Renewable Energy Targets in the Context of the EU ETS: Whom do They Benefit Exactly?

Florian Landis[a] *and Peter Heindl*[b]

ABSTRACT

We study how European climate and energy policy targets affect different member states and households of different income quintiles within the member states. We find that renewable energy targets in power generation, by reducing EU ETS permit prices, may make net permit exporters worse off and net permit importers better off. This effect appears to dominate the efficiency cost of increasing the share of energy provided by renewable energy sources in the countries that adopt such targets. While an increase in prices for energy commodities, which is entailed by the policies in question, affects households in low income quintiles the most, recycling revenues from climate policy allows governments to compensate them for the losses. If renewable targets reduce the revenues from ETS permit auctions, member states with large allocations of auctionable permits will lose some of the ability to do so.

Keywords: Distributional effects, EU climate policy, Renewable energy target, Policy interaction

https://doi.org/10.5547/01956574.40.6.flan

1. INTRODUCTION

The climate policy of the EU has distributional consequences across households, industries, and countries. In order for the EU to be able to continue to pursue ambitious targets in climate policy, policy implementation needs to keep these distributional consequences in check: In order to facilitate unanimous agreement on targets, it must be avoided that some, especially less affluent, member states bear disproportionately big shares of the overall policy cost. However, unevenly distributed impacts have to be expected in the context of CO_2 taxes or emission trading systems, as low-income households usually spend a larger share of their income on energy services when compared to wealthier households.

The EU's policy design shows recognition of this problem by allocating auction revenues from the European Emission Trading System (EU ETS) to member states based on their economic abilities (viz. 'expectations for economic growth, the energy mix, and the industrial structure of the respective Member State' according to the EU council's decision 2002/358/CE). EU rules further encourage member states to use their allocated permit auction revenue for counteracting unintended distributional impacts of climate policies (among other recommended uses of the revenue).[1]

1. Article 10 of directive 2003/87/EC.

[a] Corresponding author. Center of Economic Research at the Department of Management Technology and Economics, ETH Zürich. Send correspondence to ETH Zürich, ZUE E2, Zürichbergstrasse 18, 8032 Zürich, Switzerland. E-mail: landisf@ethz.ch.

[b] ZEW – Leibniz Centre for European Economic Research.

This paper analyses the effectiveness of the EU's distribution of permit auction revenues against the backdrop of pre-existing inequality in/across the member states and analyses the interaction of EU targets for renewable power generation with this redistribution mechanism. Mandatory targets on the member state level for renewable energy sources (RES) in the power sector increase emissions abatement under the ETS within the member states that adopt such targets.[2] By doing so, they reduce the emission reductions required from other member states.[3] At the same time, they reduce the market price for emission allowances under the ETS and thus revenues from auctioning the emission allowances, because increased renewable energy production reduces the demand for conventional power generation and consequently emissions allowances (while supply of allowances remains constant). The overall effect of RES targets on the distribution of climate policy cost is a priori unknown. We approach the analysis of the distributional effects and interactions of climate policies in the context of the EU's 20 percent emission reduction target for the year 2020 and apply the computable general equilibrium (CGE) model PACE in order to examine costs and distributional effects across and within EU member states under different policy scenarios.

There is a large body of literature on the distributional effects of climate policy. Most studies analysing expenditure patterns suggest that direct carbon taxation will cause regressive effects if the prices of necessities, such as electricity or space heating, are affected. In contrast, direct taxation of the carbon content of transport fuels tends to be neutral or even progressive (Sterner, 2012). However, restricting the analysis to expenditure patterns ignores important effects on the income side. The analysis by Fullerton and Heutel (2007) and a survey by Boccanfuso et al. (2011) emphasise the importance of general equilibrium effects in this context. If climate policy causes important changes for factor income (land rents, capital income, labour income) CGE models are a valuable tool for keeping track of these effects. Rausch et al. (2011) confirm this argument in their analysis of a hypothetical cap-and-trade scheme in the United States, assuming a carbon price of approximately USD 20 per ton of CO_2 equivalent. Buddelmeyer et al. (2012) combine a CGE model with a microsimulation model to assess the impact of carbon emission reductions by cap-and-trade in Australia. The authors find a moderately progressive distribution of costs after revenue recycling by lump-sum transfers. However, progressivity diminishes over the course of time as recycled permit revenues eventually become too small to compensate households in the second income quintile.

Distributional effects of renewable energy standards in the United States are examined in a CGE model by Rausch and Mowers (2014). They find that a renewable energy standard would be about four times more costly than a "comprehensive market-based carbon pricing policy" [p. 582]. A renewable energy standard would further cause regressive distributional effects [p. 574]. Since the policy does not raise revenues, options for mitigating distributional effects through revenue recycling do not exist. Several ways in which promotion of RES interacts with the ETS in unintended ways have been highlighted in the literature: Flues et al. (2014) show how the combination of policies make ETS permit prices more sensitive to economic activity and that policy costs increase in particular in the presence of negative electricity demand shocks. Böhringer and Rosendahl (2010) show

2. The EU assumed a common emission reduction target according to the requirements of the Kyoto Protocol (directive 2002/358/EC) and subsequent decisions. The common EU target is broken down to targets for each member state. Parts of the intended emissions reductions are achieved in the EU-wide emissions trading scheme, covering the industry and the energy sector. Sectors which are not covered by the ETS (e.g., transport, agriculture) face other regulatory obligations to reduce emissions, which are defined by member states individually. Some member states assumed additional renewable energy targets.

3. In our study, we assume that RES targets give no motive for shifting emission abatement efforts between time periods. Thus, total emissions under the ETS within a time period do not change with the introduction of a RES target and any reactions of the market stability reserve (MSR) to different levels of permit overallocation will be the same with or without the targets. We do not include the MSR in our model.

that the lower permit prices implied by binding RES targets may prove most advantageous for those fossil generation technologies that pollute the most. But an analysis of how national RES policies may affect the distribution of policy cost of the ETS across countries seems to be missing.

Our results indicate that the EU's efforts to redistribute policy costs through allocating permit auction revenues succeed in protecting the least wealthy member states in Eastern Europe from negative impacts of the ETS. In fact, most of those countries appear to profit from the current ETS design. Binding minimum requirements for RES in national power generation shift abatement costs from countries without such ancillary targets to countries that implement them but at the same time reduce revenues from permit auctions, which affects countries in proportion to the shares of auction revenues that are allocated to them. We find the latter effect to dominate the former, if several net permit importing member states adopt binding RES targets. That is, a country will tend to gain (lose) from the ancillary RES targets if it receives auction revenues from fewer (more) emission permits than its industries require under the cap. This holds almost irrespective of whether the country itself is subject to a binding RES target or not. Also, in the absence of revenue recycling, observed distributional effects within countries show regressive patterns for most EU member states. If revenues are fully or partly recycled in accordance with existing tax and transfer schemes, the resulting patterns of distribution become progressive. In some member states, the lowest income quintiles even profit in absolute terms.

The remainder of this paper is organised as follows. The model is presented in Section 2, including a data description, the procedure of disaggregation of households along the quintiles of the income distribution, and the policy scenarios. Results are discussed in Section 3. Section 4 discusses the newly introduced MSR and Section 5 concludes.

2. MODEL

Our study employs the PACE model and extends it by splitting the EU member states' representative households into income quintiles. Realistic accounting of ETS permit auctioning revenues and how they are distributed among member states allows for the analysis of distributional impacts of climate policy targets. The PACE model is well suited for the analysis of international climate policy, due to its sectoral resolution of energy production, its representation of trade patterns, physical energy flows and its calibration to the EU's scenarios for economic growth and energy use under continuation of the currently enacted climate policy. This section provides a brief overview of the model. The model is described in detail in Appendix A.

2.1 The PACE model

The PACE model is a GTAPinGAMS CGE model[4] with extensions that make it suitable for the analysis of climate and energy policies at a global scale. Besides the 28 member states of the EU, the model includes the world regions China, Japan, South Korea, Indonesia, India, Canada, USA, Mexico, Brazil, Russia, Australia, and New Zealand, Rest of Annex I[5], Rest of World. In each region, representative households own (region specific) production factors that are employed by the regional sectors for producing globally traded commodities. For each European member state, consumers are segmented into five households which represent income quintiles and both their expenditure and their income are calibrated by using survey data from European member states.

4. See for example https://www.gtap.agecon.purdue.edu/about/data_models.asp
5. That is Annex I to the United Nations Framework Convention on Climate Change (UNFCCC).

The production factors owned by the representative households are labour, capital, and resources (viz. the fossil fuels crude oil, gas, and coal). The demand for consumption goods of the representative households are given by household specific demand functions and the investment good is demanded by households in fixed amounts. Labour and capital are mobile between sectors within countries. Technology specific capital for power generation is an exception to this and is in fixed supply. Governments in each region levy taxes, issue subsidies, make transfers to households, and demand fixed amounts of government services. Taxes in PACE are levied on production factors and final products. Countries levy tariffs on imports and subsidise exports.

The production factors are employed by industrial sectors to produce sector specific outputs which are traded between regions and used as intermediate inputs by other sectors or consumed by representative agents. PACE uses nested constant elasticity of substitution (CES) production functions to represent production in different economic sectors, trade, and final consumption. The standard production function (see also Fig. 5 in the Appendix) combines the use of intermediates with a value added–energy composite at the top level.

In the case of power generation, the model distinguishes the five generation technologies 'oil', 'gas', 'coal', 'renewable', and 'nuclear'. They all produce the homogeneous good electricity which is traded at a common market price. The production technologies differ in fuel and capital intensity, as each technology uses its specific fossil fuel and capital type (see Fig. 7 in the Appendix).

Industry output thus produced in one region is either exported or sold on the domestic market alongside with the imported version of the good. Both are traded off against each other according to the Armington assumption (Armington, 1969), which results in a domestic market price index. The imported version of the good is again an aggregate of the varieties that are produced in other regions.

2.2 Climate policy in PACE

Emissions outside the ETS (subject to CO_2 taxes) and inside it (requiring submission of emission allowances) are proportional to the amount of fossil fuels demanded and burned in the process of energy generation. Regarding emissions within the ETS, the market clearing price for emission rights corresponds to the market price of ETS allowances, the supply of which is fixed by the EU-wide cap. Outside the ETS, the CO_2 tax is set by the governments to efficiently meet their national targets. Revenues from CO_2 taxation are given to households via lump-sum transfers or are spent on the investment good, depending on the policy scenario. In scenarios where member states are assumed to employ non-revenue raising policies for emissions reductions in non-ETS sectors, this policy is modelled as a carbon tax and the tax revenues from each sector and household are refunded through differentiated subsidies on sectoral output and household consumption.[6]

Additional mechanisms need to be included in the model for adequately representing EU climate policy and its distributional impacts for this study. First, some sectors governed by the ETS receive free emission allowances. While the option of selling the received permits at market prices induces firms to abate at efficient levels, the advantage of receiving free permits makes them more profitable, which induces market entry until market prices change to bring profits back to the economy-wide average. This effect can be achieved in the model by making sectors buy emission

6. These refunds make the output of emission intensive sectors less expensive than they would be under a carbon tax without refunds, which introduces an inefficiency. Yet the policies described here imply a (maybe unrealistically) perfect ability of governments to regulate different sectors such that sectors abate their emissions where it is cheapest.

permits but getting a refund in form of an endogenous output subsidy that compensates them for their expense.

Second, some countries adopt targets for the share of power generation from RES in total electricity, which shall be reached by implementing a quota. To meet the quota, the power sector internally subsidises power from RES so that their generation cost can compete with the generation cost of other technologies even at the required high deployment rates of RES. While emissions allowances in the ETS are traded (within and across countries), there is no trading scheme for renewable energy obligations. The additional costs of this internal subsidy have to be financed with a markup on total power sales, which is modelled as a sales tax. A similar scheme is, for instance, in place in Germany, where renewable subsidies are financed via a surcharge on top of the electricity price.

Third, the model distinguishes between emission allowances that are allocated to sectors for free and those that are auctioned. The revenue from auctioned permits is then distributed according to fixed shares among the governments of the member states. Depending on the policy scenarios, national governments are required to spend their revenues from permit auctioning on investments, which increases the demand for commodities that are associated with investment.

Fourth, real government consumption is kept constant by adjusting lump-sum transfers from the government to the households. Changes in lump-sum transfers are distributed among households in proportion to currently existing transfer payments in the respective member states.

2.3 Data

The data source for the calibration of PACE originates from the Global Trade Analysis Project (GTAP) (Aguiar et al., 2012). Version 8.1 of the GTAP data base provides the model with input–output structures for production sectors as well as trade patterns. Besides value flows between sectors, consumers, and governments of different countries, physical quantities in units of energy and emissions that correspond to the value flows are provided.

In order to capture impacts of rising prices of energy commodities on consumers with different levels of affluence in different countries, we disaggregate the representative household of each country into five households that represent the income quintiles. We combine two sets of survey results to split expenditures on the one and income on the other hand between the quintiles. On the expenditure side, national expenditures for different consumption goods have to be split into the expenditure of different income quintiles. The resulting expenditures are used to calibrate the nested CES functions representing the quintiles' consumption baskets. On the income side, factor endowments and government transfers have to be realistically distributed among quintiles in the benchmark.

Expenditure of income quintiles

The model imitates information from Eurostat on the amount of overall consumption and the share of the energy goods in overall consumption for each quintile. It is worthwhile to note that we rely on household expenditures in purchasing power standard (PPS) provided by Eurostat in order to make consumption bundles comparable between member states when reporting results. The household budget surveys of [EUROSTAT, 2014] provide expenditures per household and per adult equivalent for five quintiles in all EU member states for the year 2010.

Expenditures for non-energy commodities are distributed in fixed (within member states) proportions among quintiles so that expenditures for energy and non-energy commodities add up to total expenditures.

Income of quintiles in PACE

On the income side, the PACE model distinguishes between wage earnings, rents on capital and resources, and net transfers between government and households. In order to split these revenue streams among income quintiles, the Household Finance and Consumption Survey (HFCS) by the European Central Bank (ECB) is consulted. The data are available for the following 15 members of the eurozone: Austria, Belgium, Cyprus, Germany, Spain, Finland, France, Greece, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovenia, and Slovakia. We group these countries into Western, Eastern, and Southern Europe and assume that in the remaining EU member states, factor incomes are distributed across households according to the European area (viz. South, East, or West) they belong to.

Sensitivity analysis with regard to pension revenues

When calibrating income data from the ECB's HFCS to PACE, pension income in income surveys are associated with capital income according to GTAP. Thus, capital in the PACE model has been distributed between income quintiles to match the distribution of capital *and* pension income according to the income survey. The consequence is that if climate policy affects capital revenue in the PACE model, this effect will be passed on to pensioners.

As an alternative interpretation of pension revenues in the income survey, we associate it with labour income in PACE. Thus, labour income as given by GTAP is distributed across income quintiles pursuant to how labour *and* pension income is distributed.

Projecting the benchmark to 2020

The benchmark social accounting matrices (SAMS) given by GTAP reflect the global economy in 2004.[7] In order to discuss future European climate and energy policy, the data are projected to 2020. For this purpose, national factor endowments are inflated according to regional growth projections from the European Commission's reference scenario (Capros et al., 2013). To reflect progress in energy efficiency, the energy consumption of production is also reduced by exogenous factors and in line with the aforementioned reference scenario. The various imbalances created by these changes are smoothed out by letting the model solve for equilibrium after factor endowment adjustments and after numerous intermediate changes to energy intensity. This procedure leads to the desired baseline 2020 projection.

7. GTAP version 8.1 also includes balanced data for the year 2007 and more recent versions of GTAP include the year 2011 as well. The argument for using the year 2004 is that it represents the economic situation in the EU before the economic downturn following the financial crisis of 2008. Thus, the projections we use for forward calibrating the European economy to 2020 are better suited to forward calibrate from the base year 2004 than from 2007 or 2011 (projecting those years to the periods 2010 and 2015 would involve interpolating the trends of the periods 2005–2010 or 2010–2015, neither of which have been periods of even and steady growth).

2.4 Scenarios

No-policy scenario

The *NoPolicy* scenario assumes the absence of climate policy. The model baseline is calibrated to the reference scenario by the European Commission (Capros et al., 2013), which assumes a binding ETS cap and a corresponding ETS allowance price. Therefore, the no-policy scenario represents a deviation from that baseline that is endogenously determined by the model by removing the cap.

Emission target

The *Cap* scenario assumes that the EU abides by its targets for 2020 and reduces overall emissions by 20 percent compared to 1990 levels. The national targets for overall emissions are determined by reducing member states' emissions in the baseline of Capros et al. (2013) by a common factor such that the EU emission target is met. The emissions permitted under the target are distributed among ETS and non-ETS sectors according to the baseline given in Capros et al. (2013). The resulting levels of non-ETS emissions constitute binding national targets in our scenarios, while the ETS sectors can adjust their emissions endogenously by trading emission allowances internationally in order to meet the EU wide emission cap at least cost.

The ETS emission allowances are distributed for free to sectors that are on the so-called leakage list in the PACE model and the other sectors receive 30 percent of their required permits for free in 2020.[8] Only the electricity sector is exempt from this free permit allocation as it has been required to purchase all its emission permits since 2013. The model endogenously keeps track of the allowances that remain for auctioning and distributes the revenues from the auctions across member states according to the rules set up in 2009/29/EC.[9] The member states use the revenues from these auctions to compensate households for parts of the policy cost.

The scenario *Cap* assumes that the targets for greenhouse gas (GHG) emissions outside the ETS sectors are met by the member states through efficient but non-revenue raising regulatory measures.

Renewable target

In the "quota for renewable energy sources in power generation" (*Cap+RES*) scenario, member states are assumed to set themselves the same emission targets in and outside the EU ETS system as in the aforementioned scenario *Cap*. However, in addition to the emission target, several member states set themselves targets for the share of power they generate from RES. These member states are Belgium, Denmark, France, Germany, Luxembourg, the Netherlands, Sweden, and the UK. Each of them increases the share of RES in power generation to ten percent above 'current policies' levels (Table 1).[10] The scenario *Cap+RES* assumes that these member states reach the target

8. This represents the EU's intention of switching towards an auction based system for most sectors by 2027.

9. According to directive 2009/29/EC (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0029 from=en; accessed 24/01/2018), auction revenues shall be distributed according to fixed shares, which are based on historic emissions and motives of "Community solidarity and growth". The shares are given in Appendix B.

10. We recognize that under EU climate policy, all member states have targets for energy generation from renewable sources. We posit that those targets have a tendency to be more stringent for wealthy member states in Western Europe. This assessment is due to a perceived higher political willingness to support such targets and a higher capacity to pay of these

by mandating a renewable quota, which the power sector has to finance by raising electricity prices. Thus, from the national governments' point of view, the renewable targets are revenue neutral.[11]

Table 1: Assumed renewable targets for 2020 in percent of total power generation

Country	Target [%]
Belgium	28
Denmark	69
France	30
Germany	43
Luxembourg	43
Netherlands	35
Sweden	64
UK	45

Investment of ETS auctioning revenues

The "invest ETS auctioning revenues" (*Invest*) scenario again assumes the emission targets of *Cap*, but unlike the latter, does not recycle revenues from auctioning EU ETS allowances by transferring them to households. Instead, the *Invest* scenario assumes that member states use the revenue to make general purpose investments (which, in our model, is consistent with investing into clean technologies). This increases the demand for investment goods but leaves less money to be allocated to consumption by the various households. In terms of current consumption, this policy scenario obviously reduces welfare and the benefits that the investments will have in the future are not captured by the PACE model. Therefore, the scenario results only serve to consider the distributional equity within member states in the case where permit auctioning revenue cannot be used for redistribution to households. It should not be used to compare consumer welfare across scenarios.

Renewable target with investment of ETS auctioning revenues

The "quota for renewable energy sources and invest ETS auctioning revenues" (*Invest+RES*) scenario assumes the emission targets of *Cap*, the RES targets of *Cap+RES*, and that the decision to invest ETS auctioning revenues is in accordance with *Invest*. In terms of revenue to the government, the renewable target remains revenue neutral. The auctioning of EU ETS permits generates revenues that have to be invested in clean technologies.

Taxation of non-ETS emissions with emission target

Just as *Cap*, the "tax non-ETS emissions" (*TaxCap*) scenario includes national targets for non-ETS emissions, but assumes that they are reached by national carbon taxes. This generates addi-

member states, both of which will influence the political process of target setting. By only setting explicit RES targets for eight member states implicitly assumes that the targets for the other member states are not binding and will be reached by the EU ETS alone.

11. A variant of this would be that member states subsidize RES instead of mandating the quota. This would necessitate large volumes of subsidies that carbon tax revenues cannot finance. When discussing results we refer to Appendix C for partial results for this variant.

tional revenue, which may be recycled. The part of the carbon tax revenue that is levied on industrial fuel consumption is rebated to the industries in proportion to sales volumes and the part levied on households is returned to them on a lump-sum basis.

Taxation of non-ETS emissions with emission target and renewable target

Just as *Cap+RES*, the "tax non-ETS emissions and quota for renewable energy sources in power generation" (*TaxCap+RES*) scenario includes national targets for non-ETS emissions and shares for renewable power generation, but assumes that they are reached by national carbon taxes. The additional revenues are redistributed among industries and different households as in the scenario "tax non-ETS emissions" (*TaxCap*).

3. RESULTS

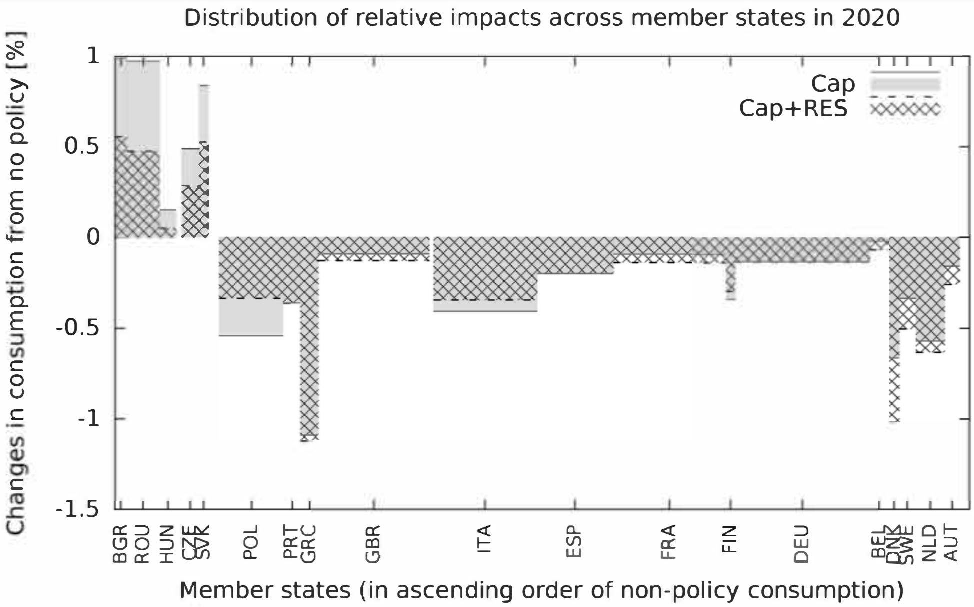
In order to understand how RES targets in selected countries affect the distribution of climate policy costs across member states, we first compare welfare effects on the member state levels for the scenarios *Cap* and *Cap+RES*. When analysing distribution of policy income across income groups within member states, we compare all the different policy scenarios with different options of revenue recycling in order to understand to what extent national transfer schemes and the available budgets for recycling are suitable for counteracting potential regressive distribution of policy cost.

3.1 Distribution of costs across EU

Figure 1 depicts the change in consumption budgets relative to the no-policy case at the member state level. Results refer to the relative change in aggregated consumption budgets of households within member states. Detailed results for each member state are reported in Tables 12–17 (column "overall", scenario *Cap* and *Cap+Res*) of Appendix D. A decrease of consumption in aggregate is expected by 2020 for most EU member states as a result of introducing the ETS cap (scenario *Cap*). However, the decrease in the consumption budget is moderate in most member states. Countries with a more pronounced reduction in the consumption budget include Greece, Denmark, the Netherlands, and Poland. Many Central and Eastern member states (for brevity 'Eastern member states' in what follows) are expected to benefit from EU climate policy. One reason for this is the relatively generous allocation of EU allowances to Eastern member states. Gains from the introduction of the ETS cap are most pronounced in Bulgaria, Romania, and Slovakia. This result illustrates that many Eastern member states are actually over-compensated as a result of the EU-wide allocation of emission allowances.

If the ETS cap is augmented by a renewable energy target (scenario *Cap+Res*), moderate changes in the consumption budgets occur. The observed changes are small for most of the member states and originate from changes in the ETS allowance price as well as from changes in associated costs and benefits from allowance trading: The renewable standard increases supply from renewable energy sources, which in turn causes a decrease in demand for the non-renewable energy sources and an associated lower demand for emissions allowances. This reduces market prices for emission allowances and member states with over-allocation of allowances (which are net sellers) will therefore forgo revenues from allowance trading. Table 2 shows how industry use of auctioned ETS permits compares to the shares of permits which the member states receive. A positive surplus (see columns three and four of Table 2) indicates that a member state receives auction revenues from more permits than its industries need and consequently, the member state as a whole incurs losses

Figure 1: Relative policy cost by EU member state and scenario. Countries are sorted in ascending order of non-policy consumption based on Eurostat data. The width of the bars is proportional to the share of the population of each member state.



if the market price for ETS permits decreases. This explains why additional RES quotas and the resulting drop in ETS permit prices cause policy costs to decrease in Poland and Italy under *Cap+Res* when compared to scenario *Cap*. Strong negative effects caused by the introduction of the RES quota in addition to the ETS cap are observed for Bulgaria and Romania; Slovakia, the Czech Republic, and Hungary are also negatively affected. The reductions in abatement costs resulting from a lower allowances price within their own ETS sectors do not outweigh forgone revenues for these member states. For these countries, instantaneous economic benefits[12] under the additional RES quota are lower than in the situation without the RES quota. Denmark, as a net seller of ETS allowances, is expected to face a considerably larger loss in the presence of the RES target (–1.02%) when compared to the ETS only scenario (–0.66%). Other Western EU member states, such as the United Kingdom, France, Belgium, Sweden, the Netherlands, and Austria, also face larger costs under the additional RES target, but the changes in costs are not very pronounced.

Scenario *Cap+Res* assumes that member states with a RES target implement a renewable energy standard. Alternatively, they might implement a subsidy on electricity generated from RES. Member state level results for this version of reaching RES targets are given in Appendix C. In this case, consumer prices for electricity generated in these member states is lower than in *Cap+Res* and thus more electricity generated from fossil fuels is consumed. The resulting increase in demand for ETS permits (combined with fix supply) increases their price to a level between *Cap* and *Cap+Res* and for member states without RES targets the policy costs lie between those two scenarios as well. For most member states with RES targets, the subsidy turns out to be more costly than the renewable energy standard.

12. Due to modeling limitations, these exclude ecological benefits or long-term benefits from R&D activities.

Table 2: Provision and actual use of auctioned ETS emission allowances by member state. Use of auctioned allowances is total use of emission allowances by ETS industries minus freely allocated allowances.

	Demand	Auctionshare	Surplus	
	(MtCO2)	(MtCO2)	(MtCO2)	(%)
Bulgaria (BGR)	26.45	30.98	4.53	17.1
Romania (ROU)	26.20	51.07	24.87	94.9
Hungary (HUN)	8.95	15.28	6.33	70.8
Czech Republic (CZE)	35.73	47.83	12.09	33.8
Slovakia (SVK)	5.22	15.70	10.48	200.7
Poland (POL)	159.46	127.78	–31.69	–19.9
Portugal (PRT)	15.01	18.00	2.99	20.0
Greece (GRC)	31.09	35.48	4.39	14.1
United Kingdom (GBR)	108.26	106.74	–1.51	–1.4
Italy (ITA)	126.01	98.58	–27.43	–21.8
Spain (ESP)	87.30	88.33	1.03	1.2
France (FRA)	26.77	55.99	29.22	109.2
Finland (FIN)	15.55	17.06	1.51	9.7
Germany (DEU)	239.52	204.80	–34.71	–14.5
Belgium (BEL)	17.90	25.95	8.06	45.0
Denmark (DNK)	10.43	12.77	2.33	22.4
Sweden (SWE)	4.93	9.10	4.17	84.5
Netherlands (NLD)	56.35	34.33	–22.02	–39.1
Austria (AUT)	9.46	14.23	4.77	50.4

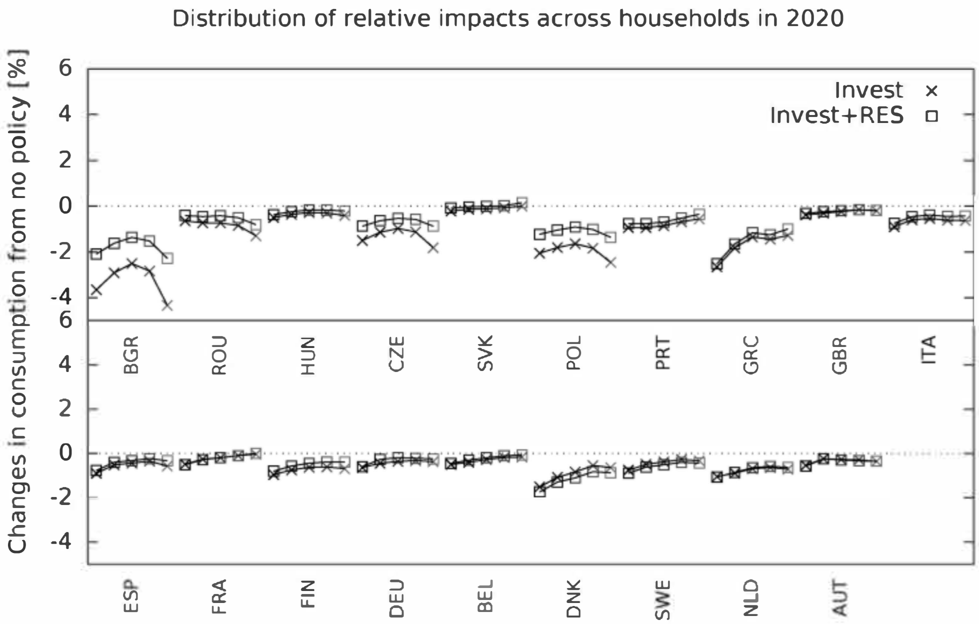
3.2 Distribution of costs within member states

In order to assess the distributive effects of EU climate policy within the member states, the household consumption in each of the states is disaggregated into five quintiles, according to the distribution of incomes, based on Eurostat data. The distribution of burdens at the household level within member states does not only depend on the overall expected costs, as depicted in Figure 1, but also on the recycling of revenues and the pre-existing tax and transfer schemes which are used for revenue recycling. In the following, we discuss the distributive impacts at the household level for three different assumptions about the amount of revenue that is available for recycling: i) no recycling; ii) full recycling of revenues from auctioning ETS permits; iii) full recycling of revenues from auctioning ETS permits *and* from taxing carbon outside the ETS.

No revenue recycling

Large costs of climate policy at the household level are to be expected in the absence of revenue recycling (scenarios *Invest* and *Invest+Res*). The situation is modelled in such a way that all revenues are invested. While the costs of these investments are incurred in the present, their benefits occur in the future and thus, climate policy revenues do not benefit current private consumption (e.g. investment in mitigation or adaptation technology with uncertain future benefits). While the model's welfare measure neglects positive effects from investments in this scenario, it allows for an examination of distributive patterns of climate policy due to increased consumer prices at unchanged transfers to private households. The distribution of costs among households of a member state thus may serve as a reference for the comparison of alternative revenue recycling schemes. Figure 2 gives a visual overview over the results. All numeric results are reported in Tables 12–17 (columns "q1" to "q5", scenario *Invest* and *Invest+Res*) of Appendix D.

Figure 2: Policy costs by member states and quintiles of the income distribution in the absence of revenue recycling. Quintiles within member states are sorted according to their no-policy income with black (leftmost marker) representing the poorest quintile and light grey (rightmost marker) representing the richest.



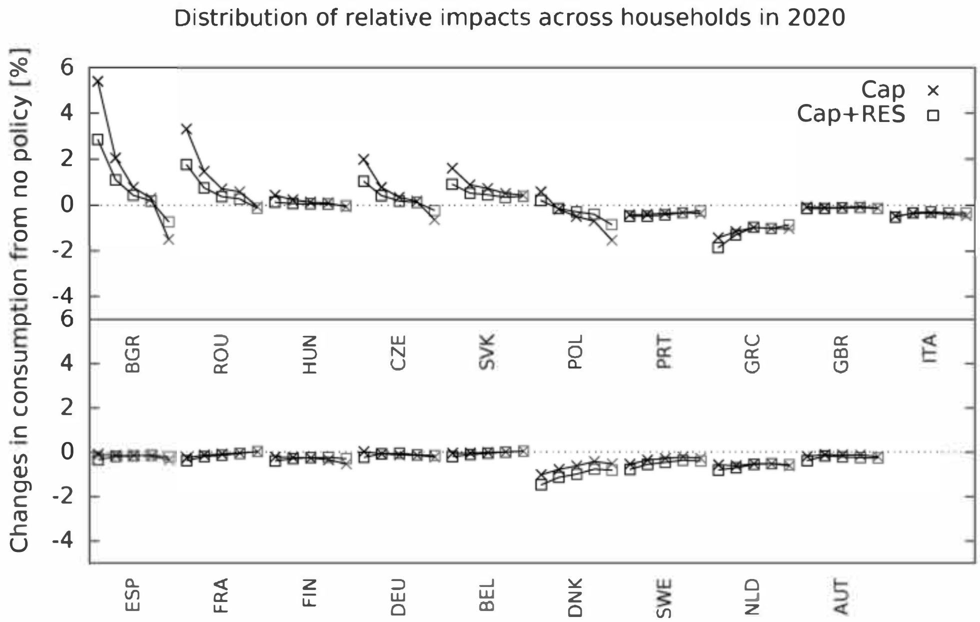
The distribution of costs differs between countries but also between the quintiles of the income distribution. Overall, there is the trend of a regressive incidence of climate policy in this scenario. There are large burdens in the top income quintile relative to other quintiles of the income distribution in some member states, viz. Bulgaria, Romania, the Czech Republic, and Poland. The observed inverted U-shaped pattern of incidence in these member states indicates that the top income quintile accounts for relatively large burdens, but at least in the case of Bulgaria, the Czech Republic, and Poland, households in the lowest income quintile also face considerable burdens. In most of the other member states, the largest burdens fall on the lowest income quintile in the absence of revenue recycling, so that we observe the trend of a regressive pattern of incidence in the scenario *Invest*. In this scenario, all member states and households, as represented by the quintiles of the income distribution, face a net loss of disposable income due to the investment of revenues in future projects.

In the scenario *Invest+Res*, where there is an additional RES target, we observe a change in the costs incurred by households. The additional RES target has pronounced effects on consumption at the country level in Bulgaria and Poland: the additional RES target implemented by other member states lowers costs considerably. However, the general pattern of incidence remains unchanged. Notably, Slovakia is expected to face net gains in the *Invest+Res* scenario compared to the no-policy scenario. This results from the upper two income deciles being able to consume more in this scenario while the remaining three income deciles can afford less consumption.

Recycling of ETS auction revenues

In scenarios *Cap* and *Cap+Res*, we assume that member states recycle all revenues generated by the ETS via the pre-existing tax and transfer schemes. The model achieves this by recycling

Figure 3: Policy costs by member states and quintiles of the income distribution with revenue recycling via existing transfer schemes.



revenues in a lump-sum fashion proportionally to the existing transfer patterns as given by the ECB's HFCS.

Figure 3 shows that the resulting distributive pattern differs strongly from the pattern in the scenario without revenue recycling. Under revenue recycling, we find a pronouncedly progressive pattern of incidence for the majority of Eastern member states (i.e. Bulgaria, Romania, and the Czech Republic). Most of the households in Eastern member states would actually benefit from climate policy with such a recycling scheme, meaning that they face an increase in their consumption budget compared to the no-policy scenario. Poland is the only Eastern member state in which the consumption budget of most of the households (apart from the lowest quintile) is expected to decrease, because Poland needs to purchase ETS allowances from abroad.

For most other member states, a rather neutral distribution of costs along the quintiles of the income distribution is observed after recycling ETS revenues, and costs are expected to be moderate. Exceptions are Greece, Denmark, and Sweden, for which a moderately regressive pattern is observed. This effect likely is due to the existing tax and transfer schemes. Under revenue recycling, the total cost of climate policy can be even negative for some households in larger Western member states. Examples are Belgium and France, in which the top income decile is expected to face negative costs. In Germany, the lowest income decile is expected to face negative costs resulting from EU climate policy if ETS auction revenues are recycled in this fashion. To summarise, revenues from auctioning ETS permits seem sufficient to avert markedly regressive impacts within most member states, if we assume current patterns of government transfers. Greece, Denmark, and Sweden are exceptions where regressive distributions of impacts persist.

The introduction of a RES target in addition to the ETS cap does not fundamentally change the patterns of cost distribution across income levels within member states, but costs tend to be larger in Western member states and gains tend to be smaller in Eastern member states (see Tables 12–17 of Appendix D for details). The strongest impact of the RES is expected for some Eastern member states. With respect to households in the lowest income bracket, the strongest impact of the RES is observed in Bulgaria (–2.5 percentage points [pp]) followed by Romania (–1.6 pp) and the Czech Republic (–1 pp). However, low income households in these countries still incur negative costs under RES.

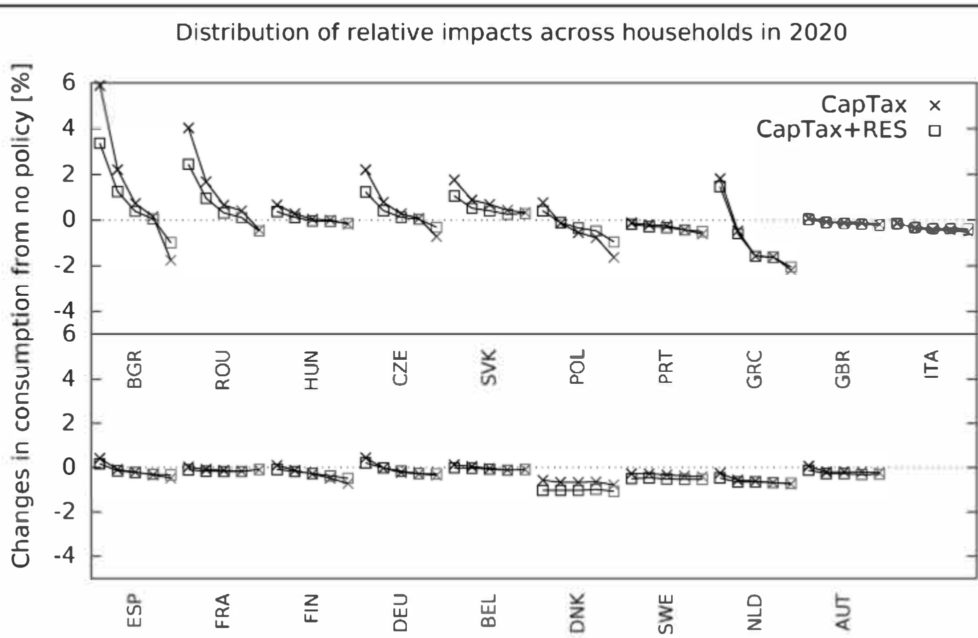
For all of the Western member states, moderate increases in costs incurred by households in the lowest income quintile are observed. Major economies with RES targets include Germany (–0.25 pp), France (–0.13 pp) and the UK (–0.08 pp). Costs increase also in Western member states without RES targets. However, cost changes under *Cap+Res* stay well below –0.5 pp compared to *Cap*.

Recycling of revenues from ETS auction and carbon taxes

The ETS covers industrial installations across Europe, but several economic sectors are not covered by the system. In the previously discussed scenarios, non-ETS emissions are reduced in a cost-efficient manner by non–revenue raising policies of the member states. In the following, we investigate scenarios where member states set (revenue-raising) carbon taxes to meet emission targets in non-ETS sectors: scenarios *TaxCap*and *TaxCap+Res*. It is assumed that both revenues from ETS auctions and carbon taxation of non-commercial emitters (i.e. private households) are returned to households in a lump-sum fashion in proportion to pre-existing transfer patterns. The results are depicted in Figure 4 and reported in detail in Tables 12–17 of Appendix D.

This tax and recycling regime leaves the distributive pattern in Eastern member states progressive. As opposed to the scenario *Cap*, a progressive pattern of incidence is now also observed for Greece, Denmark, Sweden, and the Netherlands. In the present scenario, the lowest income quintile of Greece, the United Kingdom, Spain, France, Finland, Germany, Belgium, and Austria even benefits compared to a no-policy scenario. The introduction of a RES target in addition to the

Figure 4: Policy cost by member states and quintiles of the income distribution if carbon emissions of households are taxed and revenues recycled via existing transfer schemes.



ETS and the carbon tax again causes member state specific changes in costs but leaves the overall progressive pattern unchanged.

The changes in distributional outcomes are attributable to changes in revenues that are returned to households. The additional money that becomes available by using taxes to regulate household emissions is shown in Table 3. We conclude that in case member states decide to meet their national emission targets outside the ETS by taxing carbon, revenues suffice to avoid regressive impacts of policy cost if the revenues are returned to households according to pre-existing patterns of government transfers.

Table 3: Revenue from ETS auction and carbon taxation in million EUR for scenario *TaxCap* with an emission cap and scenario *TaxCap+Res* with a cap and RES targets.

	TaxCap		*TaxCap+Res*	
	tax revenue	ETS revenue (permit price: 22.05 EUR/tCO2)	tax revenue	ETS revenue (permit price: 12.19 EUR/tCO2)
BGR	53.9	683.1	53.9	372.1
ROU	317.4	1126.3	302.7	613.5
HUN	209.9	337.0	208.0	183.5
CZE	129.5	1054.7	124.5	574.5
SVK	62.5	346.2	61.0	188.6
POL	469.3	2818.0	459.8	1535.0
PRT	507.6	397.0	510.6	216.2
GRC	3025.2	782.4	3085.5	426.2
GBR	2695.7	2354.1	2904.1	1282.3
ITA	4491.4	2174.1	4583.6	1184.2
ESP	2091.8	1947.9	2097.2	1061.0
FRA	3113.3	1234.7	3141.7	672.6
FIN	302.2	376.2	303.5	204.9
DEU	5331.0	4516.6	5641.1	2460.2
BEL	855.3	572.4	891.5	311.8
DNK	484.7	281.6	489.5	153.4
SWE	536.2	200.8	537.8	109.4
NLD	1132.0	757.0	1203.5	412.3
AUT	540.5	313.9	544.7	171.0

Table 4: Shares of refunded climate policy revenue in household income (in percent) for scenarios *TaxCap* and *TaxCap+Res* (statistics describing member state values).

	TaxCap			*TaxCap+Res*		
	minimum	median	maximum	minimum	median	maximum
q1	0.61	1.52	7.03	0.51	1.04	6.30
q2	0.30	0.87	4.06	0.25	0.64	3.55
q3	0.27	0.67	2.79	0.23	0.44	1.90
q4	0.15	0.48	2.26	0.14	0.37	1.59
q5	0.08	0.24	1.33	0.07	0.19	1.21

In order to assess how the additional transfers compare to existing transfers in EU member states, we display the minimum, median, and maximum share of those transfers for the different income quintiles across countries in Table 4. The highest shares can be observed for the lower income quintiles q1 and q2 of Bulgaria. In Eastern European countries, to the income patterns of which we calibrated Bulgarian income patterns, the initial transfers make up only a little more than eight percent of q1's income. Thus Bulgaria's additional transfers from recycling carbon pricing revenue to low income quintiles in scenario *TaxCap*are almost as large as existing transfers. Policy makers might find it irritating that climate policy should almost double government transfers to some income groups. The strongly progressive outcome in Bulgaria indicates, however, that regressive outcomes can be avoided with considerably smaller transfer payments.

3.3 Sensitivity analysis

When calibrating income data from the ECB's HFCS to PACE, pension income in the surveys is associated with capital income, according to the GTAP database. Thus, capital in the PACE model was distributed between the income quintiles to match the distribution of capital and pension income in the HFCS. The consequence is that if climate policy affects capital revenues in the PACE model, this effect will be passed on to pensioners. As an alternative interpretation of pension revenues in the HFCS, we associate pensions with labour income in PACE. Thus, labour income as given by GTAP is distributed across income quintiles, pursuant to how labour and pension income is distributed.

The results of the sensitivity analysis are reported in line *Cap*_pl of Tables 12–17 in Appendix D. The results match the scenario *Cap*, in which pensions were associated with capital income. The results show that there are minor differences between the two approaches. We observe small changes in disposable income which usually occur at the lower and upper end of the income distribution. The largest deviation is observed for Denmark. Costs are approximately 0.4 pp higher in the top income quintile under scenario *Cap*_pl than under scenario *Cap*. Deviations of up to 0.2 pp in the lowest quintile and –0.2 pp in the highest quintile are also observed for Bulgaria, Hungary, the Netherlands, and Poland. Thus, the assumption that pensions are equivalent to labour income tends to increase (decrease) costs in the lowest (highest) quintile of the income distribution, while the overall results and distributive patterns remain unchanged.

4. DISCUSSION: THE MARKET STABILITY RESERVE

The MSR, which has started operating on 1 January 2019, aims at supporting the price of ETS allowances by a rule-based removal of allowances from the market in case the number of allowances in circulation exceeds a predefined threshold. Based on the cumulative difference between allowances allocated for free, auctioned allowances, and international credits submitted on the one hand side and verified emissions since 2008 on the other, allowances are placed in (if the difference is higher than 833 million allowances) or re-released from the reserve (if the difference is lower than 400 million allowances). In Phase 4 of the EU ETS (lasting from 2021 to 2030), permanent cancellation of allowances is planned if the reserve exceeds the previous year's total volume of auctioned allowances. Also, member states that close GHG emitting power plants *may* cancel allowances from their future auctioning in correspondence to average annual emissions of those plants previous to the closure.

Our model does not allow for a meaningful inclusion of industries reactions to the MSR. The effect of the MSR on the ETS in the early years of Phase 4 would likely be a rise in allowance prices caused by a reduction in volumes of auctioned allowances (Perino and Willner, 2017). The overall effect on auctioning revenues by member states is unclear. We argue that beyond these effects, the introduction of a RES target—in particular if the target continues to be binding over a long time period—does not give a systematic incentive to shift emissions from one period to another and thus we expect the introduction of a RES target to leave annual emissions (and thus the triggering probability of the MSR) more or less unchanged. We conclude that the comparison of the distributional effects of cap-and-trade systems with and without a binding RES target would likely result in qualitatively similar results if an elaborate model of the MSR were included in the model.

5. CONCLUSIONS

In this paper, we examine the costs and distributive effects of EU climate policy across and within EU member states until 2020, based on a computable general equilibrium model with five representative households per member state representing income quintiles. We consider the policy target of reducing emissions by 20 percent relative to 1990 levels by 2020 and analyse policy options along three dimensions. First, the ETS may be complemented by nationally determined minimum requirements for power generation from RES. (Our assumption is that this will not interact with the MSR enacted on 1 January 2019.) Second, emissions outside the ETS may be regulated with non–market based policy instruments (we assume efficient distribution of abatement cost across sectors; such regulation does not raise revenue) or with carbon taxes (efficient, revenue-generating). Third, revenues from pricing carbon may be either invested for future benefits or recycled to households for compensating their current losses in purchasing power.

Our results show that, at the member state level, many Eastern member states are expected to benefit from EU climate policy due to generous permit allocation. Poland is the only exception which is expected to suffer a reduction in the aggregated consumption budget of private households. The introduction of a RES target by eight member states in Western Europe in addition to the ETS tends to decrease the overall benefits in Eastern European member states (except Poland). This is due to a drop in market prices for emission permits in the ETS and thus in revenues from permit auctions.

In the absence of revenue recycling, we observe distributive patterns which tend to be regressive. This regressivity can be avoided in the majority of member states if ETS auction revenues are recycled via the existing tax and transfer schemes of the member states. If the ETS is not the only source of revenue generated by EU climate policy but is also augmented by national carbon taxes, regressive policy impacts can be avoided in all member states.

Our results provide several policy-relevant insights. First, the generous allocation of emissions allowances to Eastern member states reduces their policy cost and provides sufficient revenues to counteract regressive impacts on households in Eastern member states. Most Eastern member states may effectively be over-compensated and are expected to benefit from EU climate policy. The existing tax and transfer schemes in different member states provide a solid basis for counteracting regressive impacts of climate policy by means of revenue recycling. Only for a few member states, ETS auction revenues and current transfer schemes are insufficient for counteracting regressive impacts. These member states, if unable to find ways to optimise their transfers schemes, may implement revenue raising climate policies to reduce emissions outside the ETS and thus achieve non-regressive impacts across households. Second, the RES targets impact the distribution of costs between the member states since they cause the ETS allowance price to decrease. They weaken the distributive impact of allocating ETS permit auction revenue across member states. Even though member states with RES targets incur extra costs, some of them still reap overall benefits due to the permit price effects if they are net permit importers in the ETS permit market.

Our analysis provides a credible prediction of how effectively the distribution of ETS auction revenue can protect low-income member states and households within them from excessive policy cost and reveals a hitherto undocumented interaction between RES targets and the effectiveness of this distribution of auction revenue. However, one important limitation should be noted. Lacking good data on the income distribution in member states outside the eurozone, we make strong assumptions about how countries outside the eurozone can be compared with certain countries inside the zone. Actual survey data from all EU member states may improve the reliability of analyses such as ours.

ACKNOWLEDGMENTS

We acknowledge financial support by the European Commission under the 7th Framework Programme of the European Union in the project Economic INsTRuments to Achieve Climate Treaties in Europe (ENTRACTE), Project number 308481. We further want to thank Sebastian Rausch, Oliver Schenker, and four anonymous referees for helpful comments.

REFERENCES

Aguiar, A., R. McDougall, and B. Narayanan (2012). *Global Trade, Assistance, and Production: The GTAP 8 Data Base*. Center for Global Trade Analysis, Purdue University.

Armington, P. S. (1969). "A Theory of Demand for Products Distinguished by Place of Production." *Staff Papers (International Monetary Fund)* 16(1): 159–178. https://doi.org/10.2307/3866403.

Böhringer, C. and K. E. Rosendahl (2010). "Green promotes the dirtiest: on the interaction between black and green quotas in energy markets." *Journal of Regulatory Economics* 37(3): 316–325. https://doi.org/10.1007/s11149-010-9116-1.

Boccanfuso, D., A. Estache, and L. Savard (2011). "The Intra-country Distributional Impact of Policies to Fight Climate Change: A Survey." *Journal of Development Studies* 47(1): 97–117. https://doi.org/10.1080/00220388.2010.492861.

Buddelmeyer, H., N. Hérault, G. Kalb, and M. van Zijll de Jong (2012). "Linking a Microsimulation Model to a Dynamic CGE Model: Climate Change Mitigation Policies and Income Distribution in Australia." *International Journal of Microsimulation* 5(2): 40–58.

Capros, P., A. De Vita, N. Tasios, D. Papadopoulos, P. Siskos, E. Apostolaki, M. Zampara, L. Paroussos, K. Fragiadakis, N. Kouvaritakis, L. Hoglund-Isaksson, W. Winiwarter, P. Purohit, H. Bottcher, S. Frank, P. Havlik, M. Gusti, and H. P. Witzke (2013). *EU Energy, Transport and GHG Emissions: Trends to 2050, Reference Scenario 2013*. Publications Office of the European Union, Luxembourg.

EUROSTAT (2014). "Household Budget Surveys." Tables [hbs_exp_t133, hbs_exp_t211, hbs_str_t223, hbs_car_t311]; last accessed 2014-11-07.

Flues, F., A. Löschel, B. J. Lutz, and O. Schenker (2014). "Designing an EU energy and climate policy portfolio for 2030: Implications of overlapping regulation under different levels of electricity demand." *Energy Policy* 75: 91–99. https://doi.org/10.1016/j.enpol.2014.05.012.

Fullerton, D. and G. Heutel (2007). "The general equilibrium incidence of environmental taxes." *Journal of Public Economics* 91(3-4): 571–591. https://doi.org/10.3386/w13645.

Perino, G. and M. Willner (2017). "EU-ETS Phase IV: allowance prices, design choices and the market stability reserve." *Climate Policy* 17(7): 936–946. https://doi.org/10.1080/14693062.2017.1360173.

Rausch, S., G.E. Metcalf, and J.M. Reilly (2011). "Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households." *Energy Economics* 33: 20–33. https://doi.org/10.1016/j.eneco.2011.07.023.

Rausch, S. and M. Mowers (2014). "Distributional and efficiency impacts of clean and renewable energy standards for electricity." *Resource and Energy Economics* 36(2): 556–585. https://doi.org/10.1016/j.reseneeco.2013.09.001.

Rutherford, T.F. and D.G. Tarr (2008). "Poverty effects of Russia's WTO accession: Modeling 'real' households with endogenous productivity effects." *Journal of International Economics* 75(1): 131–150. https://doi.org/10.1016/j.jinteco.2007.09.004.

Sterner, T. (2012). "Distributional effects of taxing transport fuel." *Energy Policy* 41: 75–83. https://doi.org/10.1016/j.enpol.2010.03.012.

APPENDIX

A. The PACE model in more detail

A.1 The PACE model

The PACE model is a GTAPinGAMS CGE model[13] with extensions that make it suitable for the analysis of climate and energy policies at a global scale. In each region, representative households own (region specific) production factors that are employed by the regional sectors for producing globally traded commodities. Regional governments, which collect tax revenues demand government services, and make transfers to households, round off the picture. The introduction of five representative consumers per European member state is the crucial extension to the standard PACE model made by this paper. The five representative households represent income quintiles and both their expenditure and their income are calibrated by using survey data from European member states.

The production factors owned by the representative households are labour, capital, and resources (viz. the fossil fuels crude oil, gas, and coal). Those are priced at PE_L, PE_K, PR_{res} (*res*=col, cru, gas). Labour and capital are mobile between sectors within countries. Solely for power generation, capital technology is specific and in fixed supply. The five technologies for power generation are oil, gas, coal, renewables, and nuclear. The corresponding types of fixed capital are priced at PRT_{tec} (*tec* = oil, gas, coal, renewable, nuclear). The five representative households in each region consume their specific consumption bundles $g_{C_1},\ldots,g_{C_5}$ and demand fixed amounts of the investment good g_I. Another agent in each region which represents the government levies taxes, issues subsidies, makes transfers to households, and demands fixed amounts of government services g_G.

The factors owned by households are employed by industrial sectors (see Table 5 for an enumeration of sectors) to produce sector specific outputs[14] which are traded between regions and used as intermediate inputs by other sectors and are also consumed by representative agents.

PACE uses nested CES production functions to represent production in different economic sectors, trade, and final consumption. The standard production function (see also Fig. 5 in the Appendix) combines the use of intermediates (priced at $PA_{r,i,g}$) with a value added–energy composite at the top level. The value added–energy composite combines a labour–capital nest with the energy composite. The latter again combines electricity (ele) input with a col–(oil–gas) aggregate. In order to account for carbon taxation, all fossil fuel inputs to the energy composite are associated with the amount of CO_2 emitted by the burning of the fuels. This production structure applies to all productive sectors (including production of non-traded commodities for investment g_I, government consumption g_G, and private consumption by households of the different quintiles $g_{C_1},\ldots, g_{C_5}$), except power generation and extraction of fossil fuels. In the case of power generation, the model distinguishes the five generation technologies oil, gas, coal, renewable, and nuclear. Each of them provides the homogeneous good that represents electricity services and that is traded at price $P_{r,\mathrm{ele}}$. The production technologies differ in fuel and capital intensity, with each technology using its specific fossil fuel and capital type. The technologies combine non-capital inputs in fixed proportions (according to a Leontief production function) and trade them off with the technology specific capital stock. This trade-off happens at an elasticity of substitution that allows for calibration of price elasticity of electricity supply per technology (also see Fig. 6 in the Appendix). In the case of fossil fuel extraction, the fuel specific resource priced at $PR_{r,res}$ is used together with non-resource inputs

13. See for example https://www.gtap.agecon.purdue.edu/about/data_models.asp.
14. Throughout the paper sectors and their specific commodity shall carry the same identifier *i*.

Table 5: Sectors of the PACE model. The last column lists the indices that include the respective sector. Index *g* runs over all goods and consumption bundles, *i* over traded goods, *f* over fossil fuels, *res* over resources, *ets* over sectors covered by the ETS, and *nets* sectors outside the ETS. The distinction between *ets* and *nets* is only relevant for EU member states.

Code	Sector	In indices
oil	refined coal and coal products	$g, i, f, \quad ets$
gas	natural gas products	$g, i, f, res, nets$
omn	mining and construction	$g, i, \quad nets$
ppp	Paper-pulp-print	$g, i, \quad ets$
crp	Chemical-Rubber-Plastic products	$g, i, \quad ets$
nmm	Mineral products nec	$g, i, \quad ets$
i_s	Ferrous metals	$g, i, \quad ets$
nfm	Metals nec	$g, i, \quad ets$
ele	Electricity and heat	$g, i, \quad nets$
col	Coal transformation	$g, i, f, res, nets$
cru	Crude Oil	$g, i, \quad res, nets$
mch	Machinery and other manufacturing	$g, i, \quad nets$
faw	Food agriculture wood	$g, i, \quad nets$
twl	Textiles-wearing apparel-leather	$g, i, \quad nets$
trn	Transport	$g, i, \quad nets$
ser	Services	$g, i, \quad nets$
g_I	Investment	$g, \quad nets$
g_G	Government consumption	$g, \quad nets$
$g_{C_1}, \ldots, g_{C_5}$	Household consumption	$g, \quad nets$

Table 6: Regions of the PACE model.

EU		non-EU	
Code	**Region**	**Code**	**Region**
AUT	Austria	CHN	China
BEL	Belgium	JAP	Japan
BGR	Bulgaria	KOR	South Korea
HRV	Croatia	IDN	Indonesia
CYP	Cyprus	IND	India
CZE	Czech Republic	CAN	Canada
DNK	Denmark	USA	USA
EST	Estonia	MEX	Mexico
FIN	Finland	BRA	Brazil
FRA	France	RUS	Russia
DEU	Germany	ANZ	Australia and New Zealand
GRC	Greece	RAX	Rest of Annex-I
HUN	Hungary	ROW	Rest of World
IRL	Ireland		
ITA	Italy		
LVA	Latvia		
LTU	Lithuania		
LUX	Luxembourg		
MLT	Malta		
NLD	Netherlands		
POL	Poland		
PRT	Portugal		
ROU	Romania		
SVK	Slovakia		
SVN	Slovenia		
ESP	Spain		
SWE	Sweden		
GBR	United Kingdom		

Table 7: Production factors and commodities of the PACE model.

Commodity	Price	Indices
Endowments	$PE_{r,e}$	r = AUT, BEL, BGR, HRV, CYP, CZE, DNK, EST, FIN, FRA, DEU, GRC, HUN, IRL, ITA, LVA, LTU, LUX, MLT, NLD, POL, PRT, ROU , SVK, SVN, ESP, SWE, GBR, CHN, JAP, KOR, IDN, IND, CAN, USA, MEX, BRA, RUS, ANZ, RAX, ROW $e = K,L$
Specific capital	$PRT_{r,tec}$	r, tec = oil, gas, coal, renewable, nuclear
Resources	$PR_{r,res}$	r, res = col, cru, gas
Purchased goods	$PA_{r,i,g}$	r, i = oil, gas, omn, ppp crp, nmm, i_s, nfm, ele, col, cru, mch, faw, twl, trn, ser
Imported goods	$PM_{r,i}$	r, i
Output	$P_{r,g}$	r, g = oil, gas, omn, ppp crp, nmm, i_s, nfm, ele, col, cru, mch, faw, twl, trn, ser, $g_I, g_G, g_{C_1}, \ldots, g_{C_5}$
Int'l transport	PT	

Table 8: Taxes and subsidies in the PACE model. rto, rtf, rtfd, rtfi, rtxs, and rtms are fixed tax rates implied by SAM data. GFSUB, XI, and PSI are endogenously determined by the model.

Tax rate	Taxed value	Taxed sector	Tax collector
$rto_{r,g} - GFSUB_{r,g}$	$P_{r,g}$	$Y_{r,g \neq ele}$	Government r
$rto_{r,ele} + XI_r - PSI_r^{tec}$	$P_{r,ele}$	$Y_{r,ele}^{tec}$	Government r
$rtf_{r,g,K}$	$PE_{r,K}$	$Y_{r,g \neq ele}$	Government r
$rtf_{r,g,L}$	$PE_{r,L}$	$Y_{r,g}^{(tec)}$	Government r
$rtf_{r,res,R}$	$PR_{r,res}$	$Y_{r,res}$	Government r
$rtfd_{r,i,g}$	$P_{r,i}$	$A_{r,i,g}$	Government r
$rtfi_{r,i,g}$	$PM_{r,i}$	$A_{r,i,g}$	Government r
$rtxs_{r',r,i}$	$P_{r',i}$	$M_{r,i}$	Government r'
$rtms_{r',r,i} \cdot (1 - rtxs_{r',r,i})$	$P_{r',i}$	$M_{r,i}$	Government r
$rtms_{r',r,i}$	$PT^{(a)}$	$M_{r,i}$	Government r

(a) International transportation priced at PT is required for the importing activity $M_{r,i}$ for transporting the commodity i from different regions r'. The tax rate $rtms_{r',r,i}$ applies to the part of transportation that is needed to import the good from region r'.

in fixed proportions (extraction) and this composite can be traded off against more of the non-resource inputs (exploration) at a positive elasticity of substitution on the top level (see Fig. 7 of the Appendix).

The output of industry i thus produced in region r (priced at $P_{r,i}$) is then either exported or sold to sector/agent g[15] on the domestic market, alongside with the imported version of the good (priced at $PM_{r,i}$). Both are traded off against each other according to the Armington assumption, which results in a domestic market price index $PA_{r,i,g}$ (panel a of Fig. 8). The imported version of the good is again an aggregate of the varieties that are produced in other regions. They reach the market of region r by using international transport services (priced at PT), which are provided by domestic transport services according to a Cobb–Douglas production function (displays b and c of Fig. 8).

Taxes in PACE are levied on production factors and final products. Countries levy tariffs on imports and subsidise exports. Carbon taxes (for meeting emission targets outside the ETS) and emission allowance expenses (allowances are issued for sectors whose emissions are governed by the ets) are both proportional to the amount of fossil fuels burned in the process of energy generation. CO_2 emission rights are in both cases modelled as a commodity in fixed supply. Regarding

15. Index g runs over both industries i and agents g_{C_1}, g_{C_5}, g_G, g_I which are identified with the same index as the commodity they consume.

emissions within the ETS, the market clearing price for such emission rights (the model prices them at PC^{ets}) corresponds to the market price of ETS allowances. Outside the ETS, the modelled market price (PC_r^{nets}) for emission rights corresponds to the CO_2 tax that governments would have to impose on emitters in order to efficiently meet their national targets. The emission rights are owned by the national governments, and revenues from selling them are given to households via lump-sum transfers or are invested, depending on the policy scenario.

PACE is implemented as a mcp using MPSGE. As such, it consists of a set of equations with each equation complementing exactly one variable of the model. The MCP framework implies that, at a solution, equations may be violated such that the left-hand sides are bigger (smaller) than the right-hand sides if their complementary variables are at their lower (upper) bounds. The standard set of equations in CGE models consists of

- zero-profit conditions (cost ≥ revenue) for each sector (thus, determining the non-negative activity level of the sector),
- market clearing conditions (supply ≥ demand) for each commodity (thus determining the non-negative market price of the commodity), and
- budget balance conditions (spending = income) for each representative agent (thus determining the consumption expenditure by that representative agent).

In order to derive the aforementioned equations from production structures, the model assumes that inputs are chosen such that production costs are minimised. When producers take market prices of inputs as given, unit factor demand and unit production cost can be derived in closed form from the nested CES production functions. Thus, zero-profit conditions can be constructed by using unit production cost. In addition, unit factor demand multiplied by sectoral activity gives sectoral factor demand, which is needed to formulate market balance equations (and via the tax channel into income balance of governments). Appendix A.2 provides more detailed information on this.

Besides the aforementioned standard equations, additional equations are needed to determine the output subsidy $GFSUB_{r,ets}$ for sectors *ets* which receive free allowances in the ETS. The subsidy for sector *ets* is set in such a way that the value of the subsidy, which flows into the sector, cancels the expenditure that the sector incurs for the permits it should receive freely. This has the two desired effects: on the one hand, cost minimising fuel demand of sectors includes permit cost and thus reflects the opportunity cost of holding carbon permits for own use, and, on the other hand, sectors do not pass on permit cost to consumers. This corresponds to the assumption that under perfect competition, windfall profits from freely allocated permits make firms enter the sector until market prices for the produced commodity have dropped to a level where profits correspond to the average regional returns on capital. In stylised form, the equation complementary to the positive variable $GFSUB_{r,ets}$ is

$$\mathrm{GFSUB}_{r,ets} \cdot \mathrm{revenue}_{r,ets} \geq \mathrm{freeshare}_{ets} \cdot \textit{permit-expenditure}_{r,ets}.$$

$\mathrm{freeshare}_{ets}$ is a sector specific share of allowances that is allocated to sector *ets* for free and '$\mathrm{revenue}_{r,ets}$' and '$\mathrm{permit\text{-}expenditure}_{r,ets}$' are endogenously determined by the model.

In some scenarios, a target for the share of power generation from RES in total electricity shall be reached by implementing a quota. To meet the quota, the power sector, representing the operators of different generation technologies, subsidises power from RES with the rate PSI_r. Thus, its subsidised generation cost can compete with the generation cost of other technologies even at the required high deployment rates of RES. The additional costs are financed with share XI_r of total power sales, which is modelled as an internally raised sales tax rate XI_r. The stylised equations complementary to the two positive variables PSI_r and XI_r are

$$\text{power supply}_{r,\text{renewables}} \geq \text{renshare}_r \cdot \sum_{tec} \text{power supply}_{r,tec}$$

and

$$\text{XI}_r \cdot \sum_{tec} \text{power sales}_{r,tec} \geq \text{PSI}_r \cdot \text{generation cost}_{r,\text{renewables}}.$$

The parameter renshare_r is given by the policy scenario, and '$\text{power supply}_{r,tec}$', '$\text{power sales}_{r,tec}$', and '$\text{generation cost}_{r,tec}$' are endogenously determined by the model.

Real government consumption of good g_G is kept constant by the model. Lump-sum transfers from the government to the households are adjusted by the unconstrained variable RTAX_r in the case of a budget surplus or deficit to solve

$$Y_{r,g_G} = \bar{Y}_{r,g_G}.$$

In order to keep track of revenues from auctioning permits in the ETS, the model needs to distinguish between the amount of emission allowances allocated to sectors for free (FREEEUAS_r) within region r and those that are auctioned (AUCTEUAS_r) by government r. The two equations that are complementary to these positive variables are

$$\text{FREEEUAS}_r \geq \sum_{ets} \text{freeshare}_{ets} \cdot \text{permit-demand}_{r,ets},$$

$$\text{AUCTEUAS}_r \geq \text{auctshare}_r \cdot (\text{etscap} - \sum \text{FREEEUAS}_r),$$

where 'etscap', 'freeshare_{ets}', and 'auctshare_r' are exogenous parameters and '$\text{permit-demand}_{r,ets}$' is endogenously determined by the model. 'etscap' is the European ETS cap and 'auctshare_r' shares the revenue of permit auctioning among member states r ($\sum_r \text{auctshare}_r = 1$).

In some scenarios, national governments are required to spend their revenue from permit auctioning on investments. In that case, the positive variable INVDEM_r denotes the additional demand for investment good g_I which is caused by this. It is complementary to the equation

$$\text{INVDEM}_r \geq \text{PC}^{\text{ets}} \cdot \text{AUCTEUAS}_r.$$

A.2 Structure of production and trade in the PACE model

The PACE model employs the nested production functions depicted in Figure 5, where each node represents a CES nest with the child nodes as inputs and the associated σ^{node} as the elasticities of substitution governing the CES nest 'node'. The appendix illustrates how such trees correspond to nested CES production functions and how unit expenditure functions and unit factor demand functions are derived.

A.3 From nested CES functions to model equations

Let the CES production function

$$\hat{Y} = \left[\sum_{i=1}^{k} \theta_i \left(\hat{I}_i \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

describe the production of Y from inputs I_i $(i = 1,\ldots,k)$ if $\hat{V}$ denotes the value of a variable V relative to its benchmark value $\bar{V}$ to which the CES production function is calibrated. Given benchmark inputs $\bar{I}_i$ and benchmark prices $\bar{P}_{I_i}$, θ_i shall denote the value share of good i in benchmark production

$$\theta_i = \frac{\overline{I}_i \overline{P}_{I_i}}{\sum_{j=1}^{k} \overline{I}_j \overline{P}_{I_j}}.$$

Figure 5: Production of commodity g in region r for all g other than electricity (g=ele) and resources (g=col, cru, gas). The Intermediates nest does not use commodities i=ele, col, gas, as these enter the Energy nest exclusively. The commodity i=oil only enters the Intermediates nest with positive quantities in the case of oil refineries g=oil. Note that household consumption does not require the inputs labor and capital (priced at $PE_{r,L}$ and $PE_{r,K}$).

Activity $\mathbf{Y}_{r,g}$ ($g \neq$ ele, $g \neq res$):

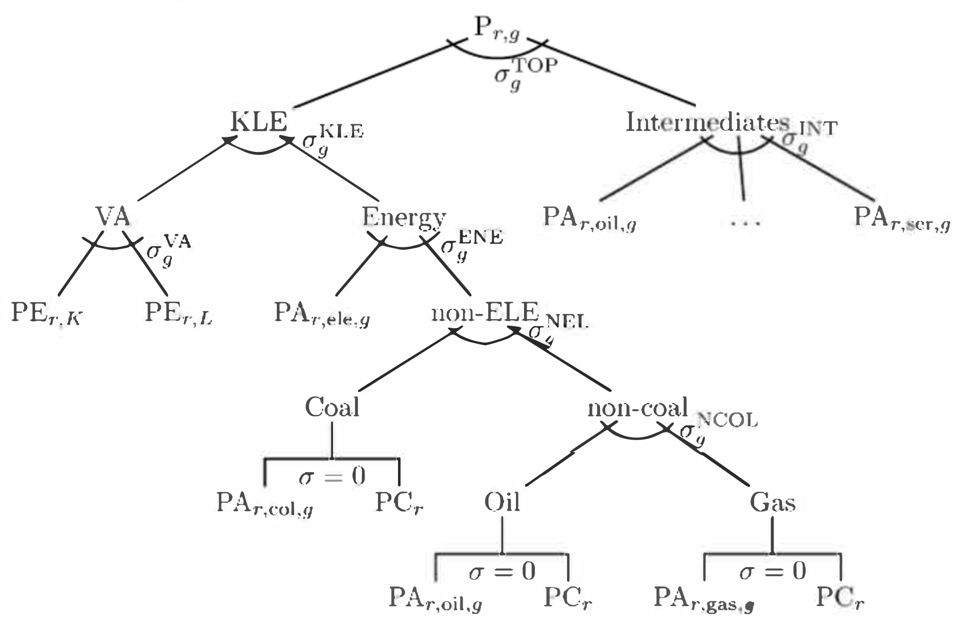


Figure 6: Power generation by technology 'tec'. Capital used in power generation is modelled as a technology specific factor priced at $PRT_{r,tec}$, which is not mobile across sectors. The variable factors include technology specific fuels f_{tec} (f_{oil}=oil, f_{gas}=gas, f_{coal}=col) on the one hand, and non-fuel variable inputs on the other. Non-fuel variable inputs are used in the *same fixed proportions* for all power generation technologies.

Activity $\mathbf{Y}_{r,ele}^{tec}$:

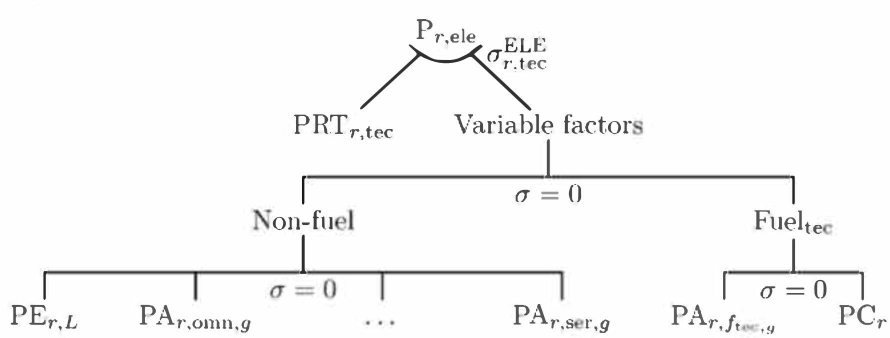


Figure 7: Production function for extraction of resources *res* priced at $P_{r,res}$. Production inputs are used in fixed proportions to produce an intermediary good $PINP_{r,res}$. Some of the $PINP_{r,res}$ is employed in fixed proportion with the resource capacity $PR_{r,res}$ itself, the rest enters production at the top-level nest which allows some degree of substitution between production efforts and resource availability.

Activity $\mathbf{Y}_{r,res}$:

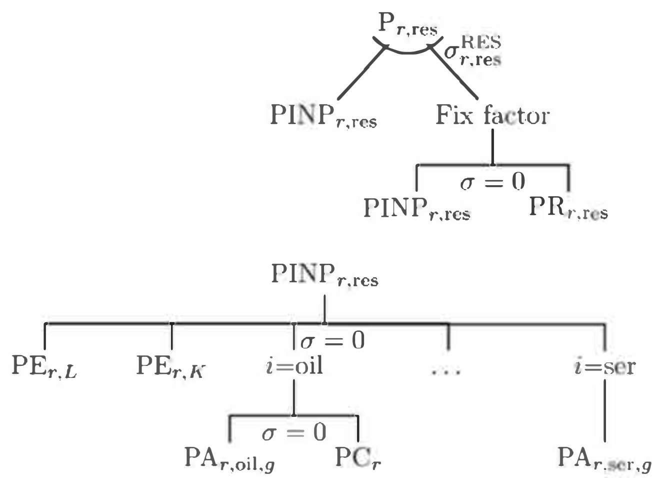
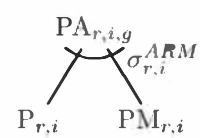
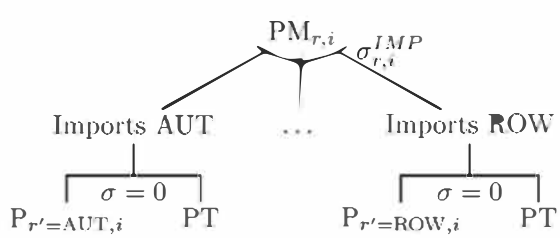


Figure 8: Armington aggregate and imports. Traded commodities *i* are purchased by production sectors and consumers in region *r* at price $PA_{r,i,g}$. This price is the result of a trade-off between the domestically produced version of the good priced at $P_{r,i}$, and the imported version priced at $PM_{r,i}$. The price of the imported version of the good is the result of trading off imports from different trade partners r' (r' = AUT,...,ROW) **priced at** $P_{r',i}$. **Additionally, importing from one region to another requires fixed amounts of international transport services priced at PT and provided by activity YT.**

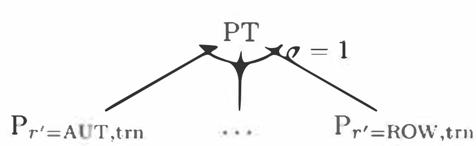
(a) Activity $\mathbf{A}_{r,i,g}$:



(b) Activity $\mathbf{M}_{r,i}$:



(c) Activity $\mathbf{YT}$:



In analogy to the following, this guarantees that benchmark input quantities correspond to cost minimising input demand for production at benchmark prices $\overline{P}_i$. Then, if prices of I_i are P_{I_i}, minimised unit production cost can be shown to be

$$\hat{e}(P_{I_1},\ldots,P_{I_k}) = \left[\sum_{i=1}^{k}\theta_i\left(\hat{P}_{I_i}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

If the zero profit condition is met and the market price of commodity Y, P_Y, equals unit expenditure ($\hat{P}_Y = \hat{e}$), the price minimising unit demand can be written as

$$d_i(P_{I_1},\ldots,P_{I_k}) = \frac{\partial e(P_{I_1},\ldots,P_{I_k})}{\partial P_i}$$

$$= \frac{\overline{e}\theta_i}{\overline{P}_{I_i}}\left(\frac{\hat{e}(P_{I_1},\ldots,P_{I_k})}{\hat{P}_{I_i}}\right)^{\sigma}. \qquad (1)$$

In the special cases $\sigma = 1$ and $\sigma = 0$, the production function takes the forms

$$\hat{Y} = \prod_{i=1}^{k}\left(\hat{I}_i\right)^{\theta_i} \qquad \sigma = 1$$

$$\hat{Y} = \min_{i=1}^{k}\left(\hat{I}_i\right) \qquad \sigma = 0$$

and the minimised unit production cost is

$$\hat{e}(P_1,\ldots,P_k) = \prod_{i=1}^{k}\left(\hat{P}_{I_i}\right)^{\theta_i} \qquad \sigma = 1$$

$$\hat{e}(P_1,\ldots,P_k) = \sum_{i=1}^{k}\theta_i\hat{P}_{I_i} \qquad \sigma = 0.$$

The following equations illustrate how the nested CES tree in Figure 5 corresponds to CES production functions and how taxes in Table 8 of the paper enter the corresponding unit cost and demand functions. In order to keep track of the cost of sub-nests, internal prices are introduced and p_{NEST} shall denote the unit cost of sub-nest NEST. The zero-profit conditions, which are complementary to $\text{Y}_{r,g}$ and relate the market prices $\text{P}_{r,g}$ with the input prices $\text{PA}_{r,i,g}$, $\text{PE}_{r,\text{K}}$, $\text{PE}_{r,\text{L}}$, the carbon prices $\text{PC}_r^{\text{nets}}$ and PC^{ets}, and the sub-nest costs $p_{\text{KLE},r,g}$, $p_{\text{VA},r,g}$, $p_{\text{ENE},r,g}$, $p_{\text{NEL},r,g}$, $p_{\text{NCOL},r,g}$ and $p_{\text{INT},r,g}$ are,

$$\hat{\text{P}}_{r,g}\left[1-\text{rto}_{r,g}+\text{GFSUB}_{r,g}\right]$$

$$\leq\left[\theta_{r,g}^{\text{KLE}}\left(\hat{p}_{\text{KLE},r,g}\right)^{1-\sigma_g^{\text{TOP}}}+\theta_{r,g}^{\text{INT}}\left(\hat{p}_{\text{INT},r,g}\right)^{1-\sigma_g^{\text{TOP}}}\right]^{\frac{1}{1-\sigma_g^{\text{TOP}}}}$$

$$\hat{p}_{\text{INT},r,g} = \left[\sum_i\theta_{\text{INT},r,g}^{i}\left(\hat{\text{P}}\text{A}_{r,i,g}\right)^{1-\sigma_g^{\text{INT}}}\right]^{\frac{1}{1-\sigma_g^{\text{INT}}}}$$

$$\hat{p}_{\text{KLE},r,g} = \left[\theta_{\text{KLE},r,g}^{\text{VA}}\left(\hat{p}_{\text{VA},r,g}\right)^{1-\sigma_g^{\text{KLE}}}+\theta_{\text{KLE},r,g}^{\text{ENE}}\left(\hat{p}_{\text{ENE},r,g}\right)^{1-\sigma_g^{\text{KLE}}}\right]^{\frac{1}{1-\sigma_g^{\text{KLE}}}}$$

$$\hat{p}_{\mathrm{VA},r,g} = \left[\theta^{\mathrm{K}}_{\mathrm{VA},r,g} \left(\widehat{\hat{\mathrm{PE}}_{r,\mathrm{K}}[1+\mathrm{rtf}_{r,g,\mathrm{K}}]} \right)^{1-\sigma^{\mathrm{VA}}_g} \right.$$

$$\left. +\theta^{\mathrm{L}}_{\mathrm{VA},r,g} \left(\widehat{\hat{\mathrm{PE}}_{r,\mathrm{L}}[1+\mathrm{rtf}_{r,g,\mathrm{L}}]} \right)^{1-\sigma^{\mathrm{VA}}_g} \right]^{\frac{1}{1-\sigma^{\mathrm{VA}}_g}}$$

$$\hat{p}_{\mathrm{ENE},r,g} = \left[\theta^{\mathrm{ele}}_{\mathrm{ENE},r,g} \left(\hat{\mathrm{PA}}_{r,\mathrm{ele},g} \right)^{1-\sigma^{\mathrm{ENE}}_g} + \theta^{\mathrm{NEL}}_{\mathrm{ENE},r,g} \left(\hat{p}_{r,\mathrm{NEL}} \right)^{1-\sigma^{\mathrm{ENE}}_g} \right]^{\frac{1}{1-\sigma^{\mathrm{ENE}}_g}}$$

$$\hat{p}_{\mathrm{NEL},r,g} = \left[\theta^{\mathrm{col}}_{\mathrm{NEL},r,g} \left(\widehat{\left[\mathrm{PA}_{r,\mathrm{col},g} + \xi_{r,\mathrm{col},g} \mathrm{PC}^{\mathrm{ets/nets}}_r \right]} \right)^{1-\sigma^{\mathrm{NEL}}_g} \right.$$

$$\left. +\theta^{\mathrm{NCOL}}_{\mathrm{NEL},r,g} \left(\hat{p}_{r,\mathrm{NCOL}} \right)^{1-\sigma^{\mathrm{NEL}}_g} \right]^{\frac{1}{1-\sigma^{\mathrm{NEL}}_g}}$$

$$\hat{p}_{\mathrm{NCOL},r,g} = \left[\theta^{\mathrm{oil}}_{\mathrm{NCOL},r,g} \left(\widehat{\left[\mathrm{PA}_{r,\mathrm{oil},g} + \xi_{r,\mathrm{oil},g} \mathrm{PC}^{\mathrm{ets/nets}}_r \right]} \right)^{1-\sigma^{\mathrm{NCOL}}_g} \right.$$

$$\left. +\theta^{\mathrm{gas}}_{\mathrm{NCOL},r,g} \left(\widehat{\left[\mathrm{PA}_{r,\mathrm{gas},g} + \xi_{r,\mathrm{gas},g} \mathrm{PC}^{\mathrm{ets/nets}}_r \right]} \right)^{1-\sigma^{\mathrm{NCOL}}_g} \right]^{\frac{1}{1-\sigma^{\mathrm{NCOL}}_g}},$$

where $\xi_{r,i,g}$ are the emission coefficients of inputs i to production process g and $\theta^{\mathrm{INPUT}}_{\mathrm{NEST}}$ are the value shares of INPUT in nest NEST such that the shares of inputs within a nest add up to one. The emission coefficients are calculated by dividing the benchmark emissions, caused by the burning of the input, by the benchmark value of inputs i to g.

If supply of the good priced at $\mathrm{P}_{r,g}$ by sector g in region r is $\mathrm{S}_{r,g}$, demands $d_{\mathrm{INT},r,g}$ and $d_{\mathrm{KLE},r,g}$ for the INT and KLE nest outputs are determined by

$$\hat{d}_{\mathrm{INT},r,g} = \hat{\mathrm{S}}_{r,g} \left(\frac{\widehat{\hat{\mathrm{P}}_{r,g}\left[1-\mathrm{rto}_{r,g}+\mathrm{GFSUB}_{r,g}\right]}}{\hat{p}_{\mathrm{INT},r,g}} \right)^{\sigma^{\mathrm{TOP}}_g}$$

$$\hat{d}_{\mathrm{KLE},r,g} = \hat{\mathrm{S}}_{r,g} \left(\frac{\widehat{\hat{\mathrm{P}}_{r,g}\left[1-\mathrm{rto}_{r,g}+\mathrm{GFSUB}_{r,g}\right]}}{\hat{p}_{\mathrm{KLE},r,g}} \right)^{\sigma^{\mathrm{TOP}}_g}.$$

From this, demand $\mathrm{DA}_{r,i,g}$ for the intermediate good priced at $\mathrm{PA}_{r,i,g}$ by the INT nest is derived as

$$\hat{\mathrm{DA}}_{r,i,g;\mathrm{INT}} = \hat{d}_{\mathrm{INT},r,g} \left(\frac{\hat{p}_{\mathrm{INT},r,g}}{\mathrm{PA}_{r,i,g}} \right)^{\sigma^{\mathrm{INT}}_g}$$

$$= \hat{\mathrm{S}}_{r,g} \left(\frac{\widehat{\hat{\mathrm{P}}_{r,g}\left[1-\mathrm{rto}_{r,g}+\mathrm{GFSUB}_{r,g}\right]}}{\hat{p}_{\mathrm{INT},r,g}} \right)^{\sigma^{\mathrm{TOP}}_g} \left(\frac{\hat{p}_{\mathrm{INT},r,g}}{\hat{\mathrm{PA}}_{r,i,g}} \right)^{\sigma^{\mathrm{INT}}_g},$$

and in analogy, demand for labour and capital by sector g in region r is given by

$$\hat{\mathrm{DE}}_{\mathrm{L/K},r;g} = \hat{\mathrm{S}}_{r,g}\left(\frac{\hat{\mathrm{P}}_{r,g}\left[1-\mathrm{rto}_{r,g}+\mathrm{GFSUB}_{r,g}\right]^{\frown}}{\hat{p}_{\mathrm{KLE},r,g}}\right)^{\sigma_g^{\mathrm{TOP}}}\left(\frac{\hat{p}_{\mathrm{KLE},r,g}}{\hat{p}_{\mathrm{VA},r,g}}\right)^{\sigma_g^{\mathrm{KLE}}} \cdot \left(\frac{\hat{p}_{\mathrm{VA},r,g}}{\hat{\mathrm{PE}}_{r,\mathrm{L/K}}[1+\mathrm{rtf}_{r,g,\mathrm{L/K}}]^{\frown}}\right)^{\sigma_g^{\mathrm{VA}}}.$$

Demands for coal ($\mathrm{DA}_{r,\mathrm{col},g;\mathrm{ENE}}$) as an energy input and for emission permits associated with coal ($\mathrm{DC}_{r;\mathrm{col},g}$) use are

$$\hat{\mathrm{DA}}_{r,\mathrm{col},g;\mathrm{ENE}} = \hat{\mathrm{S}}_{r,g}\left(\frac{\hat{\mathrm{P}}_{r,g}\left[1-\mathrm{rto}_{r,g}+\mathrm{GFSUB}_{r,g}\right]^{\frown}}{\hat{p}_{\mathrm{KLE},r,g}}\right)^{\sigma_g^{\mathrm{TOP}}}\left(\frac{\hat{p}_{\mathrm{KLE},r,g}}{\hat{p}_{\mathrm{ENE},r,g}}\right)^{\sigma_g^{\mathrm{KLE}}} \cdot \left(\frac{\hat{p}_{\mathrm{ENE},r,g}}{\hat{p}_{\mathrm{NEL},r,g}}\right)^{\sigma_g^{\mathrm{ENE}}}\left(\frac{\hat{p}_{\mathrm{NEL},r,g}}{\left[\mathrm{PA}_{r,\mathrm{col},g}+\xi_{r,\mathrm{col},g}\mathrm{PC}_r^{\mathrm{ets/nets}}\right]^{\frown}}\right)^{\sigma_g^{\mathrm{NEL}}}$$

$$\hat{\mathrm{DC}}_{r;\mathrm{col},g} = \hat{\mathrm{DA}}_{r,\mathrm{col},g;\mathrm{ENE}}.$$

Demand for other commodities by all sectors is derived in analogy to the one above, following the demand structures given in Figures 5–8. Table 9 gives an overview on which activities supply and demand which commodities in PACE. Market clearance conditions follow directly.

Table 9: Overview over demand and supply of commodities

Price	Supply (proportional to)	Demand (proportional to)
$\mathrm{P}_{r,i}$	$\mathrm{S}_{r,i}^{(tec)}\,(\mathrm{Y}_{r,i}^{(tec)})$	$\mathrm{D}_{r,i;A}\,(\mathrm{A}_{r,i,g})$ $\mathrm{D}_{r,i;M,s}\,(\mathrm{M}_{s,i})$ $\mathrm{D}_{r,i=\mathrm{trn};YT}\,(\mathrm{YT})$
$\mathrm{P}_{r,g_{C_{1..5}}}$	$\mathrm{S}_{r,g_{C_{1..5}}}\,(\mathrm{Y}_{r,g_{C_{1..5}}})$	$\mathrm{D}_{r,g_{C_{1..5}}}\left(\frac{\mathrm{HH}_{r,C_{1..5}}}{\mathrm{P}_{r,g_{C_{1..5}}}}\right)$
P_{r,g_I}	$\mathrm{S}_{r,g_I}\,(\mathrm{Y}_{r,g_I})$	$\overline{\mathrm{D}}_{r,g_I}$
P_{r,g_G}	$\mathrm{S}_{r,g_G}\,(\mathrm{Y}_{r,g_G})$	$\mathrm{D}_{r,g_G}\left(\frac{\mathrm{GOVT}_r}{\mathrm{P}_{r,g_G}}\right)$
$\mathrm{PE}_{r,\mathrm{L/K}}$	$\overline{\mathrm{SE}}_{r,\mathrm{L/K}}$	$\mathrm{DE}_{r,\mathrm{L/K};i}\,(\mathrm{Y}_{r,i}^{(tec)})$
$\mathrm{PRT}_{r,tec}$	$\overline{\mathrm{SRT}}_{r,tec}$	$\mathrm{DRT}_{r,tec}\,(\mathrm{Y}_{r,\mathrm{ele}}^{tec})$
$\mathrm{PR}_{r,res}$	$\overline{\mathrm{SR}}_{r,res}$	$\mathrm{DR}_{r,res}\,(\mathrm{Y}_{r,res})$
$\mathrm{PA}_{r,i,g}$	$\mathrm{SA}_{r,i,g}\,(\mathrm{A}_{r,i,g})$	$\mathrm{DA}_{r,i,g;\mathrm{INT}}\,(\mathrm{Y}_{r,g})$ $\mathrm{DA}_{r,i,g;\mathrm{ENE}}\,(\mathrm{Y}_{r,g})$
$\mathrm{PM}_{r,i}$	$\mathrm{SM}_{r,i}\,(\mathrm{M}_{r,i})$	$\mathrm{DM}_{r,i;g}\,(\mathrm{A}_{r,i,g})$
PT	$\mathrm{ST}\,(\mathrm{YT})$	$\mathrm{DT}_{r,i}\,(\mathrm{M}_{r,i})$
$\mathrm{PC}_r^{\mathrm{nets}}$	$\overline{\mathrm{SC}}_r$	$\mathrm{DC}_{r;f,nets}\,(\mathrm{Y}_{r,nets})$
$\mathrm{PC}_r^{\mathrm{ets}}$	$\sum_r(\mathrm{AUCTEUAS}_r$ $+\mathrm{FREEEUAS}_r)$	$\mathrm{DC}_{r;f,ets}\,(\mathrm{Y}_{r,ets})$

Income balance equations have to hold for the government and each income quintile per regions:

$$\mathrm{GOVT}_r = \mathrm{PC}_r^{\mathrm{nets}}\overline{\mathrm{SC}}_r + \mathrm{PC}_r^{\mathrm{ets}}\mathrm{AUCTEUAS}_r - \mathrm{RTAX}_r$$

$$+\mathrm{PC}_r^{\mathrm{ets}}\mathrm{FREEEUAS}_r - \sum_i \mathrm{GFSUB}_{r,i}\mathrm{P}_{r,i}\mathrm{S}_{r,i}$$

$$+\sum_i \mathrm{rto}_{r,i}\mathrm{P}_{r,i}\mathrm{S}_{r,i} + \sum_{i,r'} \mathrm{rtxs}_{r,r',i}\mathrm{P}_{r,i}\mathrm{D}_{r,i;M,r'}$$

$$+\sum_{i,r'} \mathrm{rtms}_{r',r,i}\left[(1-\mathrm{rtxs}_{r',r,i})\mathrm{P}_{r',i}\mathrm{D}_{r',i;M,r} + \mathrm{PT}\cdot\mathrm{DT}_{r,i}\right]+$$

$$+\sum_{i,e} \mathrm{rtf}_{r,i,e}\mathrm{PE}_{r,e}\mathrm{DE}_{r,e;i} + \sum_{res} \mathrm{rtf}_{r,res,\mathrm{R}}\mathrm{PR}_{r,res}\mathrm{DR}_{r,res}$$

$$+\sum_{i,g} \mathrm{rtfd}_{r,i,g}\mathrm{P}_{r,i}\mathrm{D}_{r,i;A} + \sum_{i,g} \mathrm{rtfi}_{r,i,g}\mathrm{PM}_{r,i}\mathrm{DM}_{r,i;g}$$

$$\mathrm{HH}_{r,C_q} = \kappa_{r,q}\left[\mathrm{PE}_{r,\mathrm{K}}\overline{\mathrm{SE}}_{r,\mathrm{K}} + \sum_{tec} \mathrm{PRT}_{r,tec}\overline{\mathrm{SRT}}_{r,tec} + \sum_{res} \mathrm{PR}_{r,res}\overline{\mathrm{SR}}_{r,res}\right]$$

$$+\lambda_{r,q}\mathrm{PE}_{r,\mathrm{L}}\overline{\mathrm{SE}}_{r,\mathrm{L}} - \kappa_{r,q}\mathrm{P}_{r,g_I}\overline{\mathrm{D}}_{r,g_I} + \tau_{r,q}\mathrm{RTAX}_r q = 1,\ldots,5.$$

A.4 Data

The data source for the calibration of PACE originates from the GTAP data base (Aguiar et al., 2012). Version 8.1 of the GTAP data base provides the model with input–output structures for production sectors as well as trade patterns.

In order to capture impacts of rising prices of energy commodities on consumers with different levels of affluence in different countries, we disaggregate the representative household of each country into five households that represent the income quintiles. We combine two sets of survey results to split expenditures on the one and income on the other hand between the quintiles. On the expenditure side, national expenditures for different consumption goods have to be split into the expenditure of different income quintiles $q = 1,\ldots,5$. The resulting expenditures are used to calibrate the nested CES functions representing the consumption activities $\mathrm{Y}_{g_{C_q}}$ which yield the final consumption baskets denoted by commodities $g_{C_1},\ldots,g_{C_5}$. On the income side, factor endowments and government transfers have to be realistically distributed among quintiles in the benchmark. While endowments are fixed quantities in the model, transfers are endogenously determined in the scenarios. In these scenarios, changes from benchmark transfers will be distributed among the quintiles in proportion to the initial benchmark transfers.

Expenditure of income quintiles

The model imitates information from Eurostat on the amount of overall consumption and the share of the energy goods in overall consumption for each quintile. It is worthwhile to note that we rely on household expenditures in PPS provided by Eurostat in order to make consumption bundles comparable between member states when reporting results. The household budget surveys of [EUROSTAT, 2014] provide expenditures per household and per adult equivalent for five quintiles in all EU member states for the year 2010. Also on the quintile level, consumption is split into different broad consumer good categories at the two-digit level of the Classification of Individual Consumption According to Purpose (COICOP). On the national level, Eurostat splits consumption into more detailed consumer good categories which makes it possible to identify the consumption of the energy goods electricity, liquid fuels for heating and transportation, gas, and coal.

In order to distribute consumption of energy good ii among the quintiles, its share in national consumption of the two-digit category i containing ii is used to split each quintile's consumption of category i into its parts. Call $\sigma_{ii,tot}^{national}$ the share of ii consumption in total expenditures at the national level. Similarly, $\sigma_{i,tot}^{q}$ is defined as the share of i consumption in total expenditures of quintile q. With these two definitions given by Eurostat, we compute the shares

$$\sigma_{ii,i}^{national} = \sigma_{ii,tot}^{national} / \sigma_{i,tot}^{national}$$

for energy goods ii contained in categories i, and assumes the share of good ii consumption in total expenditure of quintile q to be

$$\sigma_{ii,tot}^{q} = \sigma_{i,tot}^{q} \sigma_{ii,i}^{national}.$$

The Eurostat tables provide figures for the years 2010, 2005, 1999, and previous ones. Unavailable entries for 2005 and 2010 were imputed from 1999 or 2005 entries. This was done either by scaling them according to the next higher category which was available, or otherwise by assuming a growth of consumption according to the national growth of gdp across quintiles and categories.

Expenditure shares for energy goods in GTAP do not necessarily match expenditure shares found in the household surveys by Eurostat. We focus on energy commodities and use Eurostat survey results to distribute both total expenditures and expenditures for energy commodities realistically across quintiles. Total consumption expenditures of the representative household in GTAP are distributed among quintiles according to expenditure per household divided by the estimated household size[16] within the income quintiles defined by Eurostat household surveys. The expenditures on energy commodities ii is split across quintiles in proportion to

$$\frac{\sigma_{ii,tot}^{q} \varepsilon^{q}}{\sum_{q'} \sigma_{ii,tot}^{q'} \varepsilon^{q'}},$$

where ε^q denote total expenditures of households within quintiles. Expenditures for non-energy commodities are distributed in fixed proportions among quintiles so that expenditures for energy and non-energy commodities add up to total expenditures.

16. By comparing household expenditures per adult equivalent with household expenditures per household, we infer the number of adult equivalents per household in each quintile. Adult equivalents as a measure of household size are computed by counting the head of a household with weight 1 and adding 0.5 for each additional adult and 0.3 for each additional child in the same household. In the extreme case in which all members of all households are adults, the average household size n is

$$n = 1 + \frac{ae - 1}{0.5},$$

if ae denotes the average number of adult equivalents per household. In the other extreme case in which all households consist of one adult plus children,

$$n = 1 + \frac{ae - 1}{0.3}.$$

An intermediate estimator for the household size that fits the national average household size across countries relatively well is

$$n = 1 + 2.3(ae - 1).$$

Income of quintiles in PACE

On the income side, the PACE model distinguishes between wage earnings, rents on capital and resources, and net transfers from government to households, which are not necessarily positive.

In order to split these revenue streams among income quintiles, the HFCS by the ECB is consulted. The data are available for the following 15 members of the eurozone: Austria, Belgium, Cyprus, Germany, Spain, Finland, France, Greece, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovenia, and Slovakia. We group these countries into Western, Eastern, and Southern Europe and assume that in the remaining EU member states, factor incomes are distributed across households according to the European area (viz. South, East, or West) that they belong to. Thus, of the member states not included in the HFCS , Bulgaria, the Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, and Romania are included in the Eastern European region. Croatia is part of Southern Europe. Denmark, Ireland, Sweden, and the United Kingdom are included in Western Europe.

Income classes of the HFCS are split into the broad fields wages, capital income, pensions, and transfers. The PACE model on the other hand, distinguishes labour income, rents from capital, income from resources, and transfers from the government to households or vice versa.

Transfers in GTAP and the HFCS do not seem to have congruent meanings (in the ECB surveys, transfers principally result in positive income, whereas they can also have a negative impact on households' balance sheets in GTAP). The PACE benchmark calibration uses total (national) transfers and distributes them among quintiles q in proportion to the transfer revenue indicated by the HFCS with shares $\tau_{r,q}$.[17]

From the remaining revenue flows of households in GTAP, labour income is identified with labour income in the HFCS survey, while capital and resource rents are identified with revenues from capital and pensions. This reflects the fact that capital rents in GTAP by far exceed pure capital income according to the HFCS and can be defended by acknowledging that pensions, at least to some extent, constitute rents on earlier investments.

Shares $\kappa_{r,q}$ of the national revenue $\bar{K}_r$ from capital and resources available according to GTAP are attributed to the income quintiles $q = 1,\ldots,5$ and similarly, national wage earnings $\bar{L}_r$ are distributed according to shares $\lambda_{r,q}$. The revenues from the respective shares of $\bar{K}_r$ and $\bar{L}_r$ have to add up to the income quintiles' factor income $\mathrm{FI}_{r,q}$. For our purpose, this factor income is the residual between the income quintiles' expenditure and the benchmark government transfers allocated to them as described above. In order to achieve a good match between the shares of capital or labour income in any quintile's average household income in the PACE calibration and the shares of capital-plus-pension income ($\mathrm{cpis}_{r,q}$) or labour income ($\mathrm{lis}_{r,q}$) in any quintiles average household income according to the HFCS, the following optimisation was evaluated

$$\min_{\kappa_{r,1},\ldots,\kappa_{r,5},\lambda_{r,1},\ldots,\lambda_{r,5}} \sum_{r,q} \left[\left(\frac{\kappa_{r,q}\bar{K}_r}{\mathrm{FI}_{r,q}} - cpis_{r,q} \right)^8 + \left(\frac{\lambda_{r,q}\bar{L}_r}{\mathrm{FI}_{r,q}} - lis_{r,q} \right)^8 \right]$$

$$\text{s.t.}\ 1 = \sum_q \kappa_{r,q} \quad \forall r$$

$$1 = \sum_q \lambda_{r,q} \quad \forall r$$

$$FI_{r,q} = \kappa_{r,q}\bar{K}_r + \lambda_{r,q}\bar{L}_r \quad \forall (r,q).$$

17. If national governments transfer additional revenue from climate policies to households, transfers to quintiles in PACE change in proportion to benchmark transfers. The implemented calibration guarantees that the benefits from these additional transfers going to different quintiles are distributed in proportion to transfers in the ECB survey data.

Sensitivity analysis with regard to pension revenues

When calibrating income data from the ECB's HFCS to PACE, pension income in income surveys are associated with capital income according to GTAP. Thus, capital in the PACE model was distributed between income quintiles to match the distribution of capital *and* pension income according to the income survey. The consequence is that if climate policy affects capital revenue in the PACE model, this effect will be passed on to pensioners.

As an alternative interpretation of pension revenues in the income survey, we associate it with labour income in PACE. Thus, labour income as given by GTAP is distributed across income quintiles pursuant to how labour *and* pension income is distributed.

Projecting the benchmark to 2020

The benchmark SAMs given by GTAP reflect the global economy in 2004.[18] In order to discuss future European climate and energy policy, the data are projected to 2020. For this purpose, national factor endowments are inflated according to regional growth projections from the European Commission's reference scenario (Capros et al., 2013). To reflect progress in energy efficiency, the energy consumption of production is also reduced by exogenous factors and in line with the aforementioned reference scenario. The various imbalances created by these changes are smoothed out by letting the model solve for equilibrium after factor endowment adjustments and after numerous intermediate changes to energy intensity. This procedure leads to the desired baseline 2020 projection.

While the distribution of national income levels across member states is updated according to EU projections about GDP growth, the distribution of income within member states is left at a 2010 level. The assumption that distribution of expenditures across income quintiles in 2020 will be the same as in 2010 is contestable, but we believe that we are able to give reasonable estimates of how policy choices change the distribution of policy cost across income groups within member states. National results, at least, are largely unaffected by the way income and expenditures are distributed among quintiles: We verified that when we assume only one representative household per member state, the impacts of the policy scenarios across member states stay virtually the same. This is in line with what Rutherford and Tarr (2008) conclude from their findings.

B. Distribution of ETS auction revenue

According to directive 2009/29/EC[19], 88 percent of auctioned ETS emission allowances are distributed in proportion to a member states verified emissions within the ETS in the year 2005 (or the average verified emissions between 2005 and 2007 if that average is bigger). Another ten percent of auction revenues is allocated by increasing the aforementioned shares "for the purpose of Community solidarity and growth". The remaining two percent are given to those member states

18. GTAP version 8.1 also includes balanced data for the year 2007 and more recent versions of GTAP also include the year 2011. The argument for using the year 2004 is that it represents the economic situation in the EU before the economic downturn following the financial crisis of 2008. Thus, the projections we use for forward calibrating the European economy to 2020, are better suited to forward calibrate from the base year 2004 than from 2007 or 2011 (projecting those years to the periods 2010 and 2015 would involve interpolating the trends of the periods 2005–2010 or 2010–2015, neither of which have been periods of even and steady growth).

19. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0029&from=en; accessed 24/01/2018.

that had reduced their greenhouse gas emissions by more than 20 percent between their base year under the Kyoto Protocol and 2005.

The resulting overall shares for distribution of auction revenues were given in a commission staff working document of 08/02/2010 that is no longer available online. The shares included in the document are given in Table 10.

Table 10: Shares for distributing emission allowances for auctioning among member states.

Member state	Share (percent)	Member state	Share (percent)
Austria	1.36	Italy	9.42
Belgium	2.48	Latvia	0.20
Bulgaria	2.96	Lithuania	0.53
Croatia	–.—	Luxemburg	0.17
Cyprus	0.26	Malta	0.10
Czech Republic	4.57	The Netherlands	3.28
Denmark	1.22	Poland	12.21
Estonia	0.89	Portugal	1.72
Finland	1.63	Romania	4.88
France	5.35	Slovakia	1.50
Germany	19.57	Slovenia	0.43
Greece	3.39	Spain	8.44
Hungary	1.46	Sweden	0.87
Ireland	0.92	United Kingdom	10.20

Croatia has not been included in the aforementioned list and it does not have "verified emissions" under the ETS due to its late accession to the EU. We assume that Croatia is allocated its share of ETS emissions according to the model's base year data (0.5 percent) and reduce the shares of the other member states in Table 10 by 0.5 percent.

C. Promoting RES with subsidies

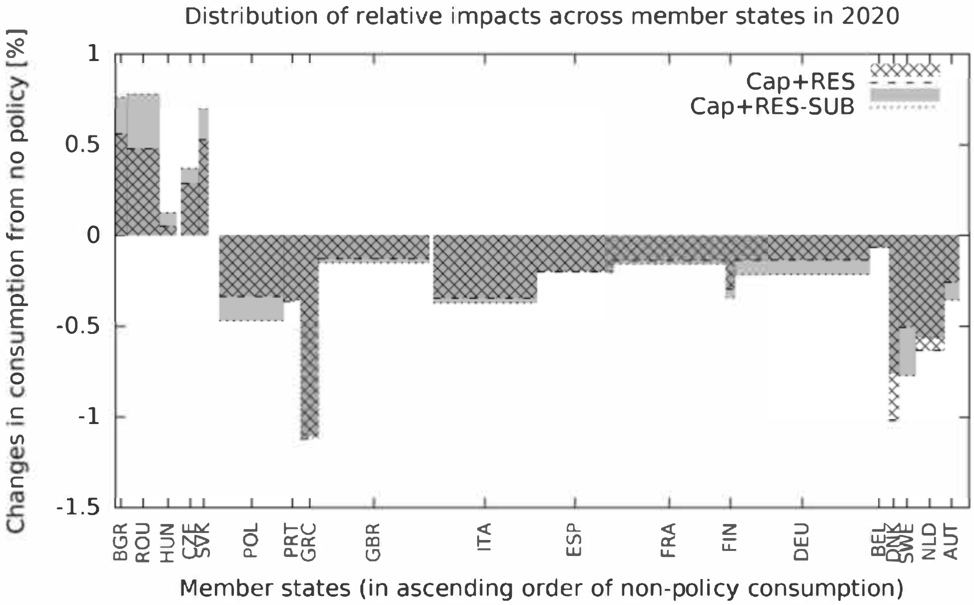
In the scenario *Cap+Res*, RES are promoted using a renewable energy standard, which in effect increases cost of electricity. The electricity sector, internalizing the costs of promoting renewable energy sources, needs to increase the consumer price of electricity in this scenario.

Alternatively, a subsidy for electricity from RES could be used to promote them. This section describes what results on the member state level would look like if that were the case and outlines the consequences on government budgets. Budget balancing requirements would make it necessary for RES promoting governments to collect funds through taxation of other transactions or through reductions in lump-sum transfers. The expected effect of this on the distribution of costs across quintiles depends on how the additional funds would be raised which can only be speculated about.

Figure 9 shows that most member states that promote RES by *subsidizing* electricity from them incur higher costs than they would if they just mandated the same share of RES in electricity generation. Denmark and the Netherlands are the exceptions. Denmark benefits from an appreciation of its ETS permit surplus (see Table 2). In the Netherlands, on the other hand, the RES subsidy seems to be the more efficient policy even compensating the appreciat

ion of the value of permit imports. Member states that do not participate in the promotion of RES in their power sectors are faced by overall costs that are between their costs in scenarios *Cap* and *Cap+Res*.

Figure 9: Relative policy cost by EU member state and scenario. Countries are sorted in ascending order of non-policy consumption based on Eurostat data. The width of the bars is proportional to the share of the population of each member state.



The main mechanism for this are again the changes in market prices of ETS permits due to changing permit demand by the electricity sector in countries that promote RES. By promoting RES through a subsidy rather than a quota, the implicit tax on electricity that the electricity sector sets under the quota falls away and power generation from fossil fuels along with overall electricity use increases. The first three columns of Table 11 show the effect of this on ETS permit purchases by industries on the national level: The countries that promote RES (except Sweden and Austria) all use more permits if they use a subsidy rather than a renewable energy standard as in scenario *Cap+Res*. Member states without a RES target, facing a higher permit price, consistently emit less in the ETS sectors.

The fourth column of Table 11 lists the volumes of subsidies for RES support. It becomes apparent that, priced at ETS permit prices of 12–22 EUR (compare to Table 3), the value of required permits is about one order of magnitude smaller than the subsidy volume. Thus, distributional effects of financing the subsidy may be considerably larger than those of recycling auctioning revenue from the ETS, depending on the precise financing mechanism.

Table 11: Member states' emissions under the ETS across different instruments for RES support and subsidy volumes for the instrument "subsidy".

	ETS emissions (MtCO2)			Subsidy volume (billion EUR)
	CAP	CAP+RES	CAP+ RES-SUB	
Bulgaria (BGR)	30.3	32.0	30.8	
Romania (ROU)	38.7	41.3	40.0	
Hungary (HUN)	14.1	14.7	14.3	
Czech Republic (CZE)	48.5	51.9	49.3	
Slovakia (SVK)	12.8	13.7	13.1	
Poland (POL)	184.3	192.3	186.7	
Portugal (PRT)	22.9	23.8	23.2	
Greece (GRC)	36.7	38.6	37.3	
United Kingdom (GBR)	154.6	147.9	152.3	14.4
Italy (ITA)	170.1	176.2	171.9	
Spain (ESP)	125.3	131.7	127.4	
France (FRA)	81.2	71.4	80.8	6.8
Finland (FIN)	23.1	28.1	25.4	
Germany (DEU)	342.4	325.4	333.9	35.7
Belgium (BEL)	48.0	47.3	48.1	1.8
Denmark (DNK)	11.8	10.0	11.2	6.7
Sweden (SWE)	12.0	12.2	12.0	11.3
Netherlands (NLD)	93.9	92.2	94.3	3.2
Austria (AUT)	18.1	16.2	16.1	4.4

D. Member state results in more detail

Table 12: Results for Austria, Belgium, and Bulgaria (annual consumption expenditure of different income quintiles in PPS)

		overall	q1	q2	q3	q4	q5
AUT	*NoPolicy*	21'524	15'562	20'204	21'619	23'143	27'137
	Cap	–0.16%	–0.20%	–0.12%	–0.13%	–0.14%	–0.21%
	Cap+Res	–0.26%	–0.39%	–0.18%	–0.22%	–0.26%	–0.27%
	Invest	–0.34%	–0.54%	–0.24%	–0.28%	–0.29%	–0.36%
	Invest+Res	–0.36%	–0.57%	–0.25%	–0.30%	–0.34%	–0.35%
	TaxCap	–0.16%	0.06%	–0.20%	–0.19%	–0.20%	–0.23%
	TaxCap+Res	–0.26%	–0.12%	–0.26%	–0.28%	–0.32%	–0.30%
	NoPolicy - pl	21'524	15'561	20'203	21'618	23'143	27'141
	Cap - pl	–0.16%	–0.21%	–0.13%	–0.14%	–0.14%	–0.19%
BEL	*NoPolicy*	20'158	14'100	18'383	20'333	22'112	25'908
	Cap	–0.02%	–0.07%	–0.05%	–0.02%	0.00%	0.03%
	Cap+Res	–0.07%	–0.21%	–0.12%	–0.06%	–0.01%	0.03%
	Invest	–0.30%	–0.50%	–0.40%	–0.28%	–0.19%	–0.17%
	Invest+Res	–0.22%	–0.45%	–0.31%	–0.20%	–0.11%	–0.07%
	TaxCap	–0.02%	0.12%	0.04%	–0.04%	–0.11%	–0.09%
	TaxCap+Res	–0.07%	–0.01%	–0.03%	–0.08%	–0.12%	–0.09%
	NoPolicy - pl	20'158	14'098	18'380	20'331	22'113	25'915
	Cap - pl	–0.02%	–0.06%	–0.04%	–0.02%	0.00%	0.01%
BGR	*NoPolicy*	5'653	3'395	4'628	5'549	6'541	8'182
	Cap	0.99%	5.40%	2.05%	0.76%	0.29%	–1.49%
	Cap+Res	0.56%	2.86%	1.10%	0.42%	0.18%	–0.72%
	Invest	–3.29%	–3.66%	–2.92%	–2.51%	–2.84%	–4.34%
	Invest+Res	–1.79%	–2.09%	–1.62%	–1.37%	–1.53%	–2.28%
	TaxCap	0.99%	5.89%	2.21%	0.73%	0.17%	–1.74%
	TaxCap+Res	0.56%	3.36%	1.26%	0.39%	0.06%	–0.98%
	NoPolicy - pl	5'653	3'386	4'624	5'550	6'543	8'195
	Cap - pl	0.99%	5.64%	2.13%	0.74%	0.26%	–1.62%

Table 13: Results for Croatia, Cyprus, the Czech Republic, Denmark, and Estonia (annual consumption expenditure of different income quintiles in PPS)

		overall	q1	q2	q3	q4	q5
HRV	*NoPolicy*	9’632	6’345	8’609	9’724	10’674	12’776
	Cap	–0.54%	–0.61%	–0.52%	–0.44%	–0.40%	–0.71%
	Cap+Res	–0.53%	–0.90%	–0.56%	–0.44%	–0.34%	–0.51%
	Invest	–0.93%	–1.50%	–0.95%	–0.76%	–0.62%	–0.95%
	Invest+Res	–0.75%	–1.38%	–0.80%	–0.61%	–0.46%	–0.64%
	TaxCap	–0.55%	0.55%	–0.33%	–0.63%	–0.88%	–1.13%
	TaxCap+Res	–0.54%	0.27%	–0.37%	–0.62%	–0.81%	–0.93%
	NoPolicy - pl	9’632	6’345	8’606	9’722	10’673	12’783
	Cap - pl	–0.54%	–0.58%	–0.44%	–0.40%	–0.39%	–0.87%
CYP	*NoPolicy*	24’166	13’349	19’885	24’315	26’924	36’521
	Cap	–0.90%	–0.92%	–0.66%	–0.56%	–0.66%	–1.46%
	Cap+Res	–0.86%	–1.23%	–0.80%	–0.69%	–0.60%	–1.04%
	Invest	–1.47%	–1.97%	–1.30%	–1.14%	–1.04%	–1.87%
	Invest+Res	–1.17%	–1.79%	–1.14%	–1.00%	–0.81%	–1.27%
	TaxCap	–0.90%	–0.03%	–0.63%	–0.53%	–1.06%	–1.65%
	TaxCap+Res	–0.86%	–0.32%	–0.76%	–0.66%	–1.01%	–1.23%
	NoPolicy - pl	24’166	13’349	19’885	24’315	26’924	36’520
	Cap - pl	–0.90%	–0.84%	–0.64%	–0.56%	–0.68%	–1.50%
CZE	*NoPolicy*	8’334	6’006	7’431	8’253	9’044	10’966
	Cap	0.49%	2.00%	0.77%	0.34%	0.17%	–0.63%
	Cap+Res	0.29%	1.03%	0.41%	0.18%	0.12%	–0.22%
	Invest	–1.33%	–1.50%	–1.15%	–0.98%	–1.13%	–1.82%
	Invest+Res	–0.71%	–0.88%	–0.64%	–0.54%	–0.58%	–0.88%
	TaxCap	0.49%	2.20%	0.79%	0.28%	0.09%	–0.71%
	TaxCap+Res	0.29%	1.24%	0.42%	0.13%	0.05%	–0.30%
	NoPolicy - pl	8’334	6’003	7’430	8’253	9’045	10’971
	Cap - pl	0.49%	2.01%	0.77%	0.34%	0.17%	–0.64%
DNK	*NoPolicy*	19’212	14’032	16’877	19’142	21’091	24’938
	Cap	–0.66%	–1.01%	–0.77%	–0.62%	–0.43%	–0.53%
	Cap+Res	–1.02%	–1.46%	–1.13%	–0.98%	–0.76%	–0.81%
	Invest	–0.91%	–1.51%	–1.07%	–0.84%	–0.55%	–0.64%
	Invest+Res	–1.15%	–1.73%	–1.29%	–1.10%	–0.83%	–0.87%
	TaxCap	–0.66%	–0.57%	–0.66%	–0.66%	–0.64%	–0.78%
	TaxCap+Res	–1.02%	–1.02%	–1.01%	–1.02%	–0.97%	–1.06%
	NoPolicy - pl	19’212	14’032	16’877	19’142	21’092	24’939
	Cap - pl	–0.66%	–0.77%	–0.60%	–0.56%	–0.50%	–0.88%
EST	*NoPolicy*	6’768	3’930	5’462	5’745	7’710	11’021
	Cap	–0.12%	3.43%	1.05%	0.24%	–0.52%	–2.57%
	Cap+Res	–0.18%	1.70%	0.48%	0.08%	–0.36%	–1.57%
	Invest	–3.07%	–3.00%	–2.57%	–2.27%	–2.65%	–4.21%
	Invest+Res	–1.80%	–1.82%	–1.50%	–1.28%	–1.53%	–2.49%
	TaxCap	–0.12%	3.72%	1.17%	0.25%	–0.61%	–2.74%
	TaxCap+Res	–0.18%	1.99%	0.60%	0.09%	–0.45%	–1.74%
	NoPolicy - pl	6’768	3’922	5’457	5’745	7’711	11’037
	Cap - pl	–0.12%	3.69%	1.17%	0.24%	–0.53%	–2.77%

Table 14: Results for Finland, France, Germany, Greece, and Hungary (annual consumption expenditure of different income quintiles in PPS)

		overall	q1	q2	q3	q4	q5
FIN	*NoPolicy*	18’114	11’250	14’897	17’669	20’319	26’461
	Cap	–0.34%	–0.23%	–0.25%	–0.27%	–0.35%	–0.54%
	Cap+Res	–0.30%	–0.40%	–0.30%	–0.25%	–0.24%	–0.30%
	Invest	–0.71%	–0.96%	–0.74%	–0.62%	–0.62%	–0.69%
	Invest+Res	–0.50%	–0.80%	–0.57%	–0.44%	–0.39%	–0.39%
	TaxCap	–0.34%	0.09%	–0.12%	–0.29%	–0.48%	–0.72%
	TaxCap+Res	–0.30%	–0.08%	–0.17%	–0.27%	–0.37%	–0.48%
	NoPolicy - pl	18’114	11’246	14’891	17’665	20’322	26’477
	Cap - pl	–0.34%	–0.27%	–0.29%	–0.30%	–0.33%	–0.46%
FRA	*NoPolicy*	18’100	12’031	15’116	17’253	20’029	26’081
	Cap	–0.09%	–0.26%	–0.14%	–0.10%	–0.05%	0.01%
	Cap+Res	–0.14%	–0.39%	–0.21%	–0.15%	–0.07%	0.02%
	Invest	–0.20%	–0.49%	–0.27%	–0.20%	–0.10%	–0.04%
	Invest+Res	–0.19%	–0.51%	–0.28%	–0.20%	–0.10%	0.00%
	TaxCap	–0.09%	0.02%	–0.09%	–0.12%	–0.16%	–0.10%
	TaxCap+Res	–0.14%	–0.10%	–0.16%	–0.18%	–0.18%	–0.08%
	NoPolicy - pl	18’100	12’030	15’116	17’253	20’029	26’082
	Cap - pl	–0.09%	–0.28%	–0.15%	–0.11%	–0.04%	0.03%
DEU	*NoPolicy*	19’247	11’313	15’545	18’544	21’441	29’411
	Cap	–0.13%	0.01%	–0.09%	–0.13%	–0.15%	–0.23%
	Cap+Res	–0.13%	–0.24%	–0.08%	–0.07%	–0.13%	–0.17%
	Invest	–0.41%	–0.64%	–0.45%	–0.36%	–0.32%	–0.37%
	Invest+Res	–0.29%	–0.60%	–0.28%	–0.19%	–0.22%	–0.25%
	TaxCap	–0.13%	0.44%	–0.03%	–0.22%	–0.28%	–0.34%
	TaxCap+Res	–0.14%	0.21%	–0.02%	–0.16%	–0.27%	–0.29%
	NoPolicy - pl	19’247	11’312	15’541	18’540	21’442	29’421
	Cap - pl	–0.13%	0.02%	–0.07%	–0.12%	–0.15%	–0.26%
GRC	*NoPolicy*	17’073	10’704	12’471	15’311	18’571	28’331
	Cap	–1.09%	–1.42%	–1.15%	–0.97%	–1.01%	–1.02%
	Cap+Res	–1.12%	–1.85%	–1.29%	–0.96%	–1.02%	–0.86%
	Invest	–1.62%	–2.65%	–1.82%	–1.35%	–1.45%	–1.28%
	Invest+Res	–1.41%	–2.52%	–1.66%	–1.17%	–1.26%	–1.00%
	TaxCap	–1.09%	1.82%	–0.46%	–1.57%	–1.59%	–2.17%
	TaxCap+Res	–1.12%	1.47%	–0.58%	–1.57%	–1.61%	–2.04%
	NoPolicy - pl	17’073	10’701	12’470	15’311	18’571	28’337
	Cap - pl	–1.09%	–1.46%	–1.17%	–0.97%	–1.01%	–0.99%
HUN	*NoPolicy*	6’833	5’205	5’927	6’569	7’376	9’097
	Cap	0.15%	0.43%	0.23%	0.13%	0.10%	–0.06%
	Cap+Res	0.05%	0.13%	0.08%	0.06%	0.04%	–0.02%
	Invest	–0.37%	–0.50%	–0.36%	–0.28%	–0.31%	–0.41%
	Invest+Res	–0.23%	–0.38%	–0.25%	–0.17%	–0.18%	–0.21%
	TaxCap	0.15%	0.68%	0.28%	0.05%	0.02%	–0.17%
	TaxCap+Res	0.05%	0.38%	0.13%	–0.02%	–0.04%	–0.13%
	NoPolicy - pl	6’833	5’204	5’927	6’569	7’376	9’098
	Cap - pl	0.15%	0.45%	0.24%	0.13%	0.10%	–0.09%

Table 15: Results for Ireland, Italy, Latvia, Lithuania, and Luxembourg (annual consumption expenditure of different income quintiles in PPS)

		overall	q1	q2	q3	q4	q5
IRL	*NoPolicy*	18’969	14’588	15’660	17’502	21’090	26’015
	Cap	–0.17%	–0.19%	–0.17%	–0.15%	–0.13%	–0.22%
	Cap+Res	–0.14%	–0.26%	–0.16%	–0.12%	–0.07%	–0.10%
	Invest	–0.39%	–0.61%	–0.43%	–0.35%	–0.25%	–0.34%
	Invest+Res	–0.25%	–0.49%	–0.31%	–0.23%	–0.13%	–0.16%
	TaxCap	–0.17%	0.15%	–0.12%	–0.20%	–0.28%	–0.34%
	TaxCap+Res	–0.14%	0.08%	–0.11%	–0.17%	–0.22%	–0.23%
	NoPolicy – pl	18’969	14’584	15’653	17’499	21’091	26’030
	Cap – pl	–0.17%	–0.17%	–0.15%	–0.14%	–0.13%	–0.25%
ITA	*NoPolicy*	17’971	11’390	14’387	16’860	19’722	27’495
	Cap	–0.41%	–0.47%	–0.36%	–0.35%	–0.39%	–0.45%
	Cap+Res	–0.34%	–0.52%	–0.32%	–0.29%	–0.33%	–0.34%
	Invest	–0.64%	–0.90%	–0.60%	–0.55%	–0.61%	–0.64%
	Invest+Res	–0.47%	–0.75%	–0.46%	–0.39%	–0.45%	–0.44%
	TaxCap	–0.41%	–0.12%	–0.35%	–0.43%	–0.43%	–0.52%
	TaxCap+Res	–0.35%	–0.16%	–0.31%	–0.36%	–0.37%	–0.40%
	NoPolicy – pl	17’971	11’388	14’385	16’859	19’722	27’500
	Cap – pl	–0.41%	–0.51%	–0.38%	–0.36%	–0.39%	–0.42%
LVA	*NoPolicy*	6’876	4’527	5’614	6’138	7’362	10’710
	Cap	–0.15%	–0.13%	–0.16%	–0.18%	–0.15%	–0.13%
	Cap+Res	–0.14%	–0.33%	–0.24%	–0.19%	–0.12%	0.07%
	Invest	–0.67%	–1.16%	–0.77%	–0.56%	–0.54%	–0.50%
	Invest+Res	–0.42%	–0.89%	–0.57%	–0.40%	–0.33%	–0.14%
	TaxCap	–0.15%	0.56%	0.05%	–0.24%	–0.36%	–0.47%
	TaxCap+Res	–0.14%	0.37%	–0.03%	–0.25%	–0.33%	–0.29%
	NoPolicy – pl	6’876	4’524	5’613	6’138	7’362	10’714
	Cap – pl	–0.15%	–0.18%	–0.18%	–0.18%	–0.15%	–0.09%
LTU	*NoPolicy*	8’672	5’872	7’294	8’449	9’529	12’227
	Cap	0.08%	0.61%	0.24%	0.05%	0.00%	–0.29%
	Cap+Res	0.16%	0.32%	0.18%	0.10%	0.12%	0.13%
	Invest	–0.76%	–0.95%	–0.72%	–0.60%	–0.66%	–0.89%
	Invest+Res	–0.30%	–0.53%	–0.35%	–0.25%	–0.24%	–0.20%
	TaxCap	0.08%	0.92%	0.34%	–0.02%	–0.09%	–0.43%
	TaxCap+Res	0.16%	0.64%	0.27%	0.03%	0.03%	–0.02%
	NoPolicy – pl	8’672	5’871	7’293	8’450	9’529	12’229
	Cap – pl	0.08%	0.59%	0.24%	0.05%	0.00%	–0.27%
LUX	*NoPolicy*	32’582	17’833	24’567	29’597	37’762	53’131
	Cap	–0.46%	–0.86%	–0.59%	–0.44%	–0.33%	–0.30%
	Cap+Res	–0.53%	–1.05%	–0.71%	–0.52%	–0.37%	–0.32%
	Invest	–0.65%	–1.27%	–0.86%	–0.63%	–0.46%	–0.39%
	Invest+Res	–0.63%	–1.27%	–0.86%	–0.63%	–0.44%	–0.37%
	TaxCap	–0.45%	–0.20%	–0.44%	–0.54%	–0.52%	–0.48%
	TaxCap+Res	–0.53%	–0.39%	–0.56%	–0.62%	–0.56%	–0.50%
	NoPolicy – pl	32’582	17’831	24’565	29’596	37’760	53’139
	Cap – pl	–0.45%	–0.85%	–0.58%	–0.43%	–0.32%	–0.33%

Table 16: Results for Malta, the Netherlands, Poland, Portugal, and Romania (annual consumption expenditure of different income quintiles in PPS)

		overall	q1	q2	q3	q4	q5
MLT	*NoPolicy*	14’620	10’722	12’649	14’855	16’069	18’819
	Cap	–2.06%	–2.43%	–2.16%	–1.83%	–1.80%	–2.13%
	Cap+Res	–2.15%	–2.94%	–2.37%	–1.86%	–1.77%	–1.96%
	Invest	–2.75%	–3.87%	–2.98%	–2.31%	–2.21%	–2.56%
	Invest+Res	–2.46%	–3.59%	–2.74%	–2.08%	–1.96%	–2.15%
	TaxCap	–2.05%	2.03%	–1.29%	–2.86%	–3.45%	–3.86%
	TaxCap+Res	–2.14%	1.53%	–1.50%	–2.90%	–3.43%	–3.69%
	NoPolicy - pl	14’620	10’722	12’648	14’855	16’069	18’820
	Cap - pl	–2.07%	–2.45%	–2.17%	–1.83%	–1.80%	–2.13%
NLD	*NoPolicy*	20’037	16’606	17’834	19’576	20’709	25’403
	Cap	–0.57%	–0.57%	–0.61%	–0.52%	–0.52%	–0.61%
	Cap+Res	–0.63%	–0.80%	–0.70%	–0.56%	–0.52%	–0.57%
	Invest	–0.80%	–1.04%	–0.89%	–0.69%	–0.64%	–0.72%
	Invest+Res	–0.76%	–1.06%	–0.86%	–0.65%	–0.58%	–0.63%
	TaxCap	–0.57%	–0.26%	–0.56%	–0.61%	–0.67%	–0.74%
	TaxCap+Res	–0.63%	–0.47%	–0.65%	–0.65%	–0.67%	–0.71%
	NoPolicy - pl	20’037	16’604	17’831	19’575	20’709	25’411
	Cap - pl	–0.57%	–0.52%	–0.52%	–0.50%	–0.53%	–0.76%
POL	*NoPolicy*	10’581	7’843	9’196	9’792	11’043	15’055
	Cap	–0.54%	0.57%	–0.17%	–0.49%	–0.69%	–1.52%
	Cap+Res	–0.33%	0.20%	–0.14%	–0.28%	–0.39%	–0.85%
	Invest	–2.00%	–2.06%	–1.82%	–1.65%	–1.84%	–2.47%
	Invest+Res	–1.13%	–1.23%	–1.05%	–0.92%	–1.02%	–1.37%
	TaxCap	–0.54%	0.78%	–0.12%	–0.54%	–0.76%	–1.62%
	TaxCap+Res	–0.34%	0.41%	–0.10%	–0.33%	–0.46%	–0.94%
	NoPolicy - pl	10’581	7’835	9’193	9’793	11’045	15’067
	Cap - pl	–0.54%	0.74%	–0.11%	–0.51%	–0.72%	–1.65%
PRT	*NoPolicy*	13’589	8’002	10’473	12’482	14’575	22’429
	Cap	–0.36%	–0.41%	–0.39%	–0.35%	–0.32%	–0.35%
	Cap+Res	–0.36%	–0.48%	–0.47%	–0.42%	–0.32%	–0.24%
	Invest	–0.76%	–0.94%	–0.94%	–0.86%	–0.69%	–0.56%
	Invest+Res	–0.58%	–0.76%	–0.77%	–0.70%	–0.52%	–0.36%
	TaxCap	–0.36%	–0.11%	–0.19%	–0.24%	–0.41%	–0.60%
	TaxCap+Res	–0.36%	–0.18%	–0.27%	–0.31%	–0.42%	–0.49%
	NoPolicy - pl	13’589	8’000	10’471	12’482	14’576	22’434
	Cap - pl	–0.36%	–0.36%	–0.36%	–0.35%	–0.33%	–0.39%
ROU	*NoPolicy*	5’389	3’262	4’394	5’186	6’024	8’091
	Cap	0.97%	3.32%	1.46%	0.71%	0.58%	–0.06%
	Cap+Res	0.47%	1.76%	0.75%	0.37%	0.27%	–0.13%
	Invest	–0.90%	–0.65%	–0.73%	–0.74%	–0.85%	–1.29%
	Invest+Res	–0.55%	–0.41%	–0.46%	–0.42%	–0.51%	–0.81%
	TaxCap	0.97%	4.03%	1.68%	0.66%	0.42%	–0.42%
	TaxCap+Res	0.48%	2.44%	0.96%	0.32%	0.12%	–0.47%
	NoPolicy - pl	5’389	3’260	4’392	5’186	6’025	8’096
	Cap - pl	0.97%	3.30%	1.45%	0.71%	0.58%	–0.05%

Table 17: Results for Slovakia, Slovenia, Spain, Sweden, and the United Kingdom (annual consumption expenditure of different income quintiles in PPS)

		overall	q1	q2	q3	q4	q5
SVK	*NoPolicy*	8’322	6’817	7’514	7’870	8’529	10’889
	Cap	0.84%	1.61%	0.87%	0.73%	0.50%	0.43%
	Cap+Res	0.52%	0.91%	0.52%	0.45%	0.33%	0.38%
	Invest	–0.11%	–0.22%	–0.14%	–0.12%	–0.08%	–0.01%
	Invest+Res	0.01%	–0.09%	–0.04%	–0.02%	0.02%	0.14%
	TaxCap	0.84%	1.76%	0.89%	0.70%	0.44%	0.34%
	TaxCap+Res	0.52%	1.06%	0.53%	0.42%	0.27%	0.30%
	NoPolicy - pl	8’322	6’816	7’514	7’870	8’529	10’891
	Cap - pl	0.84%	1.56%	0.87%	0.73%	0.52%	0.47%
SVN	*NoPolicy*	15’288	11’434	14’203	15’115	15’979	19’714
	Cap	–0.37%	–0.40%	–0.32%	–0.38%	–0.35%	–0.42%
	Cap+Res	–0.41%	–0.67%	–0.30%	–0.46%	–0.29%	–0.35%
	Invest	–0.87%	–1.32%	–0.74%	–0.98%	–0.63%	–0.70%
	Invest+Res	–0.68%	–1.17%	–0.53%	–0.79%	–0.44%	–0.50%
	TaxCap	–0.37%	0.27%	–0.44%	–0.23%	–0.70%	–0.73%
	TaxCap+Res	–0.41%	0.02%	–0.42%	–0.32%	–0.64%	–0.66%
	NoPolicy - pl	15’288	11’430	14’195	15’112	15’983	19’729
	Cap - pl	–0.38%	–0.40%	–0.32%	–0.37%	–0.35%	–0.42%
ESP	*NoPolicy*	17’878	11’196	14’498	17’204	19’845	26’659
	Cap	–0.20%	–0.09%	–0.14%	–0.14%	–0.17%	–0.35%
	Cap+Res	–0.20%	–0.34%	–0.19%	–0.17%	–0.13%	–0.21%
	Invest	–0.53%	–0.89%	–0.52%	–0.44%	–0.35%	–0.57%
	Invest+Res	–0.38%	–0.77%	–0.40%	–0.33%	–0.24%	–0.33%
	TaxCap	–0.20%	0.41%	–0.09%	–0.20%	–0.33%	–0.47%
	TaxCap+Res	–0.20%	0.17%	–0.14%	–0.22%	–0.30%	–0.33%
	NoPolicy - pl	17’878	11’192	14’494	17’202	19’844	26’671
	Cap - pl	–0.20%	–0.08%	–0.13%	–0.14%	–0.17%	–0.36%
SWE	*NoPolicy*	19’122	13’564	16’251	19’488	21’213	25’116
	Cap	–0.33%	–0.55%	–0.36%	–0.29%	–0.22%	–0.28%
	Cap+Res	–0.50%	–0.78%	–0.55%	–0.46%	–0.37%	–0.41%
	Invest	–0.44%	–0.76%	–0.49%	–0.38%	–0.27%	–0.33%
	Invest+Res	–0.56%	–0.89%	–0.62%	–0.51%	–0.40%	–0.44%
	TaxCap	–0.33%	–0.27%	–0.28%	–0.33%	–0.38%	–0.40%
	TaxCap+Res	–0.50%	–0.50%	–0.46%	–0.51%	–0.52%	–0.52%
	NoPolicy - pl	19’122	13’562	16’249	19’487	21’214	25’121
	Cap - pl	–0.33%	–0.56%	–0.38%	–0.30%	–0.22%	–0.25%
GBR	*NoPolicy*	14’786	10’677	12’038	13’712	15’611	21’903
	Cap	–0.09%	–0.07%	–0.10%	–0.09%	–0.06%	–0.12%
	Cap+Res	–0.13%	–0.15%	–0.14%	–0.12%	–0.10%	–0.14%
	Invest	–0.26%	–0.39%	–0.31%	–0.24%	–0.16%	–0.21%
	Invest+Res	–0.22%	–0.32%	–0.25%	–0.20%	–0.16%	–0.19%
	TaxCap	–0.09%	0.09%	–0.07%	–0.11%	–0.12%	–0.19%
	TaxCap+Res	–0.13%	0.03%	–0.10%	–0.14%	–0.17%	–0.21%
	NoPolicy - pl	14’786	10’678	12’038	13’712	15’611	21’902
	Cap - pl	–0.09%	0.04%	–0.01%	–0.05%	–0.09%	–0.26%

Table 18: ETS auction revenue in million EUR for scenario *Cap* with an emission cap and scenario *Cap+Res* with a cap and RES targets.

	Cap (permit price: 22.05 EUR/tCO2)	*Cap+Res* (permit price: 12.18 EUR/tCO2)
AUT	313.8	170.9
BEL	572.2	311.6
BGR	683.0	372.0
HRV	108.8	59.3
CYP	60.0	32.7
CZE	1054.5	574.3
DNK	281.5	153.3
EST	205.4	111.8
FIN	376.1	204.8
FRA	1234.4	672.3
DEU	4515.5	2459.2
GRC	782.2	426.0
HUN	336.9	183.5
IRL	212.3	115.6
ITA	2173.6	1183.7
LVA	46.1	25.1
LTU	122.3	66.6
LUX	39.2	21.4
MLT	23.1	12.6
NLD	756.8	412.2
POL	2817.3	1534.3
PRT	396.9	216.1
ROU	1126.0	613.2
SVK	346.1	188.5
SVN	99.2	54.0
ESP	1947.4	1060.6
SWE	200.7	109.3
GBR	2353.5	1281.8