Macroeconomic impact of EU mitigation policies beyond the 20% target: A general equilibrium assessment.

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1. Introduction and background

The guidelines of the EU climate change mitigation, competitiveness and energy security strategy post-2010 are defined by the 2007 EC Communications 1 and 2 [1]. They set three main targets by 2020: a 20% greenhouse gas emission reduction by 20% compared to 1990, a 20% share of total renewable energy consumption, and a 20% increase in energy efficiency compared to 2020 BAU trends.

Following the June 2009 adoption by the EU Council the "20-20-20" strategy is mandatory.

The SEC (2008) 85 report [2] proposes the initial assessment of its costs. It is based on an integrated modelling effort. According to the study, the policy macroeconomic costs quantified using GEM-E3, a computable general equilibrium (CGE) model, could amount in the EU27 to 0.54% of the GDP. This is under the assumption of unilateral EU action and of an efficient allocation of abatement effort across countries and sectors. The cost could increase to 0.68% of GDP if targets are allocated according to the actual burden sharing criteria settled for the EU ETS sectors and according an "equity" criterion based on countries' per capita GDP in the Non-ETS sectors.

Nonetheless, these EU emission reduction targets could become even more ambitious if other countries implement and participate in the abatement effort. In this perspective, the EC released the 2010 Communication: "Analysis of options to move beyond 20% GHG emission reductions and assessing the risk of carbon leakage" (SEC (2010) 650)[3]. It assesses the costs of moving toward a 30% emission reduction target compared to 1990 levels in 2020, which can be justified under the "pledges" that major world economies declared during the 2009 Copenhagen and 2010 Cancun COPs. This more recent document bases its analyses on a revised baseline to 2020 incorporating the economic effects of the 2008 economic crisis. Its main implication is to reduce the policy cost by nearly 40% compared to the older SEC (2008) 85. Moreover it assesses the potential costs of the EU mitigation effort also in the context of the Copenhagen Accord thus including potential feedback from non EU mitigation action. In SEC (2010) 650 direct policy costs estimated by applying the PRIMES bottom-up model amount to the 0.32% and 0.63% of GDP in the 20% and 30% emission reduction scenarios respectively. This is the investment needed by the energy system to meet the required target. Grasping macroeconomic costs, i.e. the impact of the policy on the EU

[1] "*An Energy Policy for Europe* - Com(2007) 1 final", "*Limiting Global Climate Change to 2 Degrees Celsius – The Way Ahead for 2020 and Beyond* - COM(2007) 2 final"
[2] SEC(2008)85/3, available at: http://ec.europa.eu/environment/climat/pdf/sec_2008_85_ia_lt.pdf
[3] SEC(2010) 650 part I and II. Available at: http://ec.europa.eu/environment/climat/climate_action.htm

economic performance, is more difficult. In fact, they are estimated by the GEM-E3 general equilibrium model under both assumption that non EU regions implement their low and high ends of the Copenhagen pledges. Nonetheless in the study results are then displayed as differences with respect to the EU unilateral action i.e. when no actions is taken in the non EU regions. This make it difficult to understand the total cost of the EU policy.

However some insights could still be driven although in "relative" terms. Moving from the 20-20-20 to the 30-20-20 scenario ensures a doubling of GDP cost for the EU27 (from -0,4% to -1%) irrespective of the Non-EU countries deciding to pursue their own low or high Copenhagen pledges. Instead, the cost is halved when there is access to the 1/3 reduction on the international emission trading. Finally, impact on GDP could be positive if the ETS allowances are auctioned, if a tax is imposed to the Non-ETS sectors and if the carbon revenues are recycled in favour of labour taxation.

The present study offers a similar CGE analysis, but with the following differences: it assesses the 20-20-20 and 30-20-20 costs for the EU also assuming there are no mitigation commitments by Non EU regions. In our opinion this is key to clearly understand the effective cost of pursuing a 30% target. It then analyzes how the picture for the EU could change in a Copenhagen-like structure. Finally, our study also details results for Italy and major EU economies, which are not available in SEC (2010) 650.

2. Modelling framework and methodology

In this research, we extend the ICES model developed by CMCC to incorporate alternative energy sources, which enriches the policy designs that can be analysed.

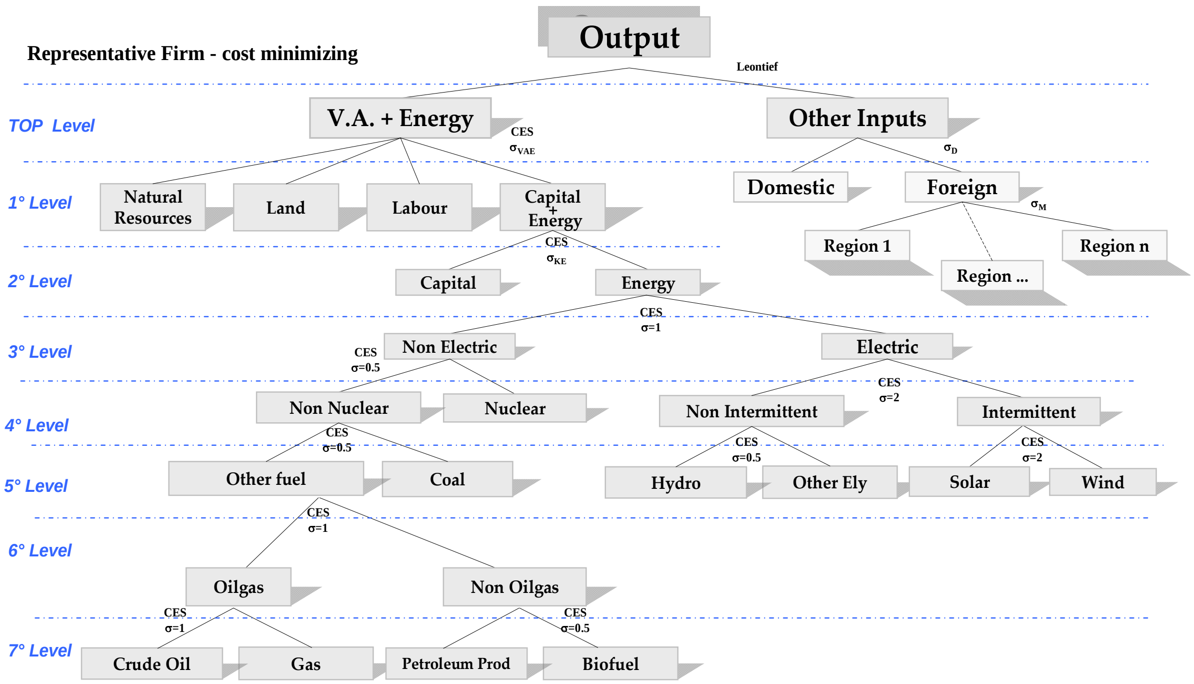
ICES geographical and sector details are reported in Table 1. There are 26 regions (Table 1 – left) and 17 sectors (Table 1 –right). The EU is divided into 17 countries plus 1 bundle grouping the ten smaller countries. Non-EU distinguishes 7 regions that have specific pledges from the Copenhagen Accord (NonA1_T considers Indonesia, Mexico, South Africa and South Korea) plus 1 main bundle including all developing non constrained countries. With reference to sectors, there are 9 energy intensive ETS sectors (among them 5 are power sources) and 4 Non-ETS sectors: agriculture, transport, other (light) industries and services.

Table 1. Regional and sectoral definitions in ICES model

Regions	Sectors
Austria	Agricolture
Belgium	Coal
CzechRep	Oil
Denmark	Gas
Finland	Oil_Pcts
France	Nuclear
Germany	Solar
Greece	Wind
Hungary	Hydro
Ireland	OthEly (Electricity from fossil source)
Italy	Paper
Netherlands	Minerals
Poland	Chemicals
Portugal	Iron_Steel
Spain	Transport
Sweden	Oth_ind (Manufacturing Industry)
UnitKingdom	Services
RoEU (Rest of Europe 27)	
USA	
Russia	
RoA1 (Rest of Annex 1)	
China	
India	
Brazil	
NonA1_T (Non Annex 1 with pledges)	
RoW (Rest of the World)	

The model is calibrated in 2004 relying upon GTAP7 database (Narayanan *et al.*, 2009) but extending it considering several energy sources (Hydro, Nuclear, Solar, Wind) not explicitly represented in the original GTAP7 database (see Figure 1).

Figure 1. ICES nested production function



Simulations take place from 2004 to 2020. ICES is a recursive-dynamic model improved to capture dynamic features (endogenous dynamics for investment and capital accumulation). Change in stock and productivity of primary factors (labour, land, natural resources) and population are exogenous drivers. International trade is explicitly modelled considering possible switching from domestic to foreign production and vice versa. The model includes CO_2 emissions from fossil fuel use in each sector and simulates the functioning of an international carbon market.

2.1. The baseline scenario

The baseline scenario represents the macroeconomics trends in a world not constrained by climate policies until 2020 (see Table 2). Historical trends are replicated from the base year 2004 until 2009. Data on population was taken from Eurostat (2010) [4] and the World Bank (2010) [5] for EU and Non-EU, respectively. GDP was replicated according to information provided by EC (2010) "Economic Forecast"[6] reporting data for both EU and Non-EU countries. CO_2 trends are in line

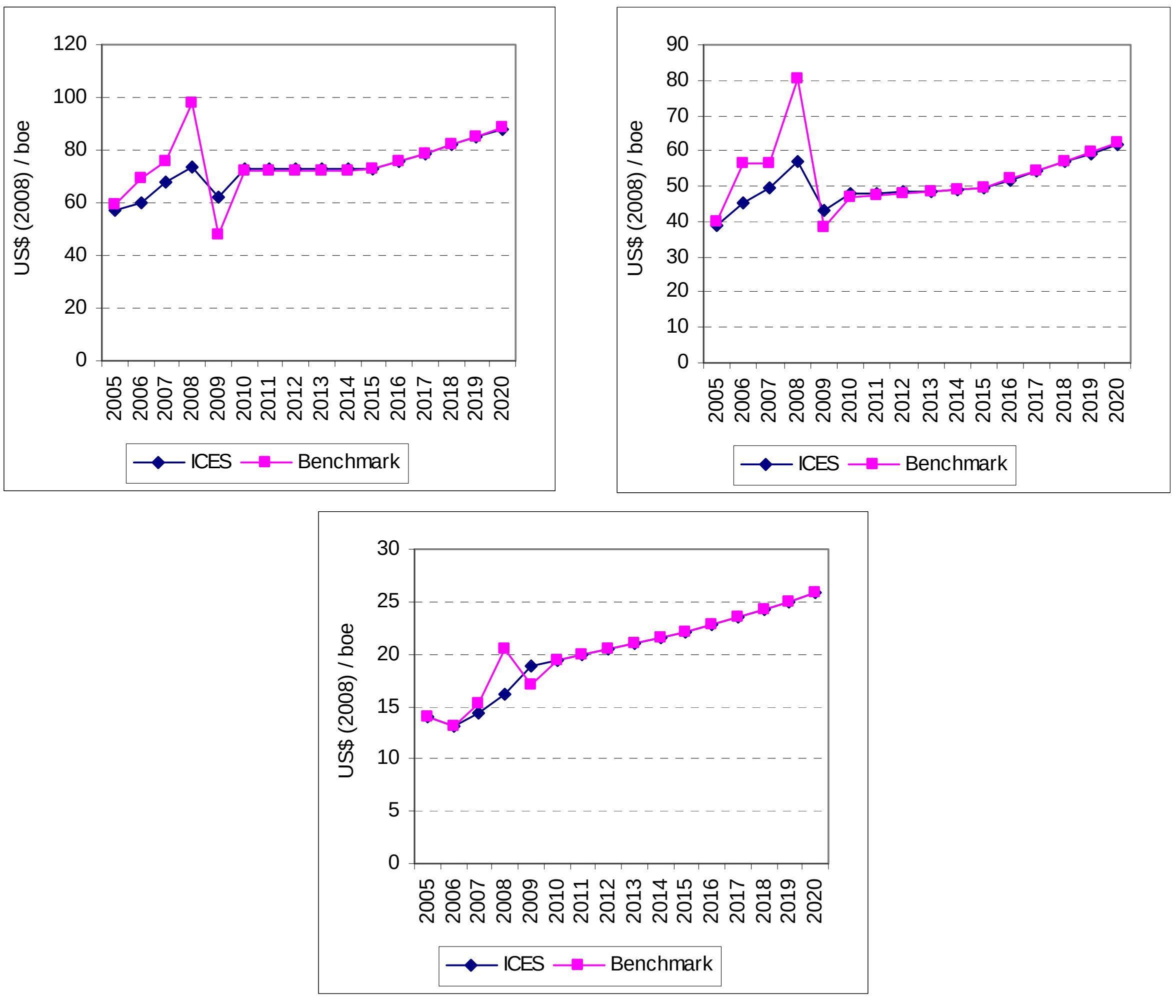
[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database
[5] http://data.worldbank.org/indicator/SP.POP.TOTL
[6] European Commission, DG Economic and Financial Affairs: Economic Forecast Spring 2010. EUROPEAN ECONOMY 3|2010, http://ec.europa.eu/economy_finance/eu/forecasts/2010_spring_forecast_en.htm

with the information found in IEA (2010)[7]. Finally, fossil fuels' prices changes according to Eurelectric (2010) "Power Choices"[8] data (see Figure 2) also used by PRIMES in SEC (2010) 650.

The model projections 2010-2020 take into account the effects of the economic crisis.

In particular, there is a low GDP growth trend until 2012 (source: EC, 2010 "Economic Forecast"). This is slightly higher in 2013-2015 at around 0,99% per year (sources: combination of EC, 2010 and EC, 2009); only after 2015, the economic growth rate will return in line with the pre-crisis trends at around 2% per year for the EU on average (source: EC, 2009 "Ageing Report 2009"[9]).

Figure 2. Fossil fuels' prices trend 2005-2020:
oil (top-left); natural gas (top- right); coal (bottom).



[7] http://www.iea.org/co2highlights/,.

[8] Power Choices Pathways to Carbon-Neutral Electricity in Europe by 2050 => Eurelectric => http://www.e3mlab.ntua.gr/)

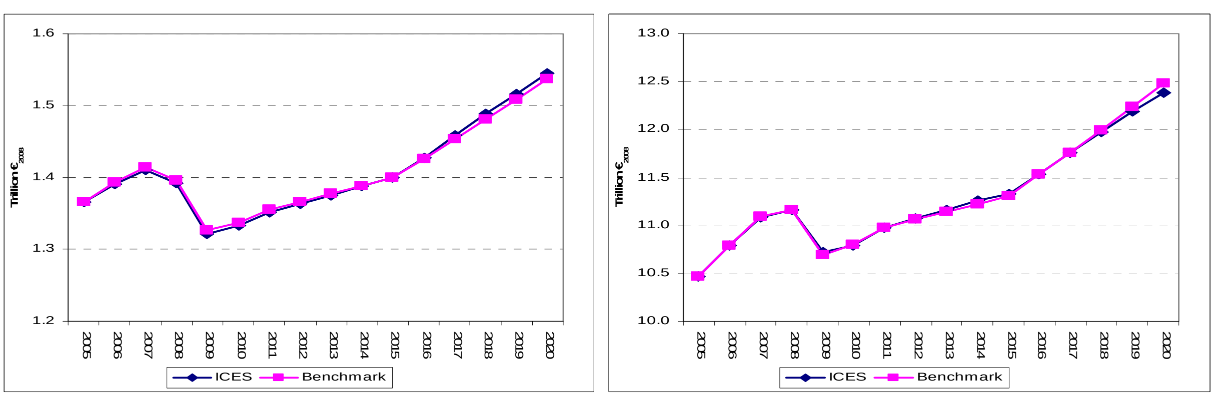
[9] European Commission, DG Economic and Financial Affairs: 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008-2060). EUROPEAN ECONOMY 2|2009, http://ec.europa.eu/economy_finance/publications/publication14992_en.pdf.

Table 2. Main macroeconomic variables. baseline scenario

		EU27	Italy
Population in 2020 (Million)		513.8	61.4
GDP	Billion €$_{2008}$ in 2020	12.61	1.54
	Average annual growth rate in 2005-2010	0.66	-0.45
	Average annual growth rate in 2011-2015	0.98	0.99
	Average annual growth rate in 2016-2020	1.82	1.98
Fossil fuel prices in 2020	Oil (€$_{2008}$/boe)	88.4	
	Coal (€$_{2008}$/boe)	25.8	
	Natural gas (€$_{2008}$/boe)	62.1	
CO_2 emissions EU27	CO_2 Million Tons in 2020	3967	431
	% variation rate in 1990	-2.14	8.53
	% variation rate in 2005	-0.40	-5.76
Energy dependence (Import/Demand)	2005	55.6	80.2
	2020	51.8	74.1
RES share over final energy consumption	% in 2005	8.9	6.5
	% in 2020	11.6	12.1

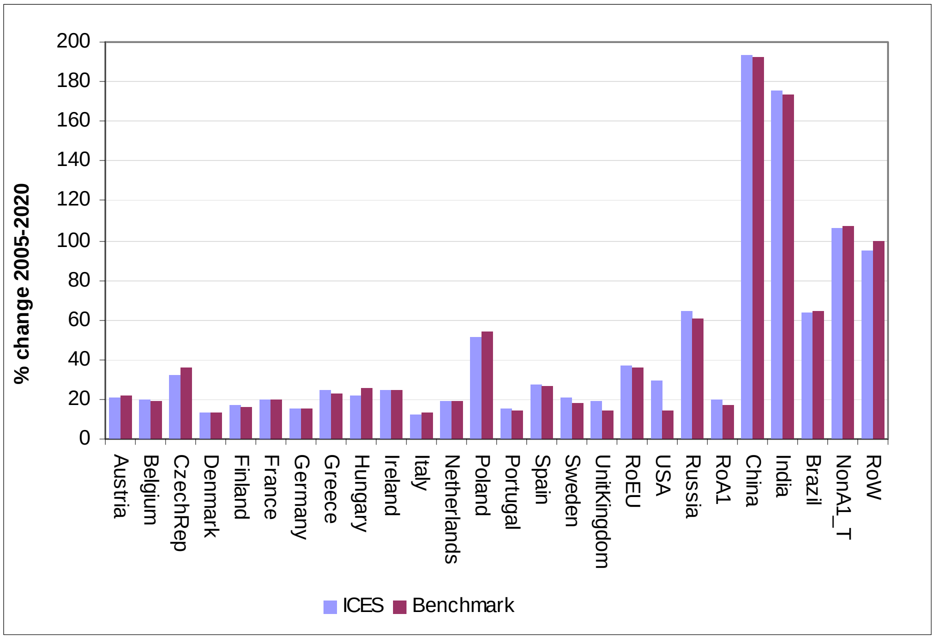
Table 2 shows a stronger effect of the financial crisis in Italy than in the EU on average. Italian GDP in 2009 decreases below the 2005 level (see Figure 3). Italian GDP growth is comparable to the EU average in 2010-2015 and slightly higher after 2015.

Figure 3. GDP (trillion €) 2005-2020: Italy (left), UE27 (right).



For Non-EU countries, GDP projections are created by using data from the World Energy Outlook 2009 (IEA, 2009)[10] with the exception of the RoW region, which uses data from IMF (2010)[11] (see Figure 4). Both sources incorporate effects of the economic crisis. From these graphs, a convergent trend in which especially Asian countries reduce economic gaps with the most developed world clearly emerges.

Figure 4. GDP growth rate (% 2005-2020) for EU and non-EU regions



[10] http://www.worldenergyoutlook.org
[11] http://www.imf.org/external/pubs/ft/weo/2010/01/weodata/index.aspx

With reference to carbon dioxide emissions, in 2020, the EU roughly returns to the same level of 2005 (-0.4%)[12]. Italy is below this level as of 20 Mt CO_2: a higher growth in 2015-2020 is not enough to compensate the decline in 2008-2010. Note that this baseline data is not comparable with PRIMES baseline because the latter already considers the EU-ETS implementation of the 20-20-20.

The high fossil fuel price fosters the development of renewable sources. Their share over total energy consumption in 2020 achieves 11.6% in Europe and 12,1% in Italy, however still quite far from the 20% target.

2.2. Policy scenario

The baseline scenario is business as usual without any mitigation policy; Table 3 summarises the alternative policy scenarios which we investigate.

Table 3. Policy scenario description

	EU27	NON EU
20-20	20% GHG emission reduction in 2020 w.r.t. 1990 20% RES over total final energy consumption	Business as Usual
30-20	30% GHG emission reduction in 2020 w.r.t. 1990 20% RES over total final energy consumption	Business as Usual
20-20 Low	20% GHG emission reduction in 2020 w.r.t. 1990 20% RES over total final energy consumption	Low pledge proposed in Copenhagen[13]
30-20 Low	30% GHG emission reduction in 2020 w.r.t. 1990 20% RES over total final energy consumption	Low pledge proposed in Copenhagen
30-20 High	30% GHG emission reduction in 2020 w.r.t. 1990 20% RES over total final energy consumption	High pledge proposed in Copenhagen

[12] This data also coincides with recent projections from the WITCH model by Bosetti et al. (2009)

[13] The pledges of Copenhagen Accord are implemented in the model as follows:

	Low pledge	High pledge
EU27	-20% (w.r.t.1990)	-30% (w.r.t.1990)
US	-17% (w.r.t.. 2005)	-17% (w.r.t.2005)
Russia	-15% (w.r.t.1990)	-25% (w.r.t.1990)
RoA1	-29% (w.r.t.2005)	-32% (w.r.t.2005)
China	-40% (CO2/GDP in 2020)	-45%(CO2/GDP in 2020)
India	-20% (C/GDP)	-25% (C/GDP)
Brazil	-5.3%(BAU)	-9.4%(BAU)
NonA1_T	-2%(w.r.t.2005)	-10.5%(w.r.t. 2005)

First, for each scenario the cost-efficient solution is determined. Within the EU, allowances and targets are initially allocated uniformly in the market across sectors and countries. Then, allowing carbon permits trade among all the sectors and countries involved, the equalisation of marginal abatement costs is achieved and a single carbon price is determined.

In the case of EU unilateral policy, we also analyse a scenario with two separate markets for ETS and Non ETS sectors. In this case, Non ETS targets are fixed per country according to the EU Decision 406/2009 and achieved through a carbon tax, while residual target to achieve the -20% goal is imposed uniformly to ETS sectors through auctioning. This way, there will be a single carbon price for ETS sectors and a differentiated price by country for Non ETS sectors. Considering the greater importance of the allocation mechanisms for the EU ETS in phase III, permits are allocated with an auctioning in the ETS sectors and with a carbon tax for the Non-ETS sectors.

In the 30-20 scenario, a full auctioning allocation scheme is compared with two alternatives aiming to alleviate the risk of leakage in the ETS energy-intensive sectors (sectoral value added reduction through competitiveness loss). Grandfathering, that is free allocation (but not extended to the electricity generation sectors) and auctioning, but coupled with Border Tax adjustments. This can partially protect domestic production from cheap imports of carbon intensive goods.

Grandfathering for ETS sectors is also used as an alternative allowances allocation mechanism in the 30-20 Low case, where EU faces a 30% GHG emissions reduction and Non-EU countries have their own low “Copenhagen pledges”. In Non ETS sectors, a carbon tax is implemented.

In the Copenhagen scenarios (20-20 Low, 30-20 Low, 30-20 High), in which also Non-EU countries have specific commitments, no access to an international carbon market is assumed. Therefore, each region implements its unilateral effort to meet its own target. Within the EU the carbon market is efficient and in place.

In every scenario, the mitigation effort is gradually implemented from 2010 until the final target achievement in 2020.

3. Results

20-20 vs 30-20

Table 4. Main macroeconomic variables in mitigation policy scenarios

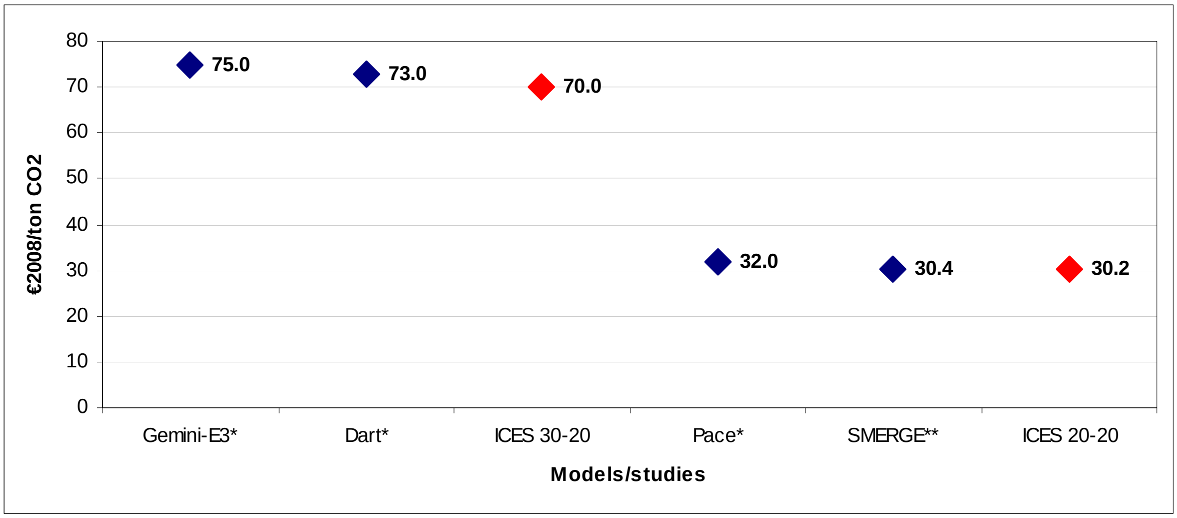
	Auctioning ETS Tax Non ETS		Grandfathering ETS, Auctioning Electricity, Tax Non ETS	Auctioning ETS Tax Non ETS & BTA
EU 27				
	20-20	30-20	30-20	30-20
GDP (% var. w.r.t. 2020 baseline)	-0,56	-1,26	-1,38	-1,34
CO2 price (€/t)	30,2	69,9	114	71
Total emissions (% var. w.r.t. 2020 baseline)	-12,3	-22,6	-22,6	-22,6
ETS emissions (% var. w.r.t. 2020 baseline)	-15,7	-27,9	-26,9	-27,1
Non ETS emissions (% var. w.r.t. 2020 baseline)	-7,6	-15,2	-16,6	-16,4
Total emissions (% var. w.r.t. 2005 baseline)	-12,7	-23,0	-23,0	-23,0
ETS emissions (% var. w.r.t. 2005 baseline)	-14,1	-26,6	-25,5	-25,7
Non ETS emissions (% var. w.r.t. 2005 baseline)	-10,8	-18,1	-19,5	-19,3
Subsidies on renewables (€/MWh % in 2020)	34,7	13,7	13,7	13,7
Renewable share over final energy consumption (% in 2020)	20	20	23	20,5
Energy dependence (import/demand % in 2020)	49,8	49	52,3	48,4
Price index (% var. w.r.t. 2020 baseline)	0,6	1,19	1,34	1,76
Italy				
GDP (% var. w.r.t. 2020 baseline)	-0,54	-1,18	-1,40	-1,20
Total emissions (% var. w.r.t. 2020 baseline)	-8,8	-16,9	-18,6	-17,2
ETS emissions (% var. w.r.t. 2020 baseline)	-10,4	-19,1	-20,5	-18,9
Non ETS emissions (% var. w.r.t. 2020 baseline)	-6,9	-14,1	-16,4	-15,2
Total emissions (% var. w.r.t. 2005 baseline)	-14,0	-21,7	-23,3	-22,0
ETS emissions (% var. w.r.t. 2005 baseline)	-13,7	-22,2	-23,5	-22,0
Non ETS emissions (% var. w.r.t. 2005 baseline)	-14,4	-21,1	-23,1	-22,0
Renewable share over final energy consumption (% in 2020)	13,8	16	15,8	16,5
Energy dependence (import/demand % in 2020)	72,6	71,7	73,5	71,1
Price index (% var. w.r.t. 2020 baseline)	0,37	0,61	1,58	1,04
Germany				
GDP (% var. w.r.t. 2020 baseline)	-0,46	-1,06	-0,85	-1,1
UK				
GDP (% var. w.r.t. 2020 baseline)	-0,42	-0,97	-1,05	-1,06
Spain				
GDP (% var. w.r.t. 2020 baseline)	-0,62	-1,38	-1,63	-1,48
Non EU27				
GDP (% var. w.r.t. 2020 baseline)	0,09	0,17	0,14	0,17
Total emissions (% var. w.r.t. 2020 baseline)	0,97	1,69	1,61	1.57
Leakage (%)	74	70	67	65
Price index (% var. w.r.t. 2020 baseline)	0,09	0,27	-0,2	0,04

The cost-efficient achievement of 20% and 30% GHG emissions reductions compared to 1990 levels with a EU unilateral policy, implies a GDP loss of 0.57% and 1.26% and a carbon price of 30 and 70 €/ton CO_2 in 2020, respectively. Moving from 20% to 30% (that is, increasing the commitment by 50%) produces a more than proportional increase in macroeconomic costs (around +121%) as well as an increase in the price of CO_2 by 125%. This is very close with the data found in PRIMES and GEM-E3 shown in SEC (2010) 650. However, in our scenarios the CO_2 price is considerably higher than the one in SEC (2010) 650 evaluation, but lower than that reported in SEC (2008) 85. Carbon prices in ICES are higher than in PRIMES quantification, but this is an expected result when comparing Bottom-Up and Top-Down models (see box I).

BOX 1: Carbon price in EU to achieve -20% emissions reduction according to different CGE models

In Figure B1, carbon prices estimated by the ICES model in the 20-20 scenario are among the lowest proposed by comparable studies. The 30 €/t is very similar to the result of the PACE model, which is also part of the SEC (2010) 650 analysis. It is also similar to the result of SMERGE. On the other hand, DART and GEMINI-E3 show a higher CO_2 price (more than 70 €/t). ICES reaches this price only in the 30-20 scenario. Therefore, notwithstanding the higher carbon price in ICES compared to PRIMES, the figure is still lower than other modelling exercises. In general, CGE top-down models demonstrate higher abatement costs, as well as higher carbon taxes, compared to bottom-up models. The details in the energy sector and a more flexible technological improvement in bottom-up models implies that moving from carbon-intensive technologies to cleaner ones is easier.

Figure B1: Carbon price in EU to achieve -20% emissions reduction according to different studies



* Our elaboration from Bohringer *et al.* (2009)

** Our elaboration from Durand-Lasserve *et al.* (2010)

The mitigation policy, penalising fossil fuels use, stimulates renewable energy production. These reach a share over final energy consumption of 13.8% and 17.1% in 2020 (respectively with an emission reduction of 20% and 30%).

Therefore, the achievement of mitigation targets is not sufficient to stimulate renewable energy diffusion according to the EU target.

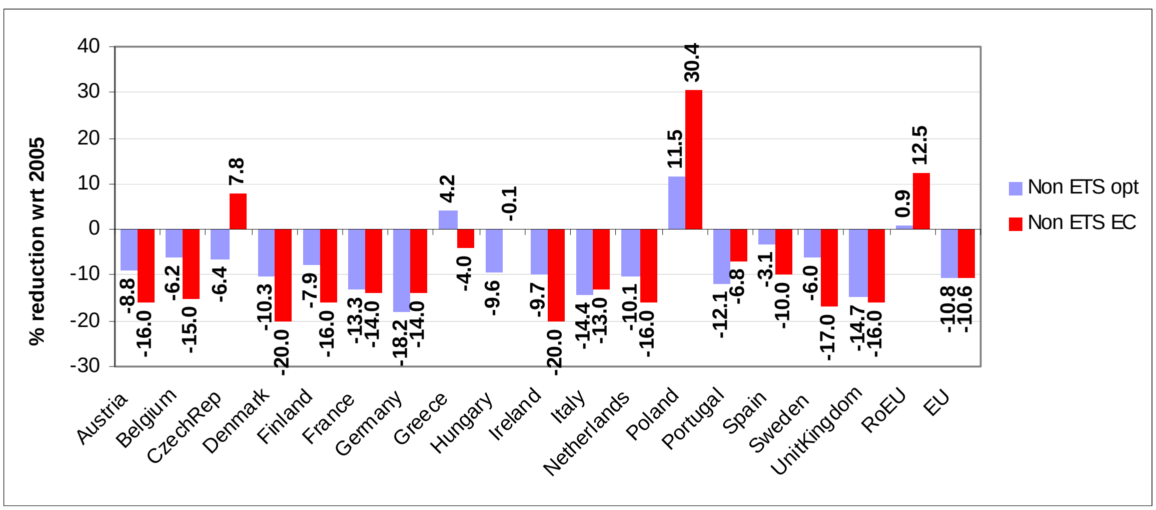
When emission reduction is 20%, it is necessary to introduce an average incentive on wind and solar of around 34.7 €/MWh; when the target is 30%, a support of 13.6 €/MWh is sufficient. Meeting the renewables target does not imply higher policy costs which, remain basically unchanged (0.56% and 1.26% of GDP). The increased costs due to the creation of new productive capacity from renewable sources and to distortions induced by the subsidies are totally compensated by the emission reduction and by the lower abatement effort required. This also emerges from CO_2 price patterns (30.2 €/t and 69.8 €/t), which are slightly lower with respect to the case of no target on renewables (Table 4). According to ICES, the 20% emission reduction compared to 1990 implies an overall emission reduction of 12.3% with respect to the baseline in the same year. The efficient allocation of abatement imposes to ETS sectors a mitigation effort of 15.7% and of 7.6% to Non-ETS. With reference to 2005, this is a reduction of 12.7% for all sectors (14.1% for ETS and 10.8% for Non-ETS).

These data coincide with Non-ETS sector dispositions in the Decision 406/2009/EC (10.6%). Thus, ICES results apparently support that the planned abatement burden sharing among sectors follows an efficiency criteria.

However, it is worth noting that the ICES model considers CO_2 emissions and not CH_4 and N_2O. As these represent a large amount of mitigation potential in Non–ETS sectors, it is possible to infer that the emission reduction effort of these sectors is in fact lower than optimal. For the same reason the 21% target for ETS sectors (Directive 2009/29/EC) appears to be too penalising.

The abatement burden sharing among countries is also sub-optimal. This analysis can be conducted only for Non-ETS sectors, which have to fulfil national targets (see Figure 5). These sectors would experience an overburden with respect to what optimal in Austria, Belgium, Denmark, Greece, Finland, Ireland, Spain, Sweden; the opposite in Czech Republic, Hungary, Poland and the remaining Eastern EU countries. The target for Italy is in line with the optimal one.

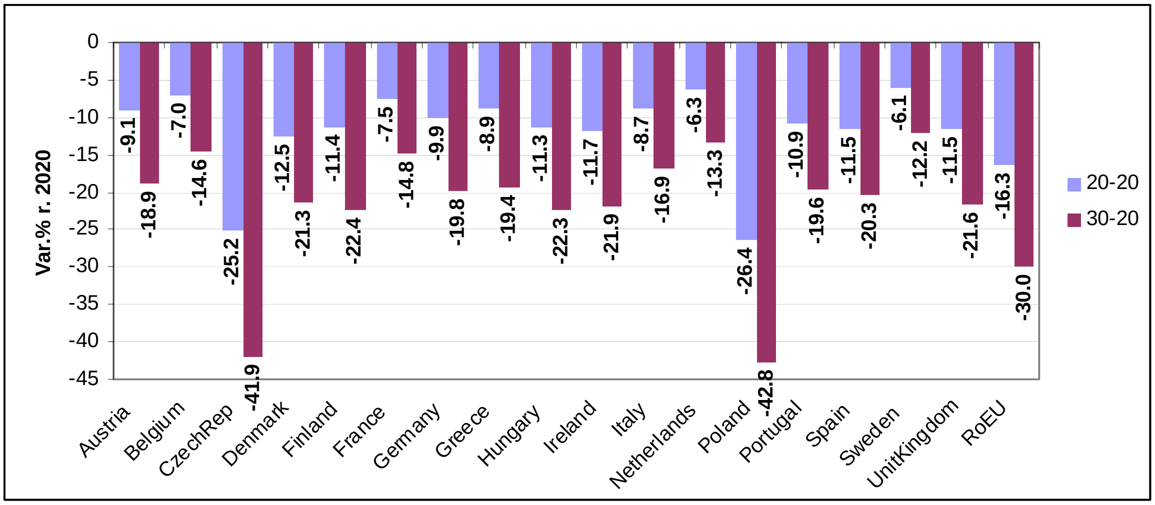
Figure 5. Abatement targets for Non-ETS sectors according Decision 406/2009/EC (EC) and simulation results (opt)



In an ad hoc simulation, the costs of a mitigation policy, which allocates the abatement effort in Non ETS sectors, according to Decision 406/2009/EC, without the possibility to trade permits between European countries, was calculated. This produces a solution in which there is only one price for the ETS sectors and country-specific prices for the Non-ETS sectors. In this case, the smaller flexibility in allocating abatement effort would generate a GDP loss up to 0.67% in 2020, i.e. an increment of approximately 20%.

Efficiency maximisation in 2020 also requires a higher abatement effort for ETS and Non-ETS sectors in new EU member states (above all Poland and Czech Republic), in which the marginal abatement costs are lower due to a relatively lower efficiency of energy intensive sectors and a less binding fiscal system, than in UE15 countries (Figure 6).

Figure 6. Efficient allocation of abatement effort in EU27 (% variation compared to the baseline in 2020)

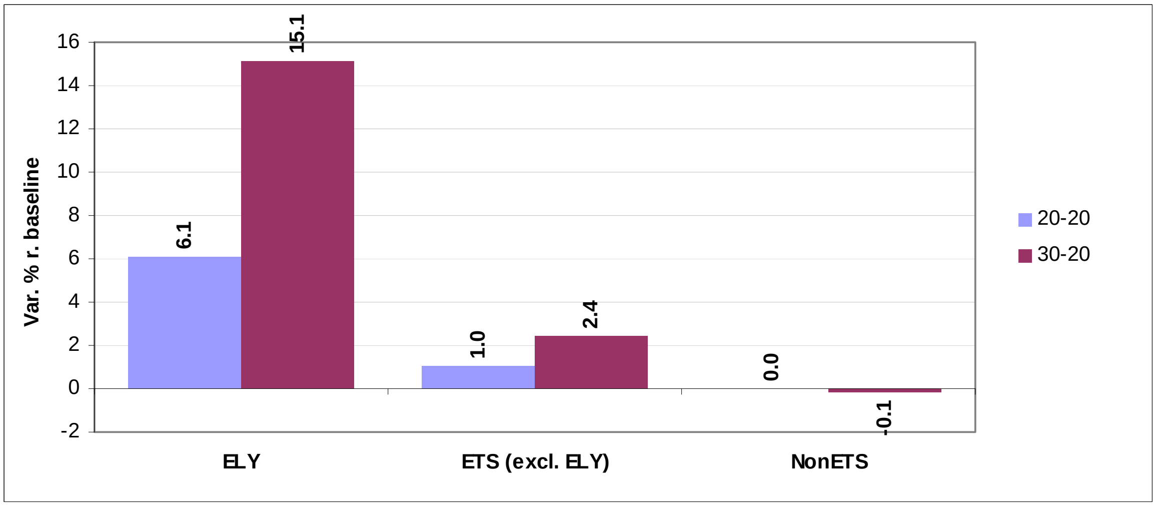


Because of the EU mitigation effort, GDP in Non-EU countries slightly increases (on average 0.1% and 0.17% in 20-20 and 30-20 scenarios). This is the well known “leakage effect”: goods can be produced at lower costs, where environmental legislation is less stringent, becoming more competitive in international markets. Their demand increases, which provides an advantage to exporting countries. These dynamics are well captured in our model, for example by presenting changes in regional price index. In the EU27, they increase on average by 0.6% and 1.2%. It is a small change, yet larger than what happens in Non-EU regions (0.1% and 0.2%).

The increases are concentrated on energy intensive sectors, from 6% in the power production due to increments of fossil fuel costs, to 1% in the other sectors (above all iron and steel). Non-ETS sectors are practically not hit from price increases (even if in the transportation sector the prices increase by 2.3%[14]) (See Figure 7).

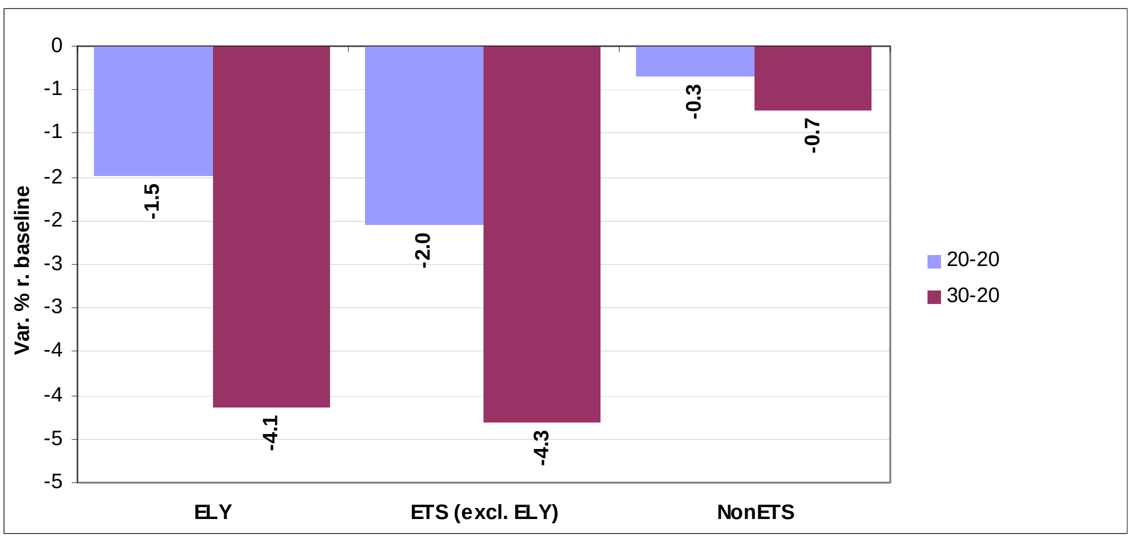
[14] In interpreting results for the transport sector, it is necessary to consider its particular characterisation in ICES, taken directly from database GTAP7. It represents the “production of mobility services” and therefore, besides transport on road, water and air, includes the services of intermediation of travel agencies and the “transport via pipelines” , i.e. the distribution costs through gas and oil-pipelines.

Figure 7. Sectoral prices in UE27: % variation compared to the baseline in 2020



The leakage, even if it is negligible in economic terms, is severe if global emission reduction are considered: in 2020 Non-EU countries increase their emissions by 0.96% and 1.7% (respectively in 20-20 and 30-20 scenarios), neutralising around 70%[15] European reduction.

Figure 8. Sectoral production in EU27: % variation compared to the baseline in 2020



[15] This happens if the leakage definition proposed in IPCC AR4 (2007) is applied: i.e. emission reduction in EU over the emission growth in Non-EU member states. Using the 'leakage' definition, adopted in SEC (2008) 85, i.e. the increase of Non-EU emissions as a percentage change compared to the EU emissions in 1990, it is possible to obtain a smaller value: 9% e 16%, respectively in the 20-20 and 30-20 scenarios. The literature typically quantifies leakage effect around 15-30% (Boheringher *et al.*, 2010), even if higher values are not uncommon. In particular, the studies introducing oligopolistic competition in energy markets obtain a leakage effect higher than 100%. The biggest difference in our study with respect to Boheringher *et al.* (2010), which obtain a leakage of 27% for a unilateral European policy, is that they found a contraction and not an increase in Non-EU GDP. Leakage in their study depends uniquely upon a re-composition effect, while in ours it stems also from a scale effect.

Larger contraction in production is experienced by energy intensive sectors (Figure 8). In the 20-20 scenario, the average contraction of production is between 1.5% and 2%. Other sectors suffer a contraction in aggregated demand, but marginally, showing an output reduction of around 0.3% compared to the baseline. Solar and wind power display a remarkable development, with a production growth of 60%. Hydroelectricity also increases, but the percentage change is reasonably limited.

The 30-20 policy implies a doubling of these figures, except the solar and wind power generation, which shows a lower increase with respect to the 20-20 scenario. Two effects are at work: a switch in favour of hydroelectric sector and, above all, a lower increment of total energy demand compared to the 20-20 scenario. Therefore, given the same target on final energy consumption, a lower renewable energy development is necessary.

Figure 9. Sectoral production in Italy: % variation compared to the baseline in 2020

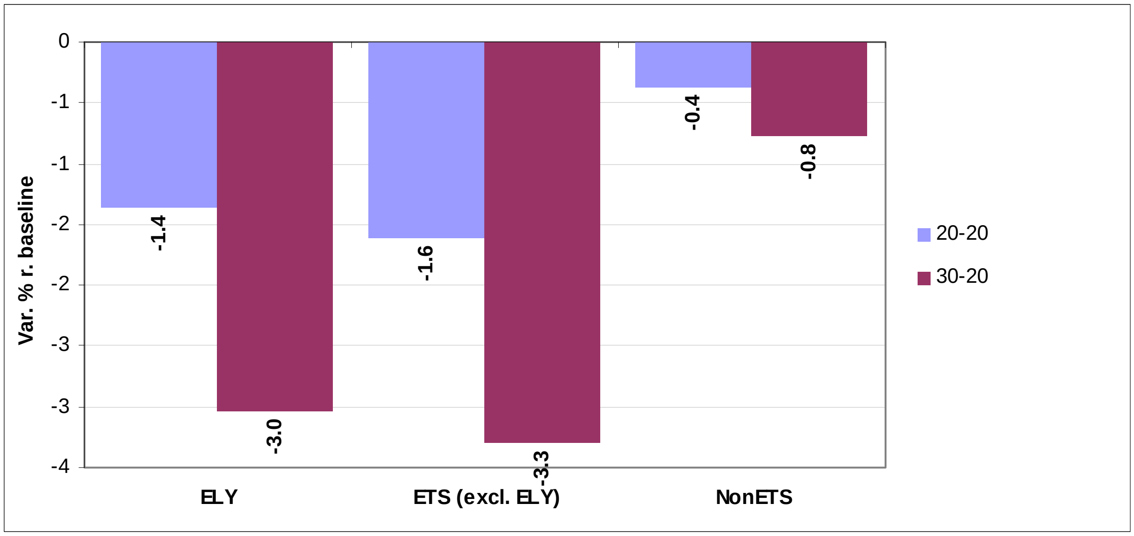
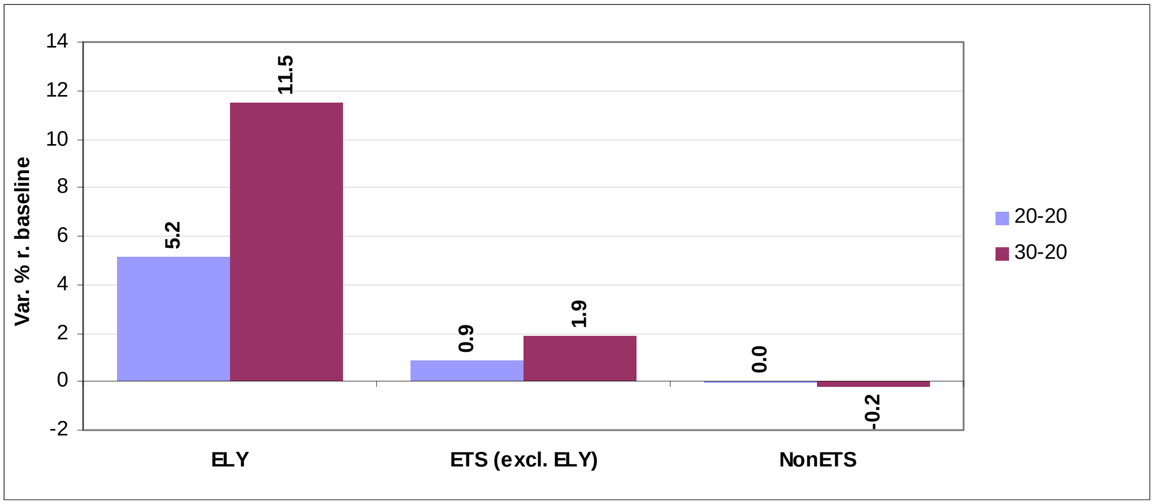


Figure 10. Sectoral prices in Italy: % variation compared to the baseline in 2020



The Italian situation is aligned to the European average (see Figures 9 and 10). The 20% and 30% mitigation targets lead to a GDP loss of 0.54% and 1.18% respectively in 2020. The country experiences slightly higher costs compared to Germany (0.46% and 1% of GDP in 2020) and UK (0.42% and 0.97% of GDP in 2020), but lower than Spain (0.62% and 1.38% of GDP in 2020).

The ETS sectors should efficiently abate the 13.7% and 14.4% of their emissions, while Non-ETS ones 22% and 21% compared t 2005. The energy intensive sectors production shows a contraction from 1.6% to 3.3%. Electricity from fossil fuels shrinks 2.2% and 4.2%, while the production of renewable energy slightly increases with respect to the European average. The net effect is a contraction between 1.4% and 3%. The prices increase, but less than the European average. This pattern is common with the major European countries (EU15), excluding Germany, which is exactly on the European average, showing lower increases in general price indices. This is due to the efficient abatement allocation among countries, which implies a greater burden for EU10 countries, and consequently higher costs and prices.

30-20 scenario: grandfathering and Border Tax Adjustment

The cost of the 20-20 policy implementation is altogether mild because of the slower GDP and emission growth following the economic crisis. However, the 30-20 policy package costs are not negligible. Therefore two different strategies in reducing these costs will be analysed: a free allocation to ETS sectors (grandfathering), with the exclusion of power sector mirroring the current legislative debate on future ETS phase starting in 2013, and the implementation of Border Tax Adjustments (BTA).

Free allocation dispenses ETS sectors from the purchase of allowances through an auction. In the second case, a tax is imposed on imports from Non-EU countries, according to carbon intensity of the productive process. Therefore, as soon as these goods are in the EU market, they will be equalised to European ones, losing the original price advantage. These strategies are expected to benefit relatively more ETS sectors as they include the majority of energy intensive sectors.

With grandfathering, the overall macroeconomic cost of mitigation policy for the EU is 1.38% of GDP compared to 1.26% under auctioning. The cost increase is around 9.5%. This a direct consequence of the lack of revenues that could have been produced from auctioning allowances. Usually these revenues are transferred in a lump sum to the households. The multiplicative effects on aggregated demand overcompensates the higher cost suffered by firms in energy intensive sectors[16].

The price in the carbon market (114 €/t CO_2 in 2020) is much higher than in the auctioning case. When the allocation is free, ETS sectors initially have a lower incentive to reduce carbon intensity and the system leans towards emitting more. This also has a direct influence on renewable energy development. On the one hand, energy intensive sectors are richer than in the auctioning scenario and are willing to increase their demand of all productive inputs (income effect). On the other hand, the higher demand of power is fulfilled with a greater use of renewable sources, given that the fossil fuel electricity is more costly. As shown in Table 4 the same subsidy on renewables receives a larger share of renewable energy consumption in total with grandfathering than with auctioning.

Compared with auctioning and tax, free allocation benefits energy intensive sectors and penalises the other as highlighted by Figure 11. In the former, the production shrinks less, in the latter more..

Considering the global EU system, the competitive loss and the leakage are slightly lower compared to full auctioning.

Summary: grandfathering reduces the mitigation policy costs in energy intensive sectors and the overall loss of competitiveness in European economy, but generates higher costs for lower energy intensity sectors (light industry, services and agriculture). This, in addition to the impossibility of obtaining revenues to sustain aggregated demand, increases the macroeconomic costs of achieving the mitigation target.

Compared to grandfathering, in addition to levelling the competitive advantages of those goods not subjected to environmental taxation, a BTA policy generates higher revenue. Nevertheless, this implies a price increase for not only imported goods, but also for all goods produced in the EU,

[16] This analysis agrees with SEC (2010) 650. However, it is not easy to draw general conclusions, given the complex interactions among tax revenues, demand and competitiveness of different sectors and countries. The SEC (2010) 650 highlights how general results cannot match all country specificity. In a simulation (here omitted, but available on demand), the *grandfathering* appears as less penalising for EU GDP than *auctioning*, (of around 30%) in the less ambitious reduction target of 20%. In this case, tax revenue effect would not compensate anymore the competiveness loss in Energy intensive sectors.

using imports as intermediate inputs. The literature on this topic agrees on the positive effects of BTA for the protected sectors (see for example Demailly e Quirion (2005), Mathiesen e Maestad (2002)), but not on the potential net effects on the GDP of countries implementing this policy. However, the substantial agreement on a small entity of these positive and negative effects leads some authors to conclude that BTA is not worth the complex administrative costs of implementation.

In our analysis, the European mitigation costs with BTA are around 1.34% of GDP. It is higher than the auctioning and tax case, but lower than the grandfathering one. The overall improvement in net competitiveness is null, given that there is no change in Non-EU GDP with respect to the non BTA case. It is interesting to note the two effects at work. On the one hand, the BTA commonly generates a greater demand and lower contraction of production, particularly in energy intensive sectors, with respect to the auctioning case, but higher on average than in the *grandfathering* case (Figure 13, however, sectoral results are indeed mixed with paper, minerals, iron and steel, coal and gas reducing their production less with BTA than with grandfathering). On the other hand the resulting price increase is stronger.

The BTA adoption, even if it is not sufficient to reduce economic leakage, implies a higher cost of imported carbon intensive inputs, reduces their world demand and allows a cut of carbon leakage.

Figure 11. Sectoral production in EU27: % variation compared to the baseline in 2020

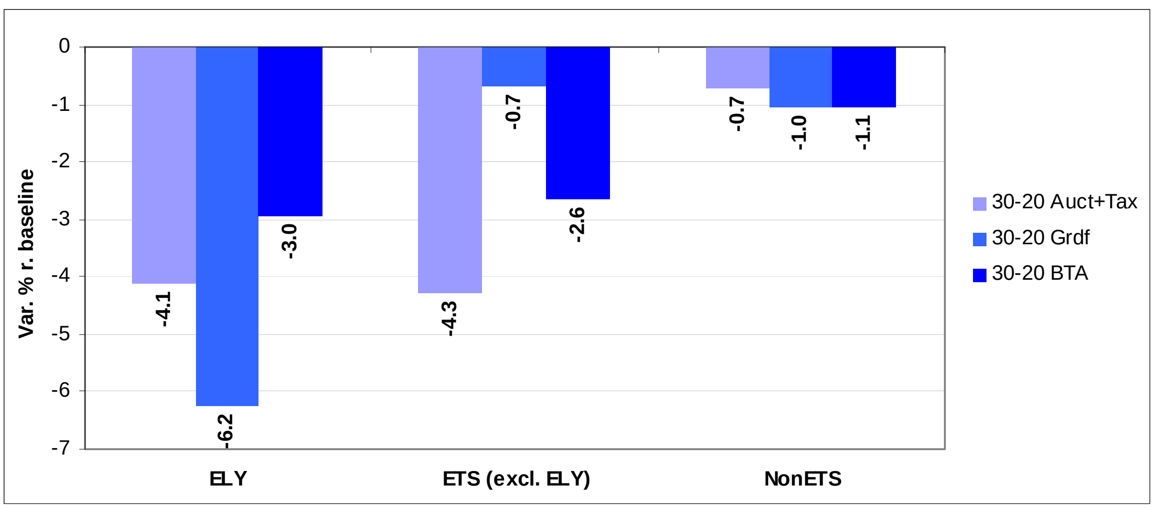
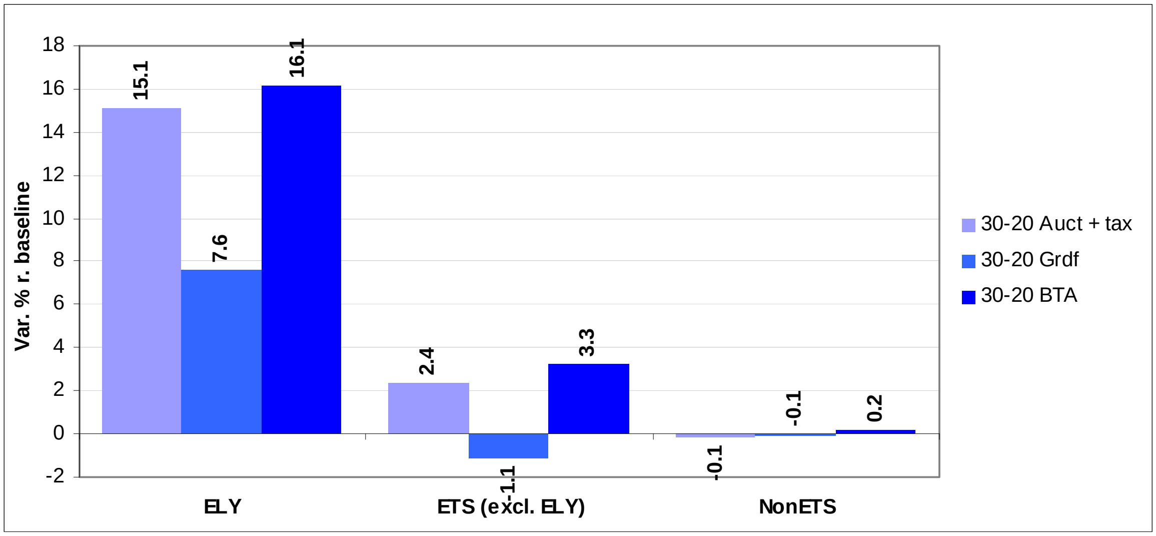


Figure 12. Sectoral prices in EU27: % variation compared to the baseline in 2020



In Italy, sectoral effects of *grandfathering* and BTA are qualitatively similar to the European results (Figure 13 and Figure 14). Similar to Spain, UK and Germany (whose ETS sectors show small gains in the grandfathering case, probably due to the high extension of iron and steel sectors), Italy also experiences GDP losses in both policy scenarios. Prices increases more in the BTA case than in the grandfathering case.

Figure 13. Sectoral production in Italy; %variation compared to the baseline in 2020

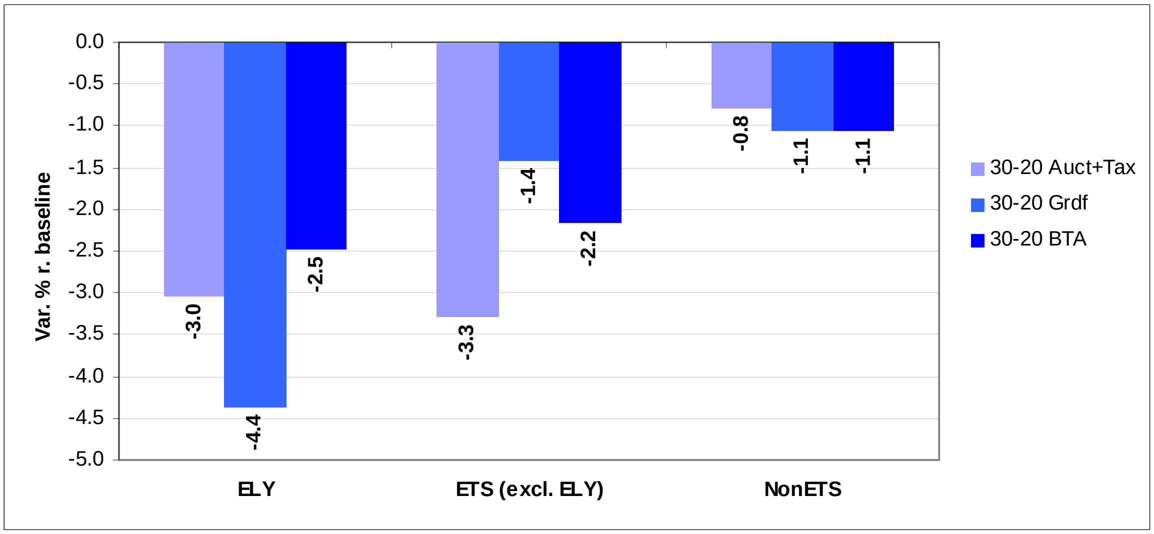
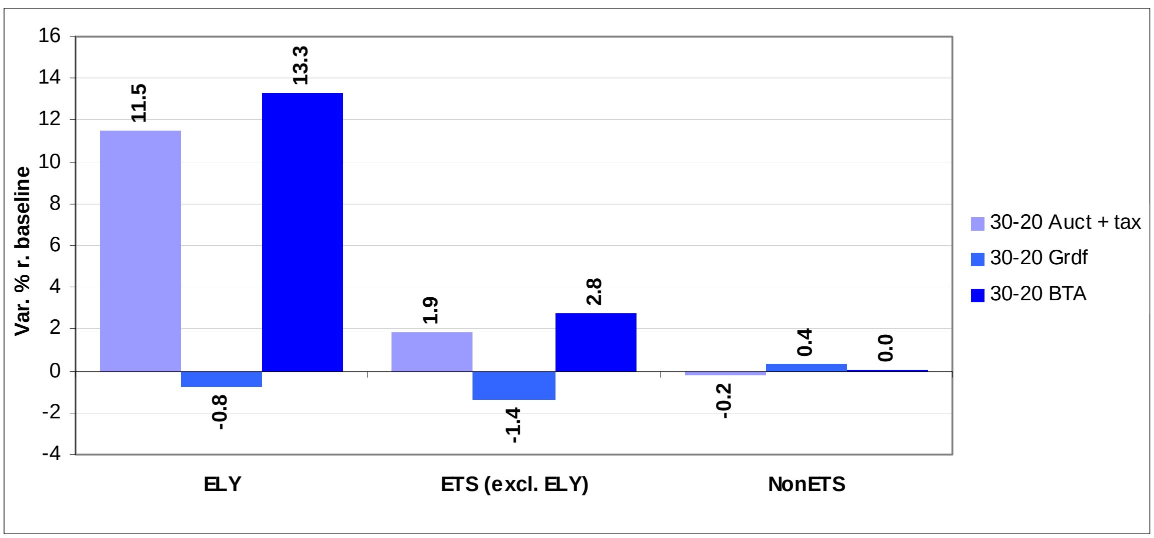


Figure 14. Sectoral prices in Italy: % variation compared to the baseline in 2020



20-20 Low, 30-20 Low, 30-20 High Scenarios

Table 5. Main macroeconomic variables in mitigation policy scenarios

		20-20 Low	30-20 Low	30-20 High	30-20 Low Grandfathering ETS, Auctioning Electricity, Non ETS Tax	30 Low Full Emission Trading (°)
UE27	GDP (% var. w.r.t. 2020 baseline)	0.12	-0.66	-0.55	-1.89	0.2
	CO_2 price (€/t in 2020)	57	102	110	205	40.8*
	Subsidies on RES (€/MWh in 2020)	34.2	10.4	9.6	10.3	
	Energy dependence (import/demand % in 2020)	52.2	51.2	51.6	56.5	53.4
Italy	GDP (% var. w.r.t. 2020 baseline)	0	-0.69	-0.61	-1.1	0.1
Germany		0.25	-0.46	-0.34	-0.49	0.3
UK		0.45	-0.17	-0.04	-0,50	0.4
Spain		0.09	-0.75	-0.65	-1.47	0.16
Non UE27		**-0.97**	**-0.91**	**-1.30**	**-0.89**	**-0.75**
All countries with pledges (World-Row)			*-1.25*			*-0.8*
USA		-0.63	-0.60	-0.56	-0.59	-0.37
Russia		-2.17	-2.37	-4.81	-2.12	-4.1
RoA1		-1.23	-1.18	-1.40	-1.13	-0.06
China		-1.66	-1.62	-3.04	-1.62	-3.8
India		1.49	1.64	1.97	1.53	-2.2
Brazil		-0.04	0.00	-0.26	0	-0.18
NonA1_T		-6.81	-6.79	-8.55	-6.77	-1.12
RoW		2.05	2.24	2.62	2.27	1.65

Note:
(°) In the full emission trading scenario the RES target is not considered
* In this case CO_2 price is equalised across signatories.

The presence of mitigation policies outside Europe generates two opposite effects on the costs of implementation of a European climate policy, which is, a priori, ambiguous.

The first induces their reduction. The fact that China, India, and Brazil pursue an emission reduction policy (as long as it is effectively binding, i.e., it requires a reduction below business as usual levels) also imposes to these economies additional costs as well as an increase in the price of goods and services produced. As a result, their relative competitiveness with respect to the EU worsens.

This, in turn, lessens the decline of the European good and services demand, resulting from the policy implementation.

The second induces an increase in the European policy cost. If following climate policy, the aggregate demand in Non-EU countries declines, the total demand for imported goods, also including the European ones, will reduce, negatively affecting GDP. The resulting dominant effect will depend on how European and Non European demand reallocate between national and foreign goods.

In our analysis, the introduction of mitigation policies in important non European economies reduces the mitigation policy costs in Europe (see Table 5). Specifically, if Non-EU countries apply Copenhagen's low pledges, the 20-20 policy does not imply a cost for Europe in 2020, but actually a small benefit (0.12% of GDP gain compared with the previous 0.56% of GDP loss). Similarly, the 30-20 policy would cost 0.66% or 55% of GDP in 2020 compared to the previous 1.26%, with low or high Copenhagen's pledges in the Non-EU respectively.

The reduction in European costs is mainly due to the lower competitiveness loss in international markets. Indeed, the carbon price in the European market is higher than in the case of a unilateral European policy (57 €/t for 20-20 and 102€/t for 30-20 with low pledge and 110 €/t in 30-20 with high pledge). This indicates that the demand for European goods, including energy and carbon intensive ones, reduces less and emissions are higher than in the case of unilateral action. In particular, the chemical sector increases its production, both in the 20 low and 30 high scenarios. Competitiveness effects are also important in Non-EU countries. For regions applying Copenhagen pledges (with the exception of Russia), the resulting costs are in fact lower when Europe introduces a 30-20 policy compared to the 20-20 case. Accordingly, benefits resulting from higher EU prices compensate the reduction of its demand. Similarly, gains in countries without a pledge (RoW) increase when more stringent climate policies are applied outside their borders.

As in the case of unilateral policy, EU losses, when observed, are concentrated in energy intensive sectors (Figure 15). Notwithstanding this, a more detailed analysis reveals that the primary sector experiences a contraction in its production equal to 1,2% to 2,3%, in line with that observed in the iron sector. On one hand, the aggregate world demand reduction is higher, selectively affecting all European export sectors, on the other hand, however, energy intensive goods produced in Europe are more competitive. The behavior of the chemical sector is particularly interesting even in the face of more stringent non unilateral climate polices. As a matter of fact, this reflects its high degree of trade openness. Within the energy sectors, a substitution of coal in favour of natural gas and oil is seen. The increasing production of renewable energy reduces fossil fuel based electricity between 3.4% and 6.1%.

The increase in EU prices (Figure 16) is much higher for the 20-20 low pledges scenario compared to unilateral action and increases for higher reduction efforts. This is not surprising as all major economies are undertaking emission reduction policies. Nevertheless, the European competitiveness rises in relative terms.

Figure 15. EU27 Sectoral Production . % change w.r.t. compared to the baseline in 2020

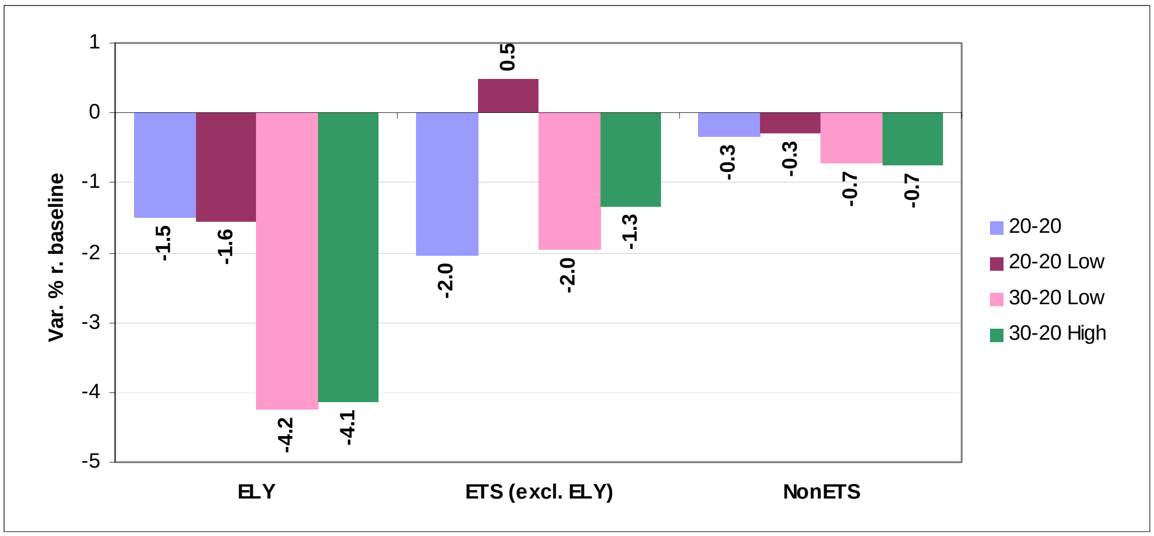
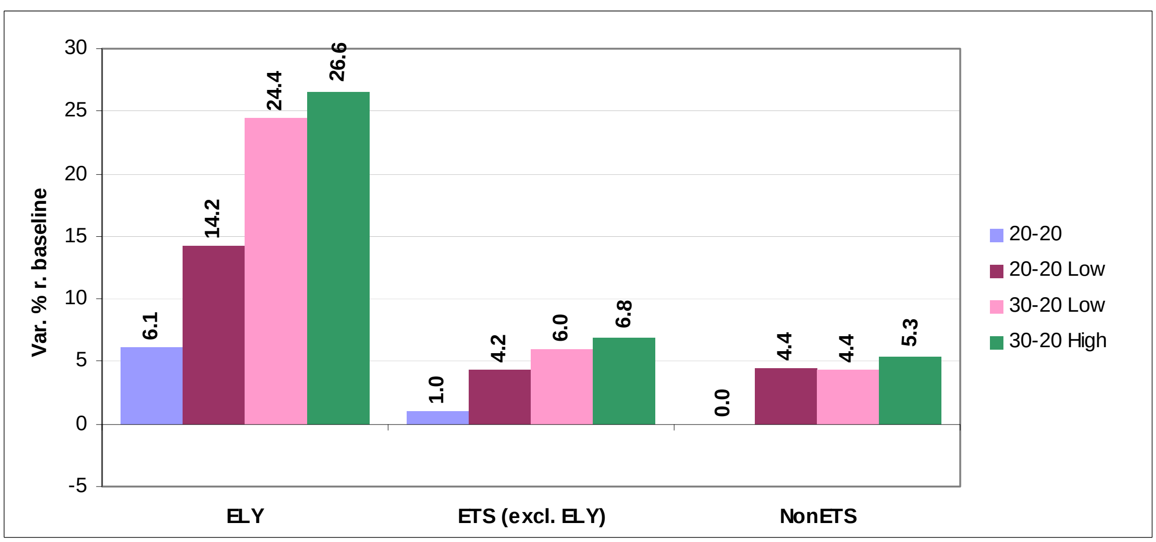


Figure 16. EU27 Sectoral prices. % change w.r.t. compared to the baseline in 2020



Considering the macro sectors, Italy does not substantially differ from Europe (see Figures 17 and 18). The chemical sector is the only one in which results are not in line with what is observed at the European level. Particularly, under the 20-30 Low pledge scenario, the Italian sector performs better. This is, indeed, a common result for the major EU15 countries such as Germany, England, France but not Spain. It is also worth noting a strong contraction in the use of coal as fossil fuel which implies that the few national producers exit from the market .

Figure 17. Italian Sectoral Production. % change w.r.t. compared to the baseline in 2020

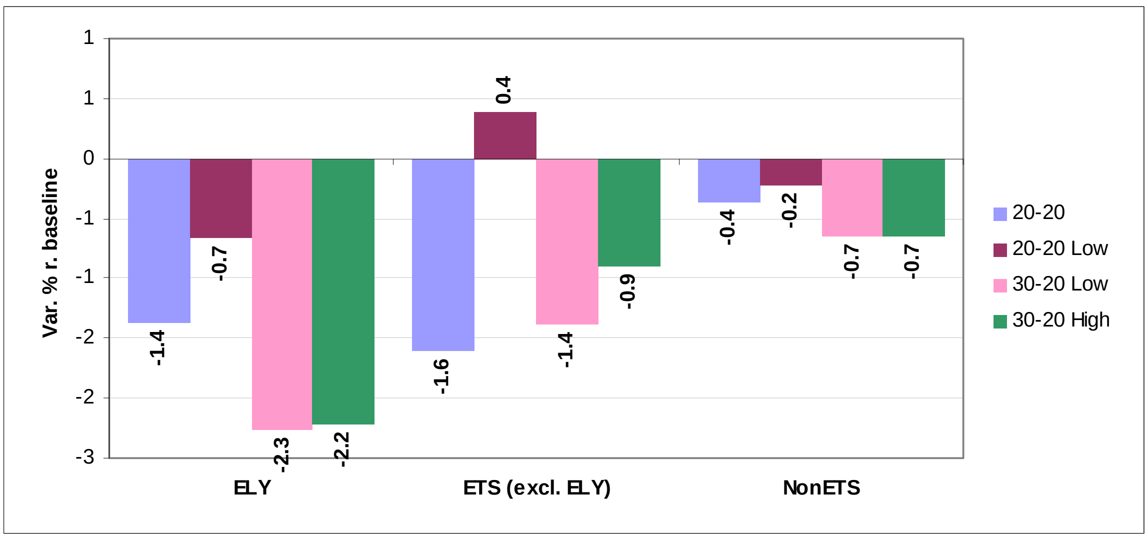
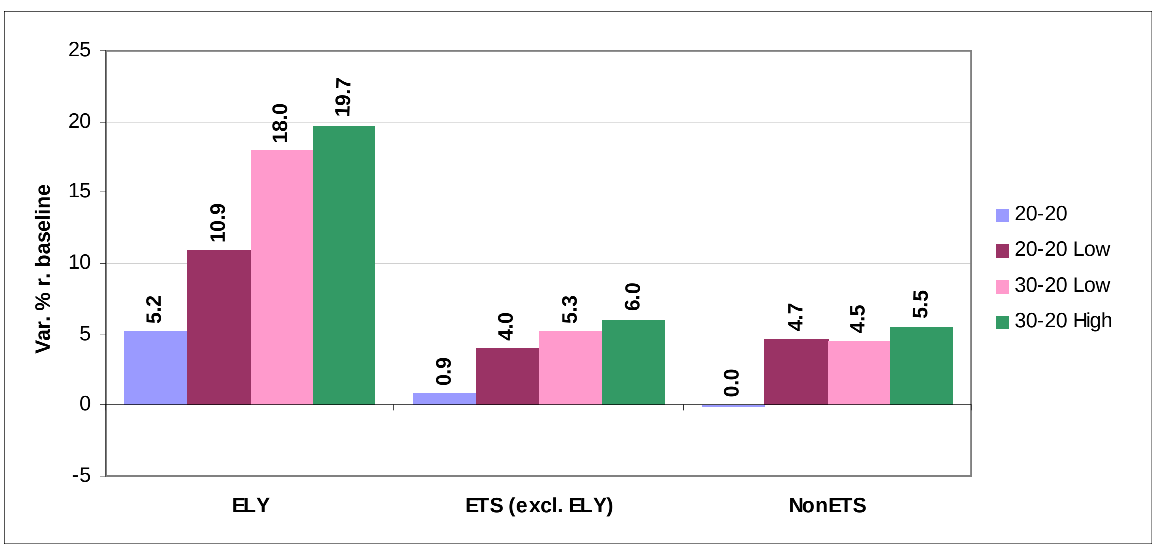


Figure 18. Italian prices. % change w.r.t. to baseline in 2020



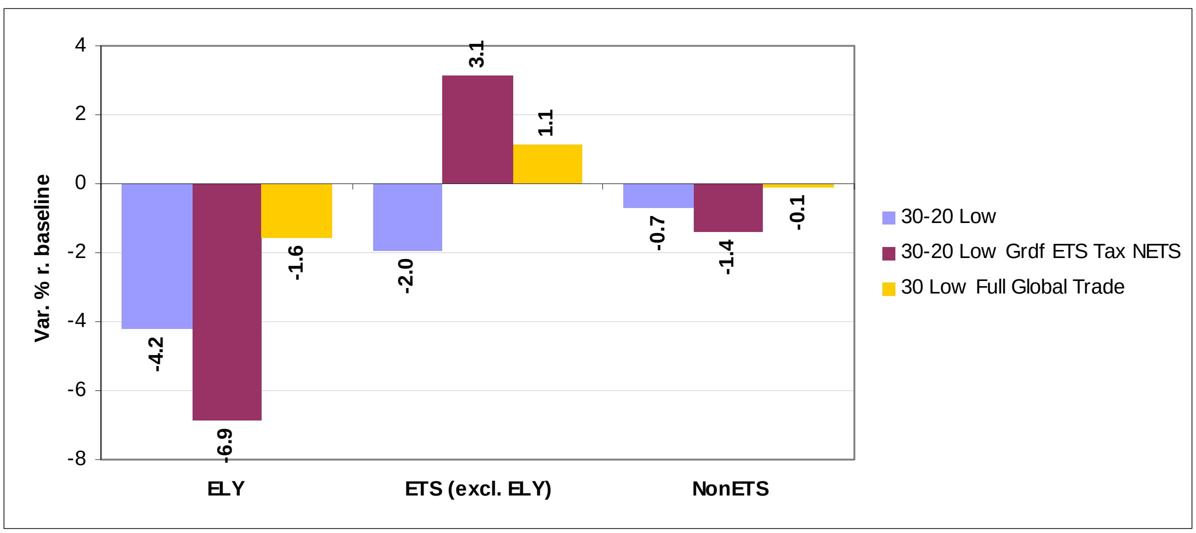
30-20 Low, Grandfathering ETS and tax Non ETS, Full Emission Trading

Within the context of the Copenhagen Accord, the 30-20 low scenario is the most costly policy for EU as well as the most realistic one in the case that EU decides to reduce its emissions by 30%. We analyse the effects on policy implementation costs when allowances are freely allocated to ETS sectors with higher energy intensity and a carbon tax is introduced for Non-ETS sectors. Allowances in the electricity sector are auctioned as before.

We also observe in this case similar results in the 30-20 scenario with grandfathering (Figure 19). Moving from auctioning to grandfathering favours energy intensive sectors, where production reduces less or, as in the chemical sector, even increases. On the other hand, this happens at the expense of non energy intensive sectors in which demand drops due to both a substitution and an income effect. In fact, the missed revenues from auctioning, lower family disposable income.

Additionally, the European price of CO_2 is higher than in the auctioning system. The net effect on European GDP is strongly negative while it is slightly positive for rival economies.

Figure 19. Sectoral Production in UE27 (a). % change w.r.t. baseline in 2020



We finally analyse the possible effects of introducing full flexibility to reach a 30-20 Low pledges scenario, assuming the existence of an international market for carbon for all the countries implementing the pledges, and an unlimited use of this market. Every region has an initial allocation of allowances, which is equal to the corresponding pledges.

A first consequence is that total mitigation costs for involved countries drops from 1.25% - in the case of a unilateral implementation to 0.8% of GDP, if full flexibility takes place (see Table 5).

World market CO_2 price reaches around 41 €/t in 2020. A second consequence is that abatement effort is transferred from more to less developed countries, i.e. to most carbon intensive countries such as Russia, China , and India (see Figure 20). Interestingly, this cost reallocation favours Europe whose GDP would still grow despite the allowances purchase corresponding to 572 million tons of carbon.

This result represents the sum of two beneficial aspects: the lower abatement effort and the higher relative competitiveness. Although they receive revenues from the sale, the GDP declines in countries, which export allowances such as Russia, China, and India. The additional abatement effort more than offsets the increase in National Income, following the direct liquidity injection from the sale of permits. In the absence of ex-post compensation mechanisms, higher carbon intensive countries would not find it convenient to enter into an international carbon market. However, the trading of permits generates a net advantage, which translates into a cost reduction of 0,45% of GDP for involved countries. The available resources for ex-post transfers would require a greater effort for EU to compensate China, India, and Russia.

4 Summary, conclusions and policy implications

This paper analyses the impacts on EU GDP from the implementation of mitigation policies considered on the “climate package” 20-20-20, and in light of the negotiations that proposed a set of pledges after the COP 15 in Copenhagen, it includes a possible extension to a 30-20-20 package.

First, this paper focuses on a unilateral EU action to be compared with a scenario in which the main Non-EU economies adopt mitigation targets coherent with the voluntary pledges of the Copenhagen Accord.

Different permit allocation schemes between ETS and Non-ETS sectors have been discussed, as well as the introduction of Border Tax Adjustment measures based on the carbon intensity of imported goods, and the establishment of an international emission market which allows maximum efficiency and flexibility in achieving a global climate target.

Our main results can be summarised as follows:

1) The package 20-20 entails moderate costs: approximately 0.56% of GDP when the EU implements the policy unilaterally, and even a small gain when Non-EU regions implement their low Copenhagen pledges. In these circumstances the improvement of EU competitiveness in the international market derived from the Non-EU commodities’ price increase outweighs the implementation costs of the EU policy. Independently from the net outcome, EU energy intensive

sectors are penalised : prices increase (min. 0.2% paper, max. 1.7% iron and steel with EU multilateral action; 5.2% paper, 6.1% iron and steel with the low pledge scenario in Non EU regions) and production diminishes (min. -0.4% paper, max -2% chemistry and iron and steel works with EU multilateral action; -0.3% paper, -0.4% iron and steel works with the low pledge scenario in Non EU regions).

2) Moving from 20-20 to 30-20 entails substantive costs: a loss of 1.26% of GDP in the case of EU unilateral action; and a loss of 0.66% and 0.55% of GDP when Non-EU regions implement their low and high pledges respectively. Therefore, costs either double or from negative (benefits) become positive. The loss of energy intensive sectors increases proportionally either in quantity or price.

3) Notwithstanding the burden on European energy intensive sectors, in the case of EU unilateral action, the advantage for Non-EU area is limited, varying from 0.09% to 0.17% of GDP. However, the effect on emission is consistent: a redistribution of the demand in favour of Non-EU carbon and energy intensive goods associated to the increase of the aggregated demand induces an increase of emissions between 1.1% and 1.7% that erodes about 70% of EU abatement effort.

4) Mitigation policies lead to a “greener” re-composition of the European production system and to a switch from fossil fuel use to renewable sources. Achieving the 20-20 rises the price of one ton of CO_2 from a minimum of 30 €/t, in the case of EU unilateral action to a maximum of 57 €/t within a Copenhagen low pledge framework. The 30-20 implies a minimum price of 70 €/t in the unilateral case and a maximum of 110 €/t within a Copenhagen high pledge framework. The higher the Non-EU abatement effort, the higher the demand for EU goods (more competitive) and the higher the price signal needed to induce the desired abatement.

Subsidies necessary to achieve the renewable targets vary from 34 €/MWh (20-20) to 10 €/MWh (30-20 with a high pledge). Subsidy decreases as more ambitious targets make the development of renewable technologies and energy efficiency more convenient. The production of electricity from renewable sources rises from a minimum of 40% to a maximum of 60%, while that from fossil fuels contracts from a minimum of 3% to a maximum of 6%.

5) The costs for energy intensive sectors could be successfully reduced either by using free allocations of allowances or Border Tax Adjustments (BTA). In both cases, the higher benefits are for the chemical, iron, and steel sectors in which losses reduce on average by 30% to 50%. In both cases, the price level slightly increases with respect to auctioning and tax. Comparing both systems, BTAs seem to be on average less effective than grandfathering in terms of lowering negative impacts on sectoral production (even though sectoral productive performances are mixed), and to

produce higher prices. The import tariff indeed increases the price of EU products that use foreign commodities as intermediate inputs. Either with grandfathering or BTAs the benefit for energy intensive sectors is counterbalanced by a more than proportional loss in the primary, light manufacturing and services sectors. Consequently, the net GDP loss (for the scenario 30-20 of about -1.38% and -1.34% with grandfathering and BTA respectively) is higher than that of the auctioning and tax cases.

6) In the 20-20 case, the efficient allocation of abatement leads to an emission reduction of 14.1% in the ETS and of about 10.8% in the Non-ETS sectors in 2020 with respect to 2005. These data coincide with the previsions for Non-ETS sectors in Decision 406/2009/EC (10,6%). However, it is necessary to stress that ICES considers only CO2 emissions and not CH4 and N2O from agriculture. Since these represent a large part of mitigation opportunities for the Non-ETS aggregate, it is possible to conclude that the foreseen effort for Non-ETS sectors would be lower than optimal. For the same reason, , the 21% target for the ETS sectors (Directive 2009/29/EC) seems to be higher than optimum. Likewise, the allocation of abatement efforts among countries is suboptimal. Austria, Belgium, Denmark, Greece, Finland, Ireland, Spain, Sweden seem excessively burdened; Czech Republic, Hungary, Poland and eastern EU countries are favoured . The Italian target seems to be quite in line with the optimal abatement.

7) Not surprisingly, the most convenient way to reduce the costs of mitigation policies would be to establish an internationally coordinated carbon market. The 30% package with low pledges would cost the involved countries 0.8% of GDP instead of 1.25%. Major gains are expected in more energy efficient economies that can shift part of the abatement burden on the less energy and carbon efficient ones where low cost abatement options are still available. Against this background the EU could even gain with respect to its no policy baseline (0,2% of GDP in 2020). This derives from a lower abatement effort and a higher competitiveness compared to Russia, China and India. Conversely, in these areas, additional mitigation costs are higher that the advantages obtained through the liquidity injection coming from the permit sale. This would lead to the conclusion that in the absence of ex-post compensation mechanisms, high carbon intensive countries would not find it worthwhile to participate in an international carbon market. Nonetheless, it is worth remembering that after the induced redistribution from permits trade, a net advantage from cooperation equaling about 0.45% of GDP of the trading countries remains. The resources for ex-post transfers could be available, but would require arelatively higher effort from EU to compensate China, India and Russia.

8) In this context, the Italian economy shares the fundamental characteristics of the European average and of its major economies. The country with a GDP loss of 0.54% in the 20-20 to 1.18% in the 30-20 scenarios demonstrates slightly higher costs than Germany and UK, but lower than Spain.

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