according to this report, the cost of implementation of the proposal would be less than 1% of global GDP, and that cost could be offset by avoiding economic losses associated with global warming and potential productive uses of carbon revenues.

Second, we investigate the economic consequences of Greenhouse Gas (GHG) emission reduction policies (i.e. mitigation policies) for all EU countries in order to assess the possible impacts on the competitiveness of the Italian economic system and on the security of energy supply. In particular, we use the dynamic multi-regional (140 regions) and multi-sector (67 economic sectors) general economic equilibrium model (CGE) ERMES - Economic Recursive-dynamic Model for Environmental Sustainability - to evaluate the overall effects of mitigation policies. We briefly discuss the methodology and, then, we focus on the main empirical results obtained for Italy⁶. We contribute to the literature focusing on the empirical evaluations of the impacts of environmental policies on different economic indicators (Arlinghaus, 2016). Our preliminary results show that the overall change in Gross Domestic Product (GDP) generated by the continuation of mitigation policies is marginal and equal to a contraction of 0.35% in 2030. This figure is consistent with the findings of the assessment of the European Commission (2014), which used its own ERMES model. We also find that, when adopting a sector-specific breakdown, production contracted more in the most emissive sectors (e.g., production of electricity from fossil fuels and steel), while the production of electricity from renewable sources (e.g., solar, wind, hydroelectric), some agricultural sectors, light industry and real estate and insurance services increased.

The rest of the work is organised as follows. In Section 2, we discuss green budgeting in the EU and Italy, by reviewing the main laws and regulations on climate change from a public economics perspective. In Section 3, we present the methodology that we adopt for evaluating the effects of the GHG emission mitigation policies on the Italian economy. In Section 4, we discuss the main empirical findings of our work. The final section concludes with some policy relevant implications.

2. Green budgeting in the EU and Italy

2.1. Environmental fiscal reforms in the EU

Environmental fiscal reforms and the recalibration of European

⁶ It is outside the boundaries of the present contribution to provide a complete treatment of the methodology applied in the empirical analysis.

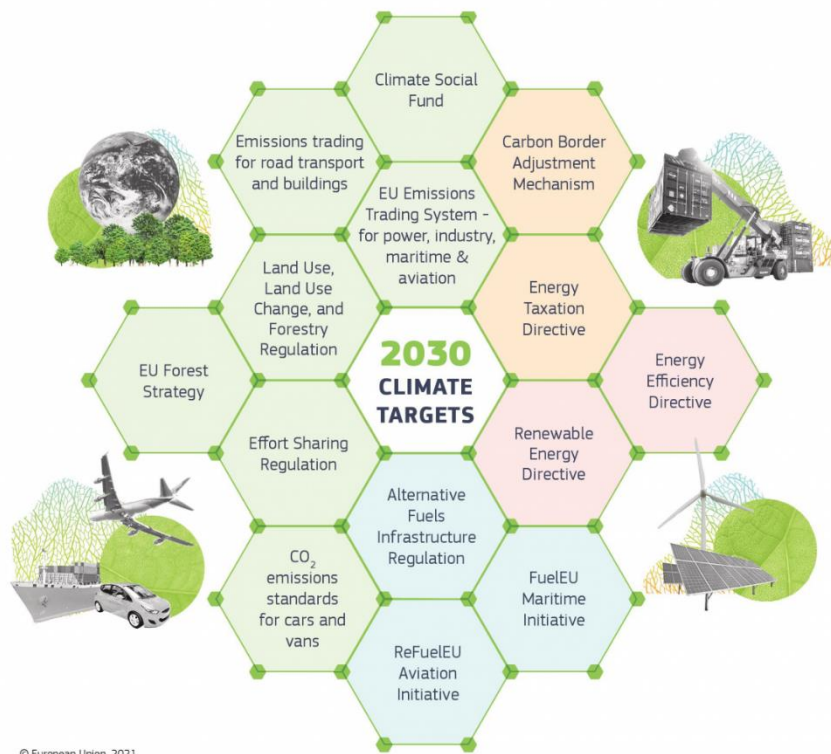
policies towards the ecological transition necessarily imply the usage of green budgeting tools, where public investment, consumption and taxation are redefined to achieve green priorities (EU Commission, 2019)⁷. In December 2019, the EU adopted the European Green Deal with the objective of transforming the EU into a modern, efficient, sustainable and competitive social and economic space: in 2050, the EU is expected to become the first climate neutral economic area⁸. In 2020, the EU Commission presented the proposal of regulation regarding the first European Climate Law to implement the 2050 climate neutrality target; in the same year, the EU Communication *Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people* provided impact assessments on the policy actions required to achieve the EU target of climate neutrality. In particular, the first operational objective has been identified as the reduction of net carbon emissions by 55% by the end of 2030: in July 2021, the Commission proposed the Fit for 55 package that defined the regulations to achieve the 2030 and 2050 targets⁹.

⁷ We follow the definition of environmental fiscal reform (EFR) provided by the World Bank (2005), where EFR refers to a range of taxation or pricing instruments that can raise revenue, while simultaneously furthering environmental goals.

⁸ For more information on the European Green Deal, see https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_it.

⁹ Specific targets set at the EU level can be listed as follows: no net emissions of GHG by 2050, economic growth decoupled from resource use, no person and no place left behind, 55% reduction of emissions from cars, 50% reduction of emissions from vans by 2030, zero emissions from new cars by 2035 (EU Commission, 2021).

Figure 1. The EU Fit for 55 package – synthesis



Source. The European Union (2021).

From the graph illustrated in Figure 1, it can be observed that the achievement of the 2030 climate target in the EU requires the modification/adoption of different budgetary policy tools, including amendments of existing directives and regulations, and the setup of new policy instruments like the Carbon Border Adjustment Mechanism (CBAM). In detail, the CBAM is finalised to impose a tax price on imports of a limited number of high-polluting goods (e.g., aluminium, iron, electricity) based on their carbon content in order to level price competitiveness between the EU MS, where environmental standards must be respected, and the non-EU countries. As for the cleaning of the energy system, the EU Commission proposes to increase the binding target of renewable sources in the EU’s energy mix to 40%. Moreover, the Commission proposes to increase energy

efficiency targets at EU level and make them binding, to achieve by 2030 an overall reduction of 36-39% for final and primary energy consumption. From the revenue side, the new Social Climate Fund will support EU citizens most affected or at risk of energy or mobility poverty, with an expected provision of EUR 72.2 billion euro over 7 years, which will fund the renovation of buildings, access to zero and low emission mobility, or even income support. This new Union-wide fund will be additional with respect to the financial resources for green investments allocated in the Next Generation EU Recovery Plan, which accounts for one third of the total EUR 1.8 trillion invested. Interestingly, the new proposals to achieve the 2030 climate target are expected to generate additional, sustainable, local and well-paid jobs: about 160,000 new green jobs are expected to be created in the building sector by 2030. In Table 1, we report selected policy actions that are part of the EU Fit for 55 Package (EU Commission, 2021).

Table 1. The EU Fit for 55 Package – selected policies

Regulation/Directive	Policy action	Expected objectives
Energy Tax Directive	Revisions	Reduction of primary energy of 39% with respect to 1990 levels
Regulation setting CO ₂ emissions	Amendment for cars and vans	Target of zero emissions for cars and vans by 2035
EU Emission Trading System for Aviation	Revisions	Introduction of a new mechanism of ETS for aviation
Renewable Energy Directive	Amendment to implement the ambition of the new 2030 climate target	Rise of renewable energy up to 40% by 2030
Effort Sharing Regulation	Proposal	Reduction of emissions in sectors not included in the ETS

Source. Our elaboration from the European Union (2021)

The European green budgeting toolkit includes different market and non-market-based policy instruments that can be used to achieve

environmental goals¹⁰. It has to be noted, however, that in this particular policy area the EU dimension needs to take into account the autonomy of each State Members given that fiscal policy is an area of intervention where State Members maintain large competencies. In particular, the revenue side of environmental fiscal reforms is made up of two main policies (OECD, 2017). Environmental taxes, that is, taxes where the tax base is a physical unit (or a proxy of it) that has a proven specific negative impact on the environment, such as energy taxes, transport taxes, pollution taxes and resource taxes (OECD, 2005). Environmentally related taxes that can be defined as payments levied by the government on tax-bases deemed to be of particular environmental relevance (OECD, 2004). The main differences between environmental taxes and environmental related taxes is that the latter do not necessarily imply a link between payments and external costs due to climate issues, while the former do.

Finally, yet importantly, the adoption of environmental fiscal reforms in the EU needs to consider all the building blocks of every green budgeting process (OECD, 2021):

- i. Green budget tagging: classifying budget measures according to their environmental and/or climate impact;
- ii. Environmental impact assessments: requiring environmental impact assessments to accompany new budget measures;
- iii. Ecosystem services: putting a price on environmental externalities (ex. taxes and emissions trading systems) to facilitate achievement of national environmental and climate goals;
- iv. Green perspective to spending review: incorporating consideration of the impact of measures on national environmental and climate goals alongside considerations of efficiency;
- v. Green perspective in performance setting: integrating performance objectives related to national environmental and climate goals.

Moreover, the OECD identifies eight principles that every green budgeting process has to respect: 1) comprehensive assessment of the budgetary impact on environmental commitments; 2) gathering and collecting evidence; 3) coherence of approaches and policies; 4) credibility of

¹⁰ «Market-based policies can be considered as actions that address the market failure of “environmental externalities” either by incorporating the external cost of production or consumption activities through taxes or charges on processes or products, or by creating property rights and facilitating the establishment of a proxy market for the use of environmental services» (OECD, 2007).

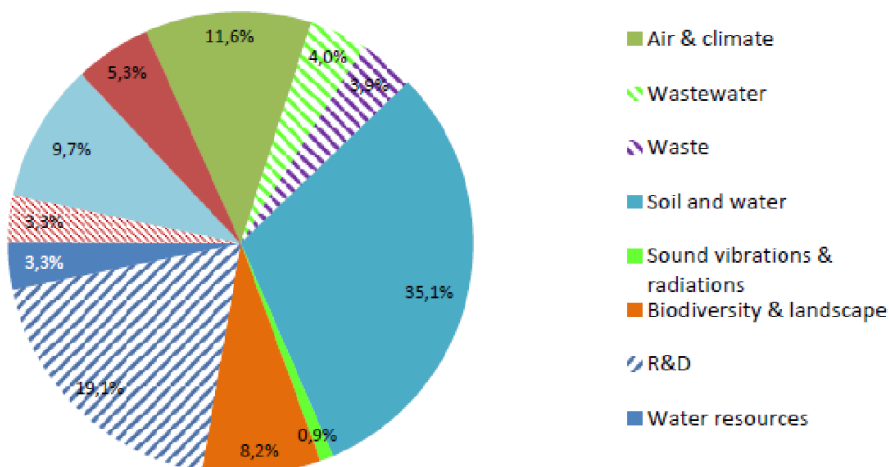
commitments; 5) transparency; 6) fully integrating the environmental perspective into existing budget processes; 7) ensuring fiscal sustainability, and; 8) a whole-of-government (or comprehensive) approach (OECD, 2021)

2.2. *The Italian green budgeting process*

Italy is one of the EU MS with more experience in green budgeting dating back to early 2000, since the Italian eco-budget is set by the Ministry of Economy and Finance; then, the Law 196/2009 provided a detailed methodology to guide the public administration in the assessment of the greenness of items, providing definitions, classifications and instructions on how to apply them to specific actions (Bova, 2021). In particular, the eco-budget (*ecobilancio*) is an annex to the budgetary plan with details regarding expenditure on environmental protection and resource management. Since 2010, pursuant to Law 196/2009, a similar document reporting the budgetary execution of the same expenditure items was presented (*ecorendiconto*). The eco-budget for the year 2021 provides a medium-term planning for the period 2018-23 and it is planned to allocate about EUR 6 billion in environmental spending. In Figure 2, the composition of Italy's eco-budget by environmental objectives is reported (MEF, 2021a). It can be observed that about half of the environmental allocation is devoted to air & climate, soil and water, and water resources objectives. Green budgeting also reports by activity of environmental protection (CEPA) and of resource management (CREMA)¹¹. The two classifications complement each other and allow for a comprehensive and detailed treatment of the environmental goals. To account for different contributions to an objective, the Italian authorities assign a weight in percentage to each action of a program in order to express the extent to which it contributes to the environment at large and, then, to each specific objective.

¹¹ The CEPA classification includes activities whose main purpose is prevention, reduction and elimination of pollution, while the CREMA classification includes activities whose main purpose is preserving and maintaining the scope of natural resources and their safeguarding against depletion.

Figure 2. Composition of Italy’s eco-budget 2021 by environmental objectives



Source. Our elaboration from MEF data (2021)

Since 2017, the *Allegato Indicatori Benessere Equo e Solidale* (BES) is published as an appendix of the annual document on economy and finance (DEF), where data on CO₂ emissions, and other gas emissions, per-capita are reported with the indication of the different targets to be achieved (*indicatore dominio Ambiente*). In 2020, CO₂ emissions decreased by about -0.5 tons with respect to the previous year following the COVID-19 pandemic restrictions, while expectations for the year 2021 register +0.3 tons per-capita following the economic recovery (MEF, 2021b). This indicator provides a description of the quality of environment and the impact of climate change policies *lato sensu* in the Italian economy. There are another two important documents in the Italian green budgeting process. According to the Law 28/2015, every year the Ministry of Environment publishes a *Catalogue of harmful and favorable subsidies to the environment* that report direct subsidies (spending laws) and indirect subsidies (tax expenditures) related to the environment; in 2018, spending laws were equal to about EUR 15.3 billion, where tax expenditures were equal to EUR 19.7 billion. Moreover, the annex on Climate of the Stability Program reports on progress in the implementation of commitments for the reduction of GHG emissions.

The Italian RRP provides relevant support to green transition, including energy efficiency renovations of buildings, both through tax incentives and direct investments for renovations of public buildings, schools, courts, hotels, museums, cinemas and theatres. The plan also includes measures to support offshore power production and smart electricity grids, and actions to reduce GHG emissions from transport, with investments in sustainable urban mobility as well as railway infrastructure to support a shift from more carbon-intensive modes of transport. In detail, the main resources/objectives are expected to be allocated as follows: i) target of 72% of renewable energy by 2030; ii) about EUR 23.88 billion to sustainable mobility, of which 30% is to be allocated to local mobility; iii) EUR 140 million to the green community for supporting small villages and provincial projects; iv) EUR 15 billion for resilient land and sea ecosystems. The RRP's Mission 2: *Ecological Transition* is made up of the following «components»: C1) Sustainable agriculture and circular economy; C2) Renewable energy and mobility; C3) Energy Efficiency and renewal of public and private buildings; C4) Protection of land and water resources. It has to be noted that a mix of tax credits (ex. Industry 4.0 package, etc.) and regulations are expected to effectively support the green transition.

In the next years, the Italian fiscal system has to manage and address three main challenges, as stated in the Country Specific Recommendations for Italy of the Council Recommendation of 2019 and 2020: i) the very low economic growth, well below both the Euro area and the EU average; ii) the high tax burden on labour and capital that discourages employment and investments; iii) the persistence of regional and individual disparities in economic and social conditions. In these circumstances, the design of a welfare-enhancing tax system oriented towards the promotion of a smart, sustainable and inclusive economic growth path is crucial. To achieve these objectives, the Italian Government has planned to reform and modernise the Italian tax system in two main directions. First, to shift the tax burden from labour taxes, which are detrimental for economic growth, to environmentally-related taxes (e.g., taxes on waste, energy consumption, pollution, vehicles, etc.), in a budget-neutral way. Environmentally-related tax policies pursue different goals such as counterbalancing the reduction of tax burden on labour by raising tax revenues, and promoting EU-wide energy targets including the decarbonisation of the industrial system. Second, to implement cohesion-friendly tax policies aimed at reducing regional disparities, which are relevant and persistent in Italy, and sustaining the localization of specific economic

activities in lagging regions. Recent examples of such tax policies include PIT/CIT tax credits for smart and sustainable investments in lagging Southern regions. Therefore, the careful evaluation of the overall effects of environmental fiscal reforms is crucial nowadays.

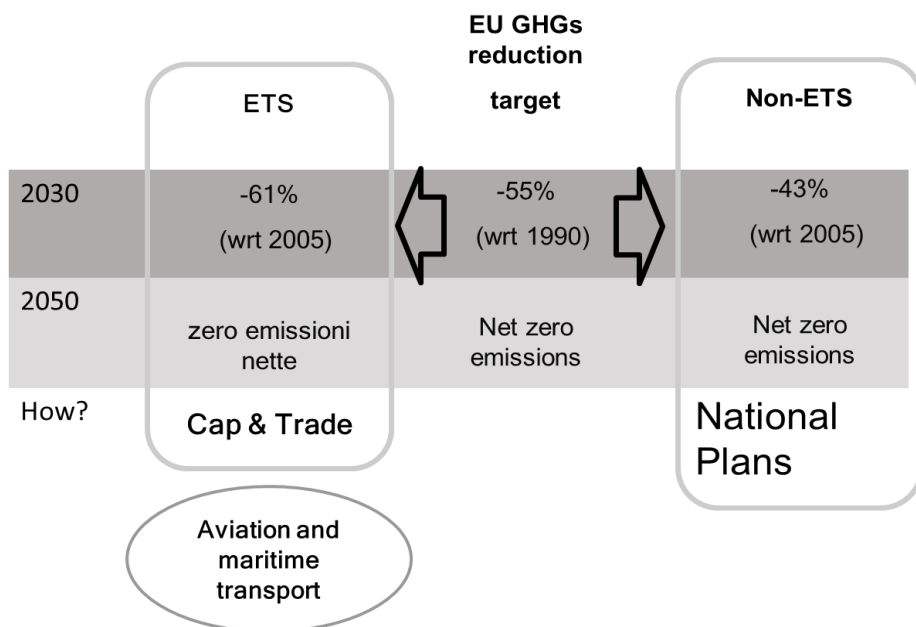
3. An evaluation of mitigation policies in Italy

3.1. Policy framework

In 2009, the EU adopted a set of policy actions - Directives, Regulations and Decisions - called the *20-20-20 Package*, which defined the following climate and energy objectives for the EU to be achieved by 2020: a) 20% reduction in CO₂ equivalent emissions compared to 1990; b) 20% of energy production from renewable sources in gross inland consumption; c) 20% reduction in final energy consumption. The three targets have been translated into national targets and assigned to each MS: the first two targets are binding at national level, while the third is binding only at EU level. In 2014, an agreement called *2030 Climate & Energy Framework* was adopted with the aim of improving the 20-20-20 Package over the period 2021-2030 as follows: a) 40% reduction in emissions compared to 1990; b) 27% of energy production from renewable sources on gross inland consumption; c) 27% improvement in energy intensity. In September 2020, the EU Commission proposed to raise the 2030 greenhouse gas emission reduction target, including emissions and removals, to at least 55% compared to 1990.

On July 14, 2021, the European Commission unveiled a *Fit for 55* package containing legislative proposals designed to enable the achievement of the intermediate targets of the European Green Deal, a 55% reduction in greenhouse gas emissions by 2030 compared to 1990 levels. The package is made up of 12 legislative instruments designed to achieve the objectives set by European climate legislation, and to give the necessary acceleration to the reduction of greenhouse gas emissions in the coming decades, and are applied in different sectors from the energy and climate sector to land use, from transport to taxation. In particular, the EU Emissions Trading System (ETS) remains at the core of the mitigation strategy and its revision aims at reducing the applicable cap on emissions from certain economic sectors each year. The Commission's proposal increases the annual rate of emission reductions, phases out free allowances for aviation and includes maritime transport in the ETS. In figure 3, we report the new EU strategies for mitigation policies.

Figure 3. The new EU strategy for mitigation policies



The transition to a net zero emissions economy requires a profound transformation of the national energy system and, in particular, the power generation sector. Accurate modelling of the power generation sector is crucial with a broad characterisation of technologies and their evolution in the medium and long term. In addition, the definition of segmented GHG emissions regulation at the EU level requires the development of appropriate tools to evaluate the effectiveness and the impact of the numerous policies adopted on the economic system (Antimiani et al., 2013; 2016).

3.2 Methodology and data

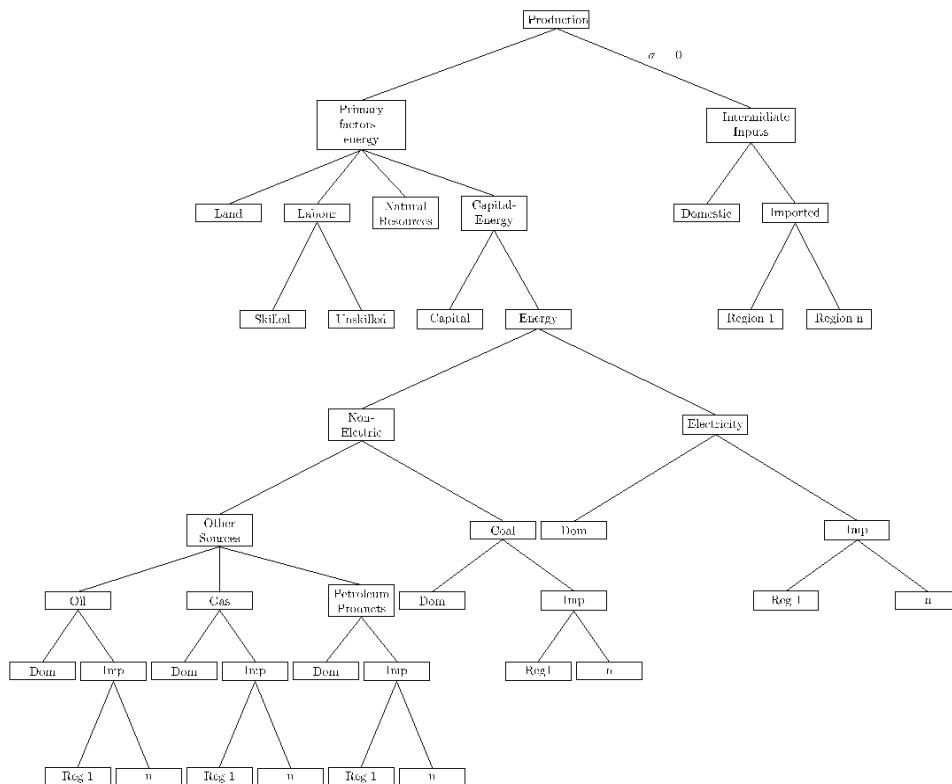
Given the complexity of climate change issues and the implications for the environment and the economy, in this work, we use a macro modelling approach based on the GTAP-E model (McDougall et al. 2007): a dynamic multi-regional (140 regions) and multi-sector (67 economic sectors) general economic equilibrium model (CGE) ERMES (Economic Recursive-dynamic Model for Environmental Sustainability). In the ERMES framework, the representative agents are firms, households and governments. Sectoral and

input markets worldwide are modelled in an open economy. The model is able to simulate a very broad set of policies: energy-climatic, fiscal (e.g., the reduction of the so-called tax wedge), and trade (e.g., the introduction of import tariffs and export subsidies), by assessing their impact both on the economy as a whole and on individual sectors. ERMES falls into the category of top-down models that also allow the indirect effects of economic policies to be analysed, i.e., how and to what extent a shock affecting certain sectors spreads to other sectors of the economic system.

In ERMES, 11 types of technology are modelled, including renewable energy sources used for electricity generation, which assume different degrees of substitutability between the different technologies. In addition, since the reduction targets cover all GHG emissions, i.e., CO₂ emissions from the combustion of fossil fuels and CH₄, N₂O and FGASS emissions from agriculture, industrial processes and the residential sector, all GHGs are modelled in ERMES. As a result, it is possible to provide a framework fully consistent with the climate policies defined at European and international level. Due to the crucial role of international trade, in ERMES, GHG emission reduction policies/mitigation policies are analysed for all European countries in order to assess the possible impacts on the competitiveness of the Italian economic system and on the security of energy supply.

Industries are modelled through a representative firm that minimises costs by taking input prices as data. In turn, production prices are given by average production costs. Figure 4 illustrates the nested production function (nest) of each representative enterprise within the model. Each nest in the tree combines single or composite inputs into a constant elasticity production function (Constant Elasticity of Substitution - CES or Constant Ratios of Elasticities of Substitution Homothetic - CRESH). The first nest combines the added value with the other intermediate inputs with a Leontief-type function so that the proportions remain fixed during the simulation. The added value, as we continue to the left of the tree, is obtained by combining the factors of production, i.e., land, labour (skilled and unskilled), natural resources and the capital and energy bundle with a CES type function. In turn, the capital & energy bundle is the result of the combination of physical capital and energy. Energy is distinguished between electricity and the rest of the energy produced for transport or heating.

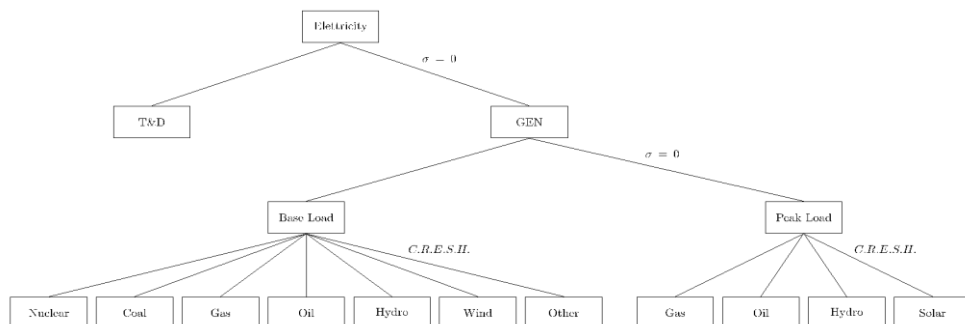
Figure 4 – ERMES model supply structure



In modelling the electricity generation part, Peters' approach (2016a) was followed. Electricity is the result of two components, «generation» which is the production of electricity itself and «transmission and distribution» which includes the distribution of electricity produced through the electricity grid. There is no substitution between these two components, i.e., the transmission and distribution costs are directly proportional to the amount of electricity generated. Finally, generation distinguishes between peak and base technology. A special feature of the electricity sector is that supply has to meet demand instantly. Electricity demand can fluctuate considerably throughout the day (during the daytime hours the demand for electricity is higher than at night; moreover, during the same daytime hours there are peaks in demand around midday), the week (during weekdays the demand is usually higher than on public holidays) and the seasons (the demand during the winter

months is lower than in summer). Some technologies can adapt more easily to these fluctuations by adjusting production (supply) instantaneously, while others require longer technical time. For example, coal-fired power plants cannot easily regulate electricity production in response to sudden changes in demand that can occur within the same day and are therefore classified as 'base' production, which means that it is not competitive in meeting peak demand or instantaneous changes in demand. On the other hand, power plants fuelled with natural gas and oil are able to quickly adjust electricity supply and are therefore competitive in meeting peak demand. In order to replicate these characteristics of electricity generation in the model, the technologies have been separated into two virtual base and peak nests. The core technologies are nuclear, coal, gas, oil, hydro, wind and other. Peak technologies are gas, oil, hydro and solar. In figure 4, we report the structure of the power sector as in the model.

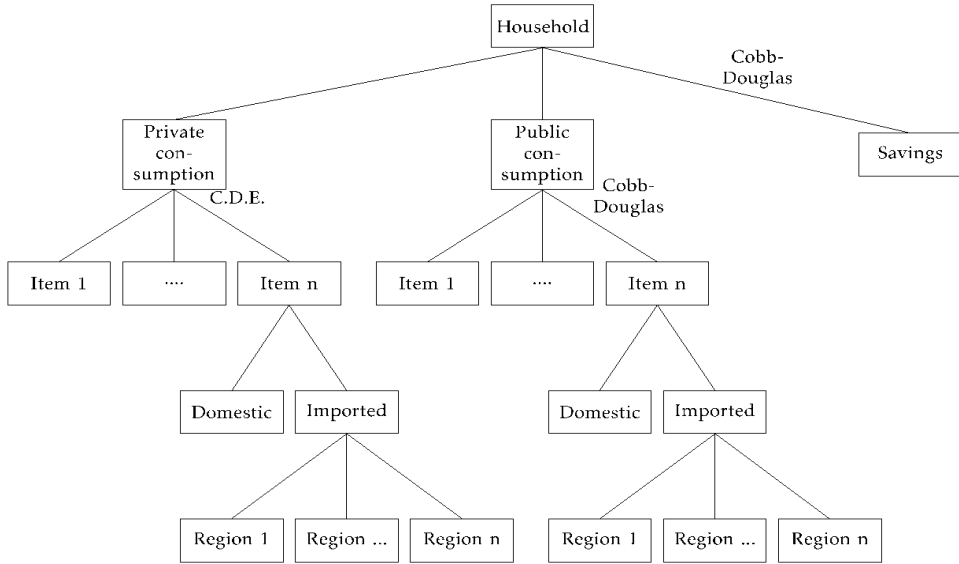
Figure 5 – ERMES model power sector structure



The demand system follows the GTAP standard structure. The economy is modelled according to a representative agent in each region whose Cobb-Douglas utility function allocates expenditure between private consumption (C), public expenditure (G) and savings (S). In turn, the constrained optimisation behaviour of the household in Region *r* for private consumption *C* is represented by a non-homothetic utility function CDE, «Constant Difference of Elasticities» (Hanoch, 1975). There is no explicit form of utility function for this functional form. Demand for private goods is derived from the differentiation of the expenditure function with respect to price and using Roy's identity. A Cobb-Douglas utility function is instead

used for public expenditure. In this case the shares of expenditure are constant on all types of goods. In Figure 6, we report the demand system as in the model.

Figure 6 – ERMES model demand system



Following Ianchovichina and McDougal (2012), the capital stock varies over time according to a recursive dynamic. In each simulation the capital stock in the following year is the same as in the last, minus the net of depreciation and increased by the investment as follows:

$$K_{r,t} = I_{r,t} + (1 - \delta)K_{r,t-1}$$

where $K_{r,t}$ is the capital in the Region r at the end of period t , $K_{r,t-1}$ is the capital in the previous period, δ is the depreciation rate and I_r is the investment in the Region r . In other words, in the future, the new capital stock may differ from the accumulated stock for two reasons: first, one can invest in new capital, then, depreciation can decrease the value of the existing capital stock. Depreciation is due to wear and tear, rupture or obsolescence of capital goods and is equal to δ a share of the existing capital stock.

As for GHG emissions, the model incorporates information on emissions of all greenhouse gases listed in the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and 14 fluorinated gases (PFC, HFC and SF₆). CO₂ emissions are generated by the combustion of fossil energy products by the various sectors of the economy, including large-scale emitters such as the energy and industry sectors and smaller ones such as the residential sector. Information on the rest of the non-CO₂ greenhouse gases is introduced into the model using the GTAP satellite database (Irfanoglu et al., 2015). In particular, the database distinguishes between three emission sources: those related to input consumption (e.g., fertiliser use in agriculture), those related to the use of primary factors (e.g., rice or capital land in livestock production) and those related to production (e.g., wastewater treatment). Emissions from the use of inputs evolve in proportion to the demand for these inputs. Emissions from the use of primary factors are linked to the evolution of their consumption. Finally, emissions from production are linked to production. For example, nitrous oxide emissions from the use of fertiliser use depend on demand from the agricultural sector (i.e., rice, other crops, vegetables and fruit) for the fertiliser producing sector (chemical sector). Methane emissions from rice cultivation are linked to land demand. A more detailed discussion of the approach taken can be found in Orecchia and Parrado (2013a, b).

The ERMES model is able to simulate a very wide set of policies. Emission mitigation policies in CGE models are mainly implemented through carbon taxes, explicit or implicit, aimed at internalising the external costs produced by polluting activities. The introduction of a price for CO₂ emissions allows us the simulation of two different policies: introduction of a carbon tax, and consequently the amount of emissions is defined endogenously by the model; introduction of an emissions cap, and consequently the carbon price is defined endogenously by the model. Carbon taxes are introduced in the model through specific *ad valorem* rates depending on the source of emissions: fossil fuels; primary factors, such as capital or land; some production sectors. Emissions tax rates are calculated, for each emission source, as the ratio between tax revenues and total tax base. Subsequently, the *ad valorem* tax is added to the supply price of the asset, thus determining the market price that households and firms face. The increased revenue generated by carbon taxation increases the government's income.

Cap on emissions.

The introduction of a cap \underline{E}_r on emissions is done through a special equation that imposes, for each sector j , a limit on the level of GHG emissions ($TGHG_r$) allowed for each Region r .

$$\underline{E}_r = \sum_{j=1}^J TGHG_{j,r}$$

The emission cap can be set exogenously by a policy maker at a certain level, leaving the model free to determine the carbon tax endogenously. ERMES also allows us the simulation of an emissions trading system (ETS) between two or more countries similar to the European system EU-ETS. To simulate the introduction of an ETS, a cap is set on the total amount of certain greenhouse gases that can be emitted by the sectors and countries covered by the system. Within this limit, the sectors receive (grandfathering) or buy (auctioning) emission allowances, which they can trade if necessary. The scarcity of allowances means that the available allowances have a price.

In the model, in particular, countries that trade «permits» form a single “block” and behave as if they were a single country with an overall emissions cap that determines a single price. Each sector will decide whether to respect the quota or issue more or less according to its own abatement costs (and therefore sell or buy «permits»), as the optimal conditions are always verified for each sector which maximises its profit and each agent its usefulness.

ERMES is built on the model prepared by the GTAP - Global Trade Analysis Project -¹² consortium and, in particular, it relies on the static model

¹² GTAP is promoted by an international consortium that includes, among others, institutions such as the World Bank, OECD, WTO, UNCTAD (United Nations Conference on Trade and Development), the European Union Commission and the International Trade Commission of the United States. Within the GTAP project both a database and a general economic equilibrium model have been developed, both hosted and periodically updated by the University of Purdue (United States of America). The model was initially used to assess trade agreements such as the Uruguay Round Agreement of the WTO but, more recently, also to assess international climate agreements within the IPCC (Intergovernmental Panel on Climate Change) and the UNFCCC. Moreover, most of the multi-regional economic-energy and environmental models derive from the GTAP model and use the GTAP Data Base: the OECD ENV-Linkages model, GEM-E3 of the EU Commission, and the EPPA of the Massachusetts Technical Institute.

GTAP-E (McDougall and Golub, 2007); it uses the data contained in the GTAP 9 Data Base (Aguilar et al., 2016). In our contribution, the GTAP's original structure has been extensively modified and updated in order to assess the impacts of greenhouse gas emission containment policies on the Italian economy. In particular:

- the capital stock is not fixed, but varies over time according to the so-called recursive dynamics;
- a recent version of the GTAP Data Base, i.e. 9.2b¹³, was used. It updates the input-output tables to those of 2010 among the most recent available for Italy and the EU;
- the energy system of the model has been extended in detail and considers the possibilities of substitution between 11 different types of sources, including renewable and clean energy (Peters, 2016a; 2016b);
- substitution between energy sources is based on CRESH - Constant Ratios of Elasticities of Substitution, Homothetic - (Hanoch, 1975) functional forms with different levels of substitution for each technology;
- CO₂ emissions from energy processes have been included; in addition to those of CH₄, N₂O and F-gases from agriculture, industrial processes and residential¹⁴;
- energy volumes per source and per final sector of use and import and export flows are included;
- the economic policy module allows three types of measures to be imposed simultaneously on different sectors: tax, setting an emissions cap and a cap & trade;
- gas types (CH₄, N₂O, and F-gases), economic sectors and countries covered by the economic policy measure can be selected;
- the economic sectors have been disaggregated considering those included in the ETS (blue cells in Table 2) and non-ETS (orange cells);
- Countries were aggregated giving their relevance as a trading partner considering the volume of bilateral trade with Italy.

¹³ <https://www.gtap.agecon.purdue.edu/databases/v9/default.asp>

¹⁴ A more detailed discussion of the approach taken to introduce taxation on non-CO₂ emissions can be found in Orecchia and Parrado (2013 a, b).

Table 2. *ERMES* – sector breakdown

Sectors	
Paddy rice	Ferrous metals
Wheat	Metals nec
Cereal grains nec	Metal products
Vegetables, fruit, nuts	Motor vehicles and parts
Oil seeds	Transport equipment nec
Sugar cane, sugar beet	Electronic equipment
Plant-based fibres	Machinery and equipment nec
Crops nec	Manufactures nec
Bovine cattle, sheep and goats, horses	Transmission and Distribution
Animal products nec	Nuclear power
Raw milk	Coal-fired power
Wool, silk-worm cocoons	Gas-fired power as base load
Forestry	Wind power
Fishing	Hydroelectric power as base load
Coal	Oil-fired power as base load
Oil	Other power: waste, biofuels, biomass, geothermal, tidal
Gas	Gas-fired as peak load
Minerals nec	Hydroelectric as peak load
Bovine meat products	Oil-fired as peak load
Meat products nec	Solar power: photovoltaic and thermal
Vegetable oils and fats	Water
Dairy products	Construction
Processed rice	Trade
Sugar	Transport nec
Food products nec	Water transport
Beverages and tobacco products	Air transport
Textiles	Communication
Wearing apparel	Financial services nec
Leather products	Insurance
Wood products	Business services nec

Paper products, publishing	Recreational and other services
Petroleum, coal products	Public Administration, Defence, Education, Health
Chemical, rubber, plastic products	Dwellings
Non-metallic minerals: cement, plaster, lime, gravel	

4. Empirical results

4.1 Calibration and Scenarios

Static calibration refers to the process by which the initial year or base year of the model is reconstructed. The GTAP Data Base used for the preparation of the ERMES model is version 9.2b which updates the Input-Output matrix of 2010 for Italy. The reference year of the database is 2011 and has been updated to 2015 by calibrating GDP, population, sectoral added value, sectoral emissions, energy volumes and fossil fuel prices to the observed data. In the dynamic calibration, a «counterfactual» balance is estimated, imposing a disturbance of exogenous factors to the model (e.g., population, GDP, stock of productive resources), building a future benchmark referring to the year 2030. Projections are taken from the EU Reference Scenario 2030 published in July 2021¹⁵. Since, at this stage, shocks related to mitigation policy are not included, the benchmark is a hypothetical picture of the world economic structure in 2030, in the absence of disruptive effects of any kind, and is called the baseline scenario (Business As Usual - BAU).

The following scenarios have been simulated with the ERMES model:

1. The “reference” scenario without additional mitigation policies: reduction of 40% of GHGs with respect to 1990 under cap and trade mechanism (ETS);
2. The “MIX” in which it is assumed that 55% emissions reduction with respect to 1990 in the ETS in line with the Fit for 55 package;
3. The “MIX-AUC” in which, in addition to the ETS, the reduction in emissions in non-ETS sectors is implemented with full auctioning in trade exposed sectors from 2015 onwards.

In this contribution, we do not explicitly analyse the effects of a full CBAM proposal implementation, which are investigated in a companion

¹⁵ <https://op.europa.eu/en/publication-detail/-/publication/96c2ca82-e85e-11eb-93a8-01aa75ed71a1>

work (Castaldi and Orecchia, 2021).

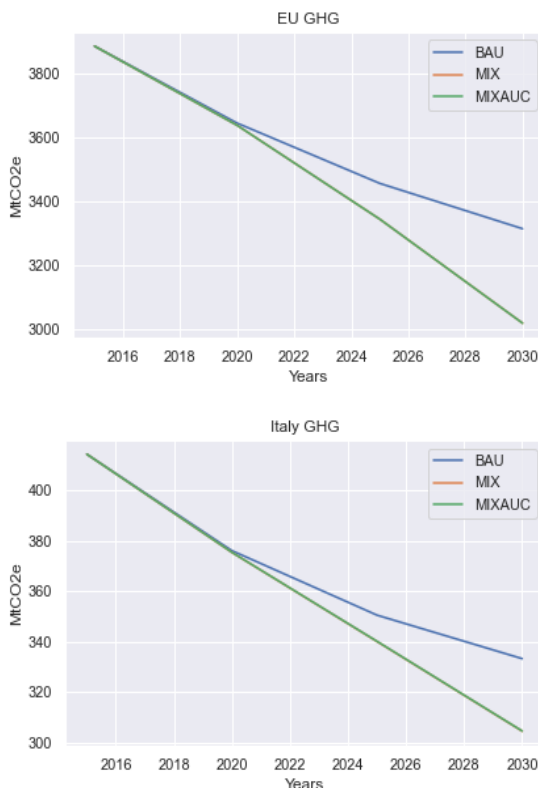
4.2 Main findings

In this section, we report the main results obtained by applying the ERMES model to simulate the effects of the two different scenarios (MIX and MIX-AUC) in terms of carbon leakage, that is, a rise in carbon prices following the climate change policies. This is endogenously calculated from the application of the model as a result of ETS exchanges among the MS. From 2020 to 2030, in all the scenarios, the emissions quota determines a reduction of 55% with respect to the levels of 2005. The first result is that, following the ETS, the carbon price rises to about 54.2 and 53.5 in the MIX and MIX-auctioning scenarios, respectively from a value of EUR 34.5 per ton/CO₂e of the reference scenario (i.e., Baseline). In Table 3, we report simulation results regarding the macroeconomic indicators. It is worth observing that, for instance, the additional reduction of emissions in MIX and MIX-auctioning scenarios of -9% leads to a small GDP loss of around -0.2% and to a leakage rate, which is calculated as the ratio between the increase of CO₂ emissions in countries that do not adopt mitigation policies and the reduction of CO₂ emissions in countries that adopt mitigation policies, equal to 0.71 and 0.75, respectively. Emissions in the Rest of the World increase by 0.38 and 0.40 in the two scenarios respectively. This finding suggests that, all things being equal, the carbon leakage effects of policies undertaken in the EU only can have relevant implications on competitiveness of EU MS.

Table 3. Simulation of environmental impact of the reforms

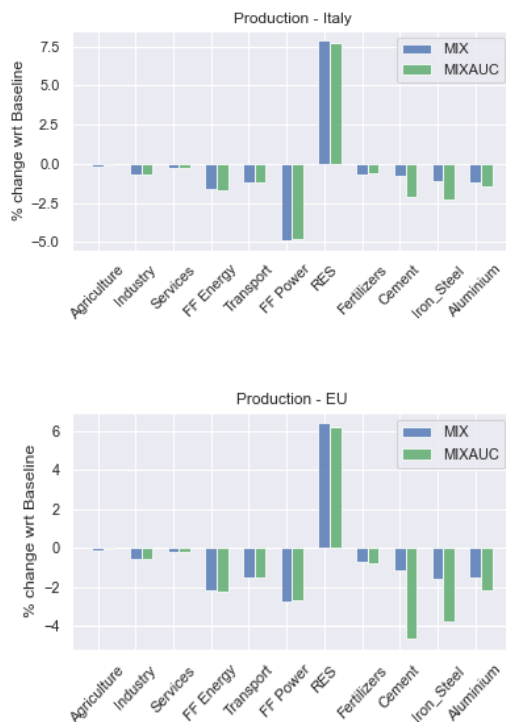
<i>Scenario</i>	GDP (% var. wrt 2030 baseline)		Emissions reductions (% var. wrt 2030 baseline)		Carbon Price (EUR per ton/CO ₂ e)	Emissions in the rest of the World (% var. wrt 2030 baseline)	Leakage rate
	TA	U	TA	U	EU	World	World
MIX	0.24	0.22	9.0	8.6	54.2	0.38	0.71
MIX -Auctioning	0.23	0.21	9.0	8.6	53.5	0.40	0.75

Figure 7. GHGs Emissions reductions in different scenarios (MtCO_{2e})



In addition, in the MIX-auctioning scenario, both imports and exports from the rest of world decrease with a net negative effect on the balance of trade, worsening the external commercial position of EU MS. This situation is counterbalanced if a full CBAM option is taken into account (Castaldi and Orecchia, 2021) at least for the sectors and products covered by the introduction of the CBAM mechanism. Finally, yet importantly, two more results are worth commenting upon. First, the loss of competitiveness of the Italian and EU economy is present when looking at the MIX and MIX-AUC scenarios, particularly in the energy-intensive sectors. Second, from a sector-specific perspective, sectors like cement, steel and iron register more pronounced welfare losses in Italy and the EU after simulating the effects of climate change policies.

Figure 8. Output by sector (% changes wrt Baseline)



In the rest of the economy, moreover, the impact of the mitigation policies simulated on production is no different under the two alternative scenarios. In the area of renewable energy, sectors like solar, wind-power and hydroelectric, register positive production changes both in the EU (about 6%) and Italy (about 7%). Lastly, from the demand side, the consumption prices show an increase in the sectors of heating, fuels, and electricity. Indeed, from our simulations, it shows that fuel prices increase by about 3% in Italy and the EU, while heating costs rise by about 9% in Italy and the EU. For a more detailed discussion, see (Castaldi and Orecchia, 2021).

5. Concluding remarks

Environmental objectives are at the forefront of the public debate and they are mounting in importance in the policy agendas of governments worldwide. One of the main policy tools is represented by green budgeting

and, in particular, green-tax reforms that can be implemented by a series of complementary measures like introducing new taxes or restructuring existing taxes (OECD, 2017). The recalibration of national, European and international policies for supporting a green transition is particularly timely given the need of focusing policy actions at the time of the COVID-19 pandemic crisis (IMF, 2021). This means that there is a need for aligning stimulus programs such as the European and national recovery and resilience plans with decarbonisation objectives. To achieve climate goals, however, there is a need for internal support (from citizens and firms) and external cooperation (among countries/continents) (Nordhaus, 2005). In other words, the principle of solidarity must inspire all climate change reforms (EU Commission, 2021).

In this work, we have contributed to the current discussion on the appropriateness of climate change policies in the EU and Italy in two main directions. First, we have provided a review of the main contents of the Union-wide and national climate change strategies in order to shed new light on recent measures, such as the European Green Deal and the Fit for 55 package at the EU level and the Italian recovery and resilience plan. In detail, we have selected the main laws and regulations regarding climate change and we have commented on the potential effects of such measures on public revenues. We have also clarified some concepts related to the green budgeting approach with application to Italy. Second, we have presented and discussed some results related to the application of the Fit for 55 package in terms of economic effects. Our impact assessment, based on a CGE-environmental model, shows heterogeneous effects of EU climate change policies on production, competitiveness, consumption and carbon leakage. The main policy message deriving from our empirical application, therefore, is that the support of climate change policies, both at national and Union-wide level, necessarily implies the understanding of the overall consequences of climate change policies.

REFERENCES

A. AGUIAR, B. NARAYANAN, R. MCDUGALL, *An overview of the GTAP 9 data base*, in *Journal of Global Economic Analysis*, 2016, 1(1), pp. 181-208.

A. ANTIMIANI, V. COSTANTINI, C. MARTINI, L. SALVATICI, M.C. TOMMASINO, *Assessing alternative solutions to carbon leakage*, in *Energy*

Economics, 2013, 36, pp. 299-311.

A. ANTIMIANI, V. COSTANTINI, O. KUIK, E. PAGLIALUNGA, *Mitigation of adverse effects on competitiveness and leakage of unilateral EU climate policy: An assessment of policy instruments*, in *Ecological Economics*, 2016, 128, pp. 246-259.

J. ARLINGHAUS, *Impacts of carbon prices on indicators of competitiveness: A review of empirical findings*, OECD, Paris 2015.

E. BOVA, *Green Budgeting Practices in the EU: A First Review*, in *European Economy-Discussion Papers*, no. 140, 2021.

G. CASTALDI, C. ORECCHIA, *The economic implications of the EU Carbon Border Adjustment Mechanism in a net importer in raw materials: the case of Italy*, paper presented at SEEDS Annual Workshop, November 2021, Rome.

CEPR, *Finance, money and climate change: open policy panel of the 74th Economic Policy Panel meeting*, London 2021.

L. CHANCEL, T. PIKETTY, *Carbon and inequality: from Kyoto to Paris. Trends in the Global Inequality of Carbon Emissions (1998-2013) and Prospects for An Equitable Adaptation Fund*, Paris 2015.

J.L. CRUZ, E. ROSSI-HANSBERG, *The economic geography of global warming*, NBER Working Paper no. 28466, 2021.

Eunomia, *Study on assessing the environmental fiscal reform potential for the EU28*, Report prepared for Jonathan Parker, DG Environment of the European Commission, Brussels 2016.

EU Commission, *The European Green Deal*, COM (2019) 640 final, Brussels 2019.

EU Commission, *Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people*, COM (2020)562, Brussels 2020.

EU Commission, *Realizing the European Green Deal*, Brussels 2021.

D. FURCERI, M. GANSLMEIER, J.D. OSTRY, *Are Climate Change Policies Politically Costly?*, IMF Working Paper no. 156, 2021.

G20, *Environment communique*, Naples, July 2021.

G. HANOCH, *Production and demand models with direct or indirect implicit additivity*, in *Econometrica*, 1975, pp. 395-419.

E. IANCHOVICHINA, R. MCDUGALL, *Theoretical structure of Dynamic GTAP*, in *Dynamic Modeling and Applications for Global Economic Analysis*, 2012, pp. 13-70.

IMF – International Monetary Fund, *Global Financial Stability*

Report, Washington 2021.

Z.B. IRFANOGLU, D. VAN DER MENSBRUGGHE, *Development of the version 9 non-CO2 GHG emissions database*, in *GTAP Data Documentation*, 2015.

R. MCDUGALL, A. GOLUB, *GTAP-E: A revised energy-environmental version of the GTAP model*, *GTAP Research Memorandum* no. 15, 2007.

MEF (a), *Ecobudget*, Ragioneria Generale dello Stato, Rome 2021.

MEF (b), *Documento di Economia e Finanza, Allegato Benessere equo e solidale*, Rome 2021.

W. NORDHAUS, *Climate clubs: Overcoming free-riding in international climate policy*, in *American Economic Review*, 2015, 105(4), pp. 1339-70.

OECD, *Environmentally-related taxes*, *OECD Glossary of Statistical Terms*, 2004, <https://stats.oecd.org/glossary/detail.asp?ID=6270>.

OECD, *Environmentally related taxes*, *OECD Glossary of Statistical Terms*, 2005, <https://stats.oecd.org/glossary/detail.asp?ID=6437>.

OECD, *Market-based instruments*, *OECD Glossary of Statistical Terms*, 2007, <https://stats.oecd.org/glossary/detail.asp?ID=7214>

OECD, *Environmental Fiscal Reform: Progress, Prospects And Pitfalls*, Paris 2017.

OECD (a), *Green budgeting and tax policy tools to support a green recovery*, Paris 2020.

OECD (b), *Climate Policy Leadership in an Interconnected World: What Role for Border Carbon Adjustments?*, Paris 2020.

OECD, *Tax and fiscal policies after the COVID-19 crisis*, Paris 2021.

C. ORECCHIA, R. PARRADO (a), *A Quantitative Assessment of the Implications of Including non-CO2 Emissions in the European ETS*, *FEEM Nota di Lavoro 100.2013*, Fondazione Eni Enrico Mattei, 2013.

C. ORECCHIA, R. PARRADO (b), *Including non-CO2 Emissions in the European ETS*, in *Review of Environment, Energy and Economics (Re3)*, 2013, <http://ssrn.com/abstract=2342119>

I.W.H. PARRY, J. NORREGAARD, D. HEINE, *Environmental Tax Reform: Principles from Theory and Practice to Date*, *International Monetary Fund Working Paper*, Washington 2012.

J.C. PETERS (a), *GTAP-E-Power: An Electricity-detailed Extension of the GTAP-E model* (presented at the 19th Annual Conference on Global Economic Analysis, Washington DC, USA), in *Global Trade Analysis*

Project (GTAP) 2016.

J.C. PETERS (b), *The GTAP-Power Data Base: Disaggregating the Electricity Sector in the GTAP Data Base*, in *Journal of Global Economic Analysis*, 2016, 1(1), pp. 209-250.

Presidenza del Consiglio dei Ministri, *Italian Resilience and Recovery Plan*, Rome 2021.

PwC and the World Economic Forum, *Climate Ambition: Analysis of an International Carbon Price Floor*, November 2021.

B. WEDER DI MAURO, *Combatting Climate Change: A CEPR Collection*, CEPR Press, London 2021.

World Bank, *Environmental Fiscal Reform*, Washington 2005.

