The removal of fossil fuel subsidies in Italy and interactions with the 2030 EU climate and energy framework

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The removal of environmentally harmful subsidies (EHS, henceforth) is at the centre of the international debate especially after the signature and entrance into force of the Paris Agreement.

To evaluate the macroeconomic benefits stemming from the removal EHS we employed the global dynamic general equilibrium model ERMES (Economic Recursive-dynamic Model for Environmental Sustainability) based on the static model Gtap-E (McDougall et al., 2007) and on the Gtap 9 database (Aguiar et al., 2016) and includes representative firms and households and production factors. This type of models has been used extensively for the evaluation of fossil fuels subsidies removal (Burniaux and Chateau , 2011 and 2014, Bosello and Standardi, 2013; Jewell et al. 2018).

- The original structure of the Gtap-E model has been extensively modified and updated:
- the capital stock is not fixed but varies over time based on the so-called recursive dynamics;
- the energy system of the model has been carefully extended and considers the substitution (with CRESH functions, Hanoch 1975) between 11 different technologies;
- considers all GHGs: CO_2 emissions, CH_4, N_2O and FGASS;
- the climate policy module is flexible enough to select the types of gas (CO_2, CH_4, N_2O, FGAS), the sector (distinguishing between ETS and non-ETS) and the country.

Introduction

The definition, both at European and Member State level, of targets for the reduction of greenhouse gas emissions (so-called GHG or CO_2 equivalent) makes it necessary to evaluate the effectiveness and the impact of the policies adopted on the economic system. Given the complexity of the issue and the implications both of environmental and economic nature, has been developed 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 ERMES, the representative agents are firms, households and government. 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, e.g. a shock due to the introduction of an emission tax or an environmental standard, also spreads to other sectors of the economic system.

The process of decarbonisation of the economy requires a profound transformation of the national energy system and in particular of the power generation sector. For this reason, 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 ERMES, 11 types of technologies are modelled, including renewable energy sources used for electricity generation, assuming different degrees of substitutability between the different technologies. In addition, since the reduction targets cover all greenhouse gas (GHG) emissions, i.e. CO_2 emissions from the combustion of fossil fuels and CH_4, N_2O and FGASS emissions from agriculture, industrial processes and the residential sector, all GHG gases are modelled in ERMES. In this way it is possible to provide a framework fully consistent with the climate policies defined at European and international level.

The role of international trade. Given the crucial role of international trade, in ERMES GHG emission reduction policies (so-called mitigation policies) are analyzed 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.

Preliminary results. The impact simulations obtained using the ERMES model show that the overall change in 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. As mentioned above, ERMES is able to provide an estimate of the impact for each of the 67 sectors in which the Italian economy has been articulated, in particular, production contracted more in the most emissive sectors (production of electricity from fossil fuels and steel), while the production of electricity from renewable sources (solar, wind, hydroelectric), some agricultural sectors, light industry and real estate and insurance services increased.

The policy context

In 2009, the European Union (EU) adopted a set of 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 CO_2 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 Member State; the first two targets are binding at national level while the third is binding only at European level.

In 2014 a framework agreement was adopted, called "2030 Climate & Energy Framework", which, starting from what is defined in the 20-20-20 Package, establishes three binding targets for the EU as a whole to be pursued over the period 2021-2030:

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.

The definition of national targets is currently being negotiated at European level. The objective of reducing emissions is pursued through two instruments: the Emission Trading System (ETS) and the Effort Sharing Directive. The first instrument is the Emissions Trading System (ETS), to which most energy intensity companies are subject; the second instrument, on the other hand, assigns to the individual Member States the objective of reducing CO_2 equivalent emissions in sectors not covered by the ETS - to date, the directive that will have to regulate the 2021-2030 period is still subject to negotiation. The reform of the ETS was launched in February 2018. Among the main innovations, there is a gradual reduction in the number of available permits (cap) through the so-called "linear reduction factor" which will be 2.2% in 2021-2030 compared to 1.74% in 2012-2020.

Both the "20-20-20 Package" and the "2030 Climate & Energy Framework" represent intermediate stages of the "2050 low-carbon economy". In particular, in order to limit global warming caused by climate change to 2ºC, the European Council, with the adoption of the "2050 low-carbon economy" in February 2011, confirmed the EU objective of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990 levels, in the context of the reductions that, according to the Intergovernmental Panel on Climate Change (IPCC), developed countries must achieve collectively.

The definition, both at European and Member State level, of these targets makes it necessary to evaluate the effectiveness of the national policies adopted in order to pursue the assigned objectives and their impact on the economic system, through the use of appropriate quantitative instruments. To respond to this need, a dynamic model of general computational economic equilibrium (CGE) multiregional and multisectoral ERMES, Economic Recursive-dynamic Model for Environmental Sustainability) has been developed.

The remainder of this report explains in section 2 the technical details of the ERMES model and the methodologies used, in section 3 the results of a first application of the model and in section 4 possible further developments of the model.

The Model

ERMES (Economic Recursive-dynamic Model for Environmental Sustainability) is a dynamic model of computational general equilibrium (CGE) multiregional and multisectoral. The representative agents of the model are firms and households; economic sectors and production factors are modelled worldwide. The category of CGE models (also called top-down models) also allows to analyse the indirect effects of energy and climate policies, i.e. how and to what extent a shock affecting certain sectors of the economic system, for example the shock produced by the introduction of a carbon tax or an emissions trading scheme that affects the most polluting sectors, also impacts indirectly on the whole economic system. As shown in Figure 1, the ERMES model chains the different economic sectors (on a national and international scale) through input-output relationships.

The model simulates the functioning of an economic market system with neoclassical assumptions such as the existence of perfect competition, full employment, the achievement of balance in all markets and the presence of international trade. Flexibility, i.e. the variation in relative prices, is the means by which, in markets characterised by perfect competition, it is ensured that demand equals supply and that, whenever there is an exogenous shock, a new balance is always achieved. Within each country, perfect mobility of capital and labour between economic sectors is assumed. Land and natural resources are immobile.

ERMES is built on the model prepared by the Gtap[1] consortium (Global Trade Analysis Project), in particular on the static model Gtap-E (McDougall et al. 2007), and uses the data contained in the Gtap 9 database (Aguiar et al. 2016).

The database is calibrated on real data and the parameterization of the variables of interest (e.g. substitution elasticity between domestic and foreign goods) is based on econometric estimates obtained from the scientific literature (Hertel et al. 2016). It includes 140 countries and regions (aggregates of countries) in the world and 67 economic sectors in an open economy with international trade. International trade examines, for each economic sector, bilateral flows between all regions and is based on developments in the neoclassical theory of comparative advantages and the so-called Heckscher-Ohlin-Samuelson model. This model identifies the causes of the diversity of comparative costs among the different countries and, therefore, the causes of (and incentives to) international trade in their different factor endowment. Like most models of general economic equilibrium, following the approach proposed by Armington (1969) it is assumed that the substitutability in consumption between goods produced in different countries is not perfect

Gtap's original structure has been extensively modified and updated in order to assess the impacts of greenhouse gas emissiosn containment policies on the Italian economy. In particular:

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[1] 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). Both the database and the model have been widely used both in scientific and institutional contexts at international level. 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 database. Among the best known, the OECD ENV-Linkages model, GEM-E3 of the European Commission, EPPA of the Massachusetes Technical Institute (MIT).

- the capital stock is not fixed, but varies over time according to the so-called recursive dynamics;
- a recent version of the Gtap database, i.e. 9.2b[2], was used, which for Italy and the EU updates the input-output tables to those of 2010 among the most recent available;
- 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;
- 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 (as in Peters et al. 2015), but also those of CH4, N2O and FGASS from agriculture, industrial processes and residential;
- 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 FGASS), economic sectors as well as 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 1) and non-ETS (orange cells);

Table 1 - Sectoral 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 fibers	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: photovoltaics and thermal
Vegetable oils and fats	Water

[2] https://www.gtap.agecon.purdue.edu/databases/v9/default.asp

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, Defense, Education, Health
Chemical, rubber, plastic products	Dwellings
Mineral products nec	

- countries were aggregated giving their relevance as a trading partner considering the volume of bilateral trade with Italy. The Regions thus obtained are shown in Table 2.

Table 2 – Regional aggregation

Regions	
01 Italy	09 China
02 Germany	10 Russia
03 France	11 South Asia
04 Spain	12 Latin America
05 United Kingdom	13 Middle East and North Africa
06 Poland	14 Sub-Saharan Africa
07 Rest of EU	15 Rest of the World
08 United States (USA)	

The production

Industries are modelled through a representative firm that minimizes costs by taking input prices as data. In turn, production prices are given by average production costs.

Formally, each firm minimises costs under the production constraint. To simplify the representation, we consider an economy that produces a certain amount of the good Y using two intermediate inputs X_1 and X_2.

Assuming a CES production function, the representative enterprise faces the following minimization problem:

$$\min\ P_1X_1 + P_2X_2 \tag{1}$$

$$s.t.\ Y = A\left(D_1 X_1^{\frac{\sigma-1}{\sigma}} + D_2 X_2^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

where: P_1 and P_2 are market prices, X_1 and X_2 two inputs expressed in quantity, *Y* is the output level, D_1 and D_2 are specific productivity parameters for distribution/factor and σ is the substitution elasticity.

The conditions of the first order of this problem express the demand for each input:

$$X_1 = Y\left(\frac{P_1}{D_1 P_y}\right)^{-\sigma} A^{\sigma-1} \qquad (2)$$

$$X_2 = Y\left(\frac{P_2}{D_2 P_y}\right)^{-\sigma} A^{\sigma-1} \qquad (3)$$

where P_y is the unitary cost of the output Y for the optimal combination of inputs:

$$P_y = \frac{P_1 X_1^* + P_2 X_2^*}{Y}$$

Equations (2) and (3) are linearized and written as percentage changes:

$$x_1 = y - \sigma\left(p_1 - p_y - a_1\right) + (\sigma - 1)a \qquad (4)$$

$$x_2 = y - \sigma\left(p_2 - p_y - a_2\right) + (\sigma - 1)a \qquad (5)$$

Figure 1 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 (Costant 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 Leontiev-type function so that the proportions remain fixed during the simulation. The added value, continuing 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 an 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.

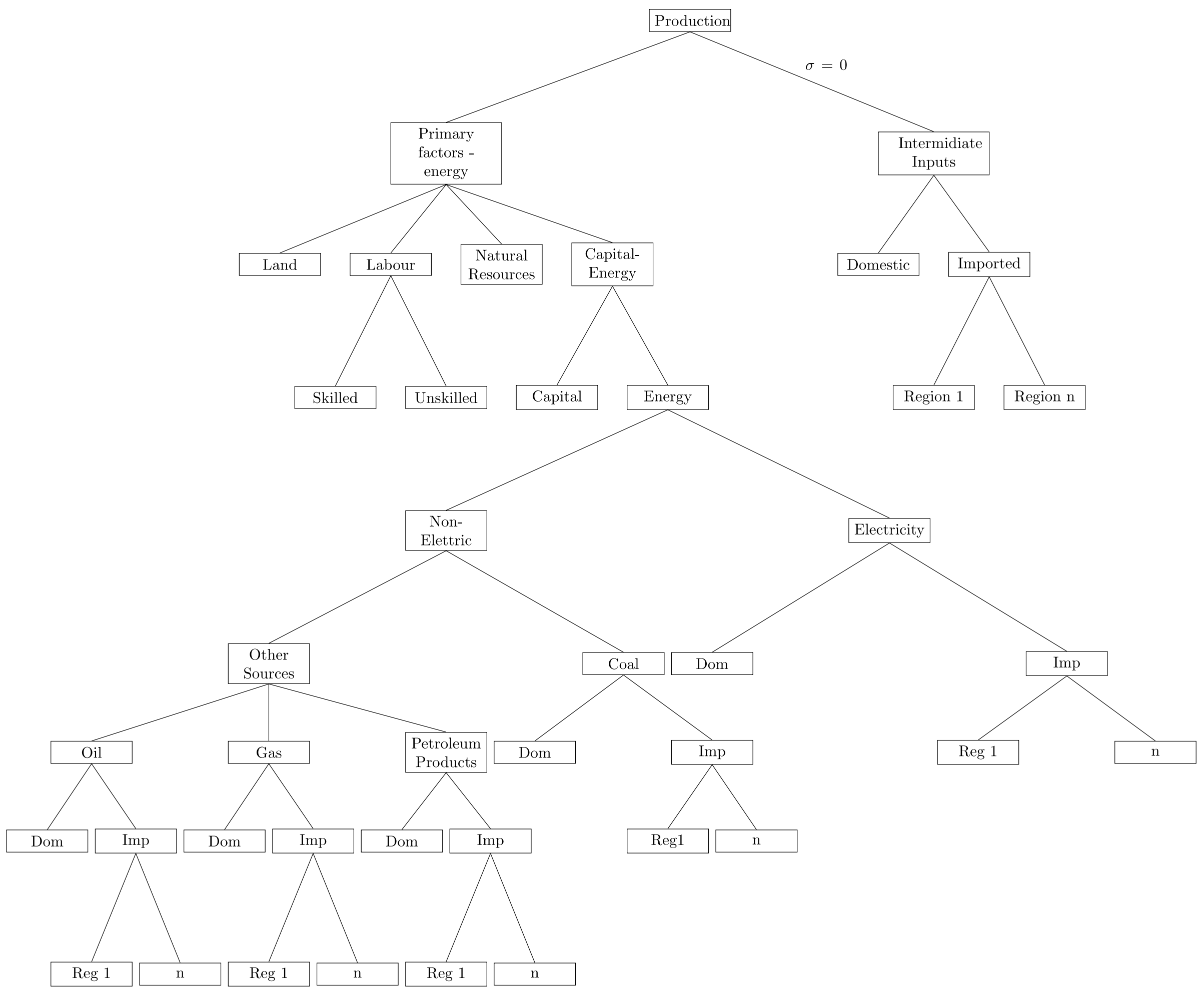

Figure 1 - Supply structure

The power sector

In modelling the electricity generation part, Peters' approach (2015) 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 near the central hours), 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.

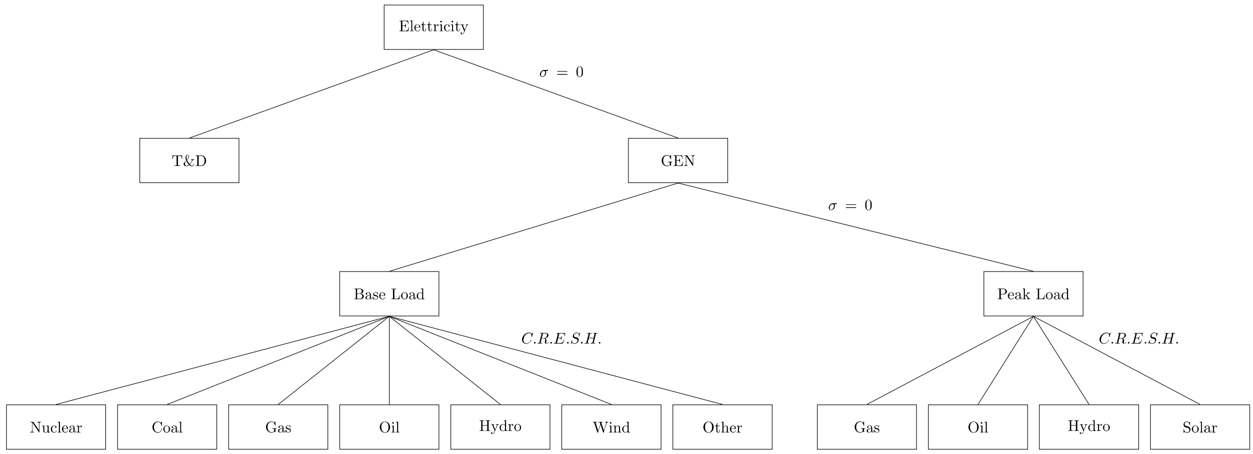

Figure 2 - The power sector

The demand system

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) a nd savings (S) as follows:

$$\max U = H \prod_i U_i^{B_i} \ per\ i = C, G, S \tag{6}$$

$$subject\ to\ \ M = \sum_i E_i(P_i, U_i)$$

Where U_i is the utility of the agent as a function of *C*, *G* and *S*; *H* is a scale factor and B_i are constants, whose sum is equal to 1, and represent the fraction of the income spent on i. E_i represents the expenditure function, the sum of which must be equal to the agent's income.

In turn, the constrained optimization 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. Therefore, the following expenditure function is considered:

$$1 = \sum_c B_c\, U_c^{\Upsilon_c R_c} \left(\frac{P_c}{M}\right)^{\Upsilon_c} \quad per\ c = bene\ 1, \ldots, bene\ n \tag{7}$$

Where U represents utility, P_c the price of the good c, M the income, B_i are the "distribution parameters", Υ the "substitution parameters" and R_c "expansion parameters". The parameters Υ_c and R_c allow to incorporate different elasticities of demand to income for different goods.

Demand for private goods are derived from (7) differentiating with respect to price and using Roy's identity. A Cobb-Douglas utility function is instead used for the public expenditure. In this case the shares of expenditure are constant on all types of goods. The entire demand system described is summarized in Figure 3.

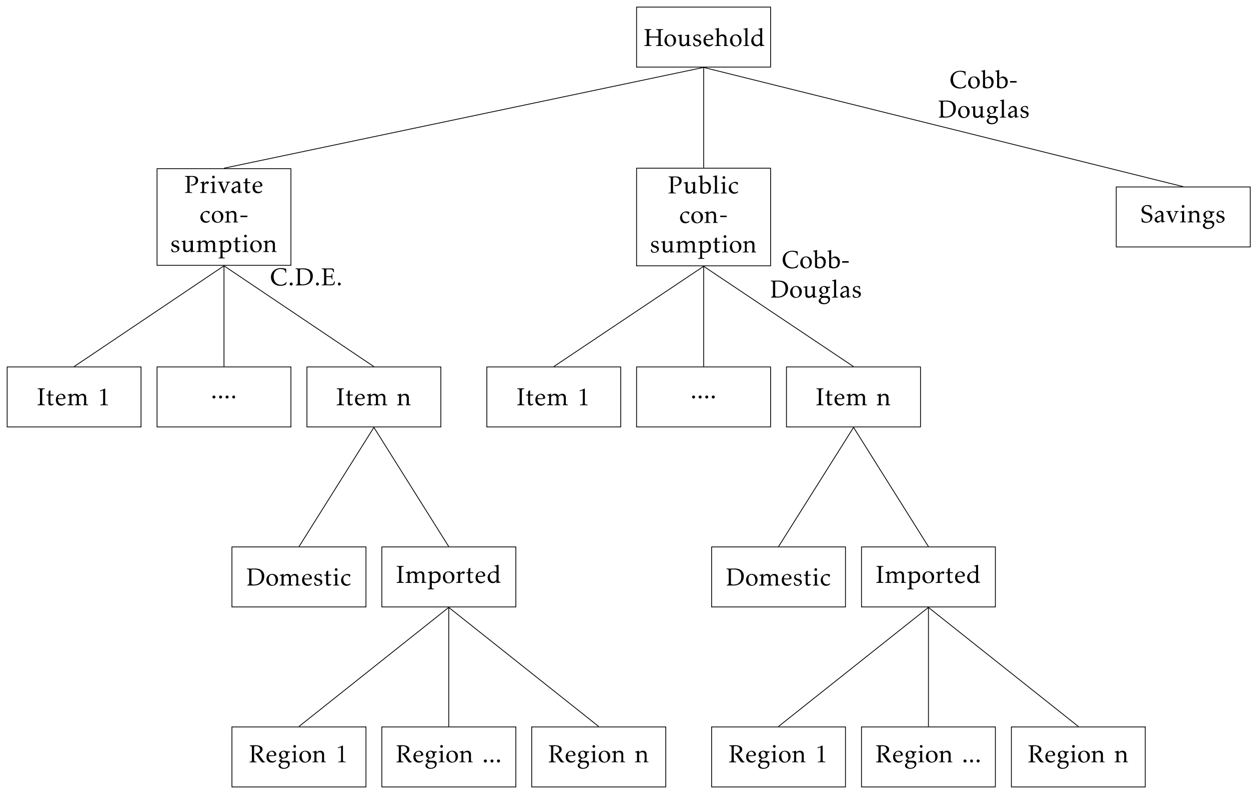

Figure 3 - The demand System

The dynamics

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

$$K_{r,t} = I_{r,t} + (1-\delta)K_{r,t-1} \quad (8)$$

where $K_{r,t}$ is the capital in the r region 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 *r* region. 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. Second, 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. For the capital stock to grow, gross investment must exceed depreciation.

The savings of each region are collected by a "global bank" which then decides how much and in which region to invest them according to the rule:

$$I_{r,t} = PROD_{r,t}\, e^{[(\rho_{r,t}(R^E_{r,t} - R^W_t)]} \quad (9)$$

where PROD is an index of production, $R^E_{r,t}$ and R^W_t are respectively the expected rate of return on capital in the *r* region and the world rate of return on capital or a weighted average of regional returns $R^E_{r,t}$. The assumption is that economic agents have adaptive expectations or gradually correct their errors. According to this approach, if they have underestimated the rate of return in the last period, they then adjust their expectation upwards; if they overestimate it, they adjust it downwards.

According to equation (9) a region in demand (or, put differently, is able to "attract" investment as long as its production increases, or its expected rate of return is higher than the world rate of return. The demand for investment is negatively correlated to R^w, which in turn is determined by the general equilibrium condition that requires equality between global savings and investment.

The parameter $\rho_{r,t}$ reflects the flexibility of capital movements linked to changes in the current rate of return. If $\rho_{r,t}$ has a low value, then it will reduce the effect of the growth of the current rate of return when compared with the growth of the global rate of return.

GHGs Emissions

The model incorporates information on emissions of all greenhouse gases listed in the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and 14 fluorinated gases (PFC, HFC and SF6). CO_2 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 non-CO_2 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. fertilizer 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 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.

Formally, recalling (1), GHG emissions (*W*) that depend on the output produced (Y) evolve according to:

$$W_y = \alpha_y Y \qquad (10)$$

where W_y is the level of production output emissions and α_y is an emission conversion factor. In a similar way, we link greenhouse gas emissions that depend on the use of the input / primary factor X_i to the demand of this input/factor:

$$W_{X_i} = \alpha_i X_i \qquad (11)$$

where W_{X_i} are emissions related to input use, α_i is an emission conversion factor and X_i is the level of the intermediate good or primary factor used to produce the *Y* output.

All emissions are expressed in millions of tonnes of CO_2 equivalent (CO_2e).

Environmental policy and taxation

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 internalizing the external costs produced by polluting activities. The introduction of a price for CO2s emissions allows to simulate 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 tax. 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.

If input X_i is used in sector *j* in region *r*, the carbon rate $TRC_{x_i jr}$is defined as follows:

$$TRC_{x_i,j,r} = \left(\frac{W_{x_i jr} CTAX_r}{PM_{jr} QO_{jr}}\right) \tag{12}$$

where $W_{x_i jr}$ are GHG emissions related to the use of X_i input for sector j in region r; $CTAX_r$ is the nominal value of the tax (i.e. euro per tonne of carbon); $PM_{jr}QO_{jr}$ provides the value of production (i.e. the total tax base) produced by sector j.

Inputs purchased by companies may already be subject to pre-existing ad valorem taxes defined as:

$$PF_{x_i jr} = PM_{jr}(1 + TR_{x_i jr}) \tag{13}$$

where *PF* is the price paid by the company per input unit, *PM* the market price of the input and $TR_{x_i jr}$ is the pre-existing ad valorem rate[3]. Therefore, the introduction of a carbon tax changes (13) as follows:

$$PF_{x_i jr} = PM_{jr}(1 + T_{x_i jr}) + TRC_{x_i jr} \tag{14}$$

Cap on emissions. The introduction of a cap $\bar{E}_r$ 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.

$$\bar{E}_r = \sum_{j=1}^{J} TGHG_{j,r} \tag{15}$$

[3] In Gtap taxes are expressed as powers of the ad valorem tax: in this case the power is $T_{x_i jr} = (1 + TR_{x_i jr})$. If $T_{x_i jr}$ is greater than 1 indicates an ad valorem tax while a number less than 1 an ad valorem subsidy.

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 allows to simulate 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.

Given this premise, the following equation is introduced in addition to the equation (15):

$$T_r = \mathrm{CTAX}\,(QGHG_r - E_r) \tag{16}$$

Where T_r is the total value of the permits traded by the country, *CTAX* the price of the permits, $QGHG_r$ the allowance allocated to each country and E_r the actual emissions of the country. The country is a net buyer of emission permits if T_r is negative, and a net seller if T_r is positive. The sum of all T_r is zero.

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 which each sector maximizes its profit and each agent its usefulness.

Scenarios and Results

The contribution of this work is threefold: first of all, it exploits and presents a novel database, based on the G20 Self-Report on Fossil fuel subsidies in Italy that integrates the 2018 Inventory on fossil fuels subsidies recently released by the OECD. The amount of subsidies considered in the scenarios is equal to 11.6 billion euro.

Secondly, our study focuses on fossil fuels subsidies and involves an inter-sectoral analysis that allows to fully estimate the effects of their removal on different actors in the Italian economy such as firms and households.

Thirdly, we analyse the links between the removal of EHS and the EU 2030 climate and energy framework. We explicitly consider both types of EU emissions reduction targets: that on the EU emissions trading system (ETS) sectors with the exchange of emission permits in the EU zone and a carbon price endogenously determined in the carbon market and that on the rest of the sectors which every country should put in place autonomously to cut emissions by 30% (compared to 2005).

Scenario	Description
01 ETS	Emission Trading System with cap and trade in 2020 (-20%)and 2030 (-43%)
02 ETSFFS	ETS + Fossil fuel subsidies gradual phase-out in Italy with revenues that result from the removal split equally between two types of recycling: i) increase the current budget savings and ii) subsidize renewables.

Preliminary results show that Italy can even achieve higher emissions reductions with lower costs when the ETS is combined with a gradual removal of fossil fuel subsidies.

igure 4 – Italy: Emission pathways

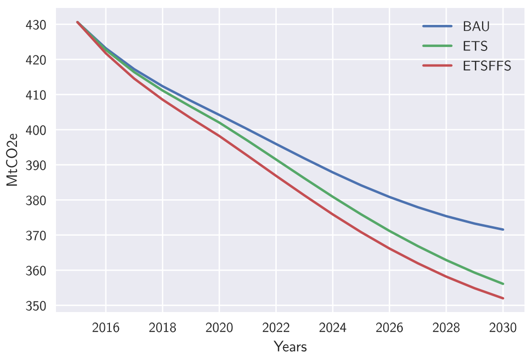

Figure 5 – Italy: GDP (% change wrt BAU)

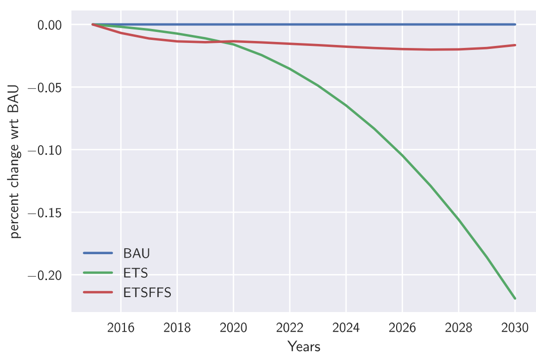

Table: ETS carbon prices (EUR per tCO2e)

Scenario	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ETS	8.5	10.0	11.6	13.4	15.5	17.7	20.1	22.8	25.7	28.8
ETSFFS	8.3	9.7	11.3	13.1	15.0	17.2	19.6	22.2	25.0	28.1

Table: Emissions trade in Italy: value of permits in euro (million, negative buying)

Scenario	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ETS	-2.6	-4.4	-6.7	-9.6	-13.3	-17.8	-23.2	-29.7	-37.4	-46.5
ETSFFS	2.1	2.4	2.7	2.8	2.6	2.1	1.0	-0.6	-3.1	-6.5