Socio-economic implications of different options for a 2040 EU climate target

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Abstract:

Europe has set a climate target for 2030 as well as a climate neutrality target for 2050. It is obliged both by EU law and the Paris agreement to provide an intermediate target. Here, we carry out a socio-economic analysis for different options of a 2040 climate target using a CGE model that is informed by detailed energy system modelling. In the modelling exercise, we pay particular attention to the assessment of investment needs and distributional implications on households.

Keywords: Climate Policy, European Union, CGE modelling, Distributional Analysis

Introduction and Background

The EU has set greenhouse gas emission reduction targets for 2030 (-55% relative to 1990) and 2050 (-100%, or carbon neutrality). The European Climate Law mandates setting an intermediate target for 2040 after the first global stocktake, which was concluded formally at COP 28 in Dubai. The EU's 2040 target will also be important for the next round of Nationally Determined Contributions (NDCs) that countries are committed to submit under Article 4 of the Paris Agreement in the coming years; these NDCs are then addressing targets for emission reductions post 2030.

Against this backdrop, the European Commission proposed an EU climate target of 90% for early 2024 (EC, 2024a). After the next Commission takes office later in 2023, after the European elections, it will need to make a legislative proposal which will need to be agreed with the European parliament and European Council to formally amend the European climate law.

To make an informed choice, an impact assessment was carried out to evaluate the outcome of different reduction targets (EC, 2024b). The quantitative assessment of the targets relies on a modelling toolbox including energy system modelling as well as macroeconomic modelling. The macroeconomic modelling carried out by the European Commission's Joint Research Centre used the JRC-GEM-E3 computable general equilibrium (CGE) model which was closely integrated with the energy system modelling for consistent representation of key transitions towards a net zero economy. As in the assessment for the 2030 climate target (see Weitzel et al., 2023), the JRC's CGE model was further complemented by downscaling tools in order to assess heterogeneity in results, such as the impact of price changes and different carbon revenue recycling options on income groups. The modelling further was refined along two key political dimensions of interest to provide additional insights on the investment requirements (and related impacts through supply chains) as well as distributional impacts on households for a policy that will affect households mainly only in the next decade.

In this paper, we present the socio-economic implications prepared for the European Commission's impact assessment guiding the proposal of a climate target for 2040. It also complements the impact assessment of the European Commission (2024b) in that it provides further explanation on the technical details of the modelling underlying the impact assessment. Finally, the paper also is helpful in showcasing how economic modelling in CGE models can be augmented both on the input side (i.e. using input from energy modelling) and on the output side (to downscale variables of interest or feed them into additional tools) when modelling deep emission reductions.

Methods

Modelling Toolbox & JRC-GEM-E3

While a whole toolbox of models is used to assess different elements (such as the energy transition, land use, non-CO_2 emissions etc) in more detail, we here focus on the socio-economic aspects of the analysis. In particular, we employ the CGE model JRC-GEM-E3 tailored towards the assessment of energy and climate policies, which captures interactions between sectors and different world regions through international trade. For this exercise, the model used the GTAP-Power v10 dataset (Chepeliev, 2020) as a starting point and was calibrated forward to energy and emission data from the energy system model PRIMES using a modified multi-regional RAS procedure (Wojtowicz et al., 2019). This implies that the starting point for the analysis is consistent between energy and macroeconomic models. For scenarios analysis, information from the energy system model is also used in the CGE model to describe decarbonization (i.e. fuel inputs) in key sectors such as the power sector, buildings, and transportation, while at the same time also integrating cost information from the energy model as reported in Weitzel et al. (2023). This ensures that (prior to general equilibrium effects) changes in energy demand and emissions are in line with energy models as well as changes in costs, e.g. due to additional capital requirements. The linking is helpful as energy models are able to take into account specific constraints and dynamics of the energy sector which cannot be depicted well in a more aggregate CGE model (see linking paper Delzeit et al., 2020; Faehn et al., 2020).

For the 2040 assessment, two elements were of particular interest when carrying out the modelling: the investment requirements (and related impacts through supply chains) as well as distributional impacts on households.

Following discussions about the capital needs for the economic transition towards net zero (e.g. Pisani-Ferry et al., 2023), several improvements were carried out in the CGE model to better represent additional investment needs. In particular, to capture investments in new technologies (such as hydrogen, e-fuels and direct air capture) which may not be fully captured explicitly in the JRC-GEM-E3 model and might have been underestimated otherwise. Here, we were taking additional investments from the energy models and implemented this as additional investment demand by the electricity sector to capture macroeconomic effects of this additional investment.

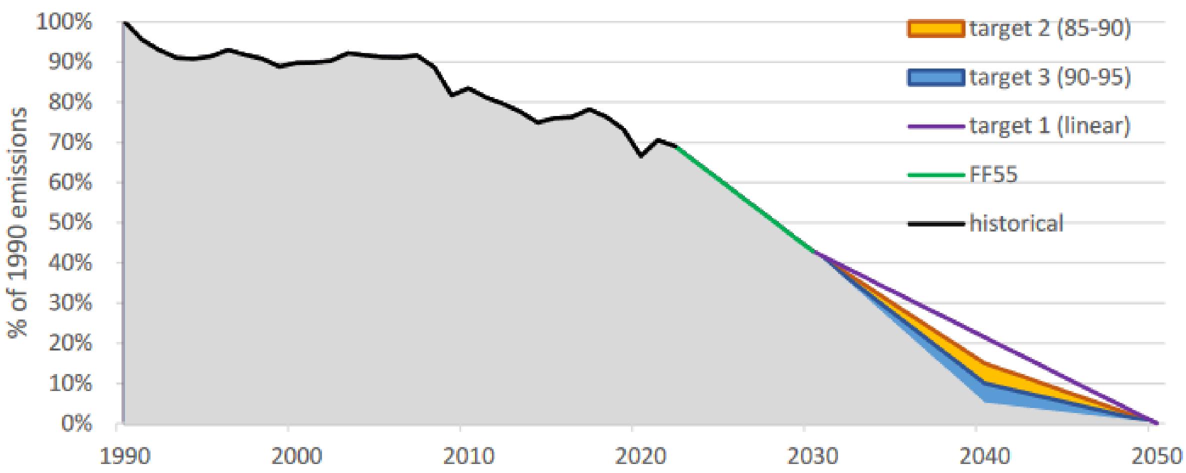
In addition, making use of a new sectoral detailed investment matrix (Norman-López et al., 2023), the supply chain connections were improved. In particular, the large investment required to provide clean power, like wind and solar to support the electrification not only in transport and buildings, but also in industry, was better captured. Using a general equilibrium framework can show effects on upstream sectors supplying investment goods, such as the construction sector.

As carbon pricing can lead to regressive effects and social acceptance of climate policy may hinge on (perceived) fairness of measures, an important aspect of the analysis was the extension to include distributional effects. To obtain results that differ for various income groups from a CGE model with a single representative household, price changes calculated in the CGE model were passed to data from a household budget survey, along with potential carbon revenues to redistribute. While previous exercises (e.g. Weitzel et al, 2023) kept expenditure shares of individual households constant as reported in the underlying survey data, for this exercise we developed a projection method to update household expenditure in line with macro trends to account for (on average) richer households in 2040 with different (aggregate) expenditure patterns. In particular, we used a new RAS-based approach to update household-level consumption expenditures that are in line with aggregate targets on expenditure and population dynamics as projected in the CGE model (Temursho et al., 2024).

Scenarios

Three scenarios with different levels of ambition in 2040 were constructed, with S1 being the least ambitious scenario and S3 the most ambitious scenario. Results are typically compared to the S2 scenario which is based on an extension of existing legislation. Figure 1 provides an overview of the pathways.

Figure 1: Profile of net GHG emissions until 2050 relative to 1990.



Source: EC (2024b)

Results

At the macro-economic level, impacts to GDP are limited in JRC-GEM-E3, with a difference of 0.7% lower GDP in S3 compared to S1 (Table 1). The least ambitious scenario featured higher GDP, consumption and aggregate employment values, in the more ambitious policy scenario the role of additional investment in zero emission technologies becomes more evident as this is the main driver for differences between S2 and S3. The additional harmonization of investment levels between the energy and the macroeconomic model improved the results related to investment. Concretely, with the enhanced coupling, the model output demonstrates more clearly the increase in the aggregate need for investments in the EU economy that is required to reach the policy targets. This shifts the structure of GDP from consumption to investments, as well as changing the trade balance as a means to source additional resources for investments.

Table 1: Macro-economic impacts (relative to S2)

	S1 fragmented		S1 global		S3 fragmented		S3 global	
	2040	2050	2040	2050	2040	2050	2040	2050
JRC-GEM-E3								
GDP	0.5%	0.1%	0.6%	0.2%	-0.2%	-0.1%	-0.2%	-0.1%
Private consumption	0.7%	0.1%	1.8%	2.1%	-0.5%	-0.1%	-0.5%	-0.1%
Investment	-0.1%	0.3%	-0.5%	-0.5%	1.1%	-0.1%	1.1%	-0.1%
Exports	1.2%	0.1%	-0.1%	-2.6%	-0.8%	-0.1%	-0.7%	0.0%
Imports	0.3%	0.1%	1.6%	1.5%	0.1%	-0.1%	0.1%	0.1%
Employment	0.3%	0.1%	0.3%	0.1%	-0.1%	0.0%	-0.1%	-0.1%

Zooming in to the individual sectors, it is not surprising that output is affected in particular for fossil fuel industries, where output declines faster in 2040. In other word, already declining trend of output seen between now and all 3 scenarios would be accelerated with more ambitious climate targets. As a result of additional investment demand to build the equipment for a net zero transition, moving to the most ambitious scenario leads to additional demand in the equipment industry as well as construction services.

Table 2: Sectoral output in 2040 (relative to S2)

	S1 fragmented	S3 fragmented	S1 global	S3 global
GDP (*)	0.5%	-0.2%	0.6%	-0.2%
Fossil fuel industries	10.2%	-5.6%	15.0%	-5.2%
Energy intensive industries	1.4%	-0.2%	-0.3%	-0.2%
Transport equipment	0.7%	-0.5%	0.6%	-0.4%
Other equipment goods	0.5%	0.2%	-1.3%	0.3%
Consumer goods industries	0.7%	-0.6%	-0.8%	-0.8%
Transport	2.0%	-1.0%	1.0%	-1.1%
Construction	0.0%	0.5%	0.0%	0.6%
Market services	0.5%	-0.2%	1.1%	-0.2%
Non-market services	0.2%	-0.2%	0.4%	-0.2%
Agriculture	2.0%	-1.0%	1.0%	-1.1%
Forestry	-10.9%	0.5%	-13.1%	-1.4%

The declining trend of fossil industries can also be seen from the declining share of sectoral employment (both absolute and as a share in total employment). Table 3 also shows the further increase of the service industry over time.

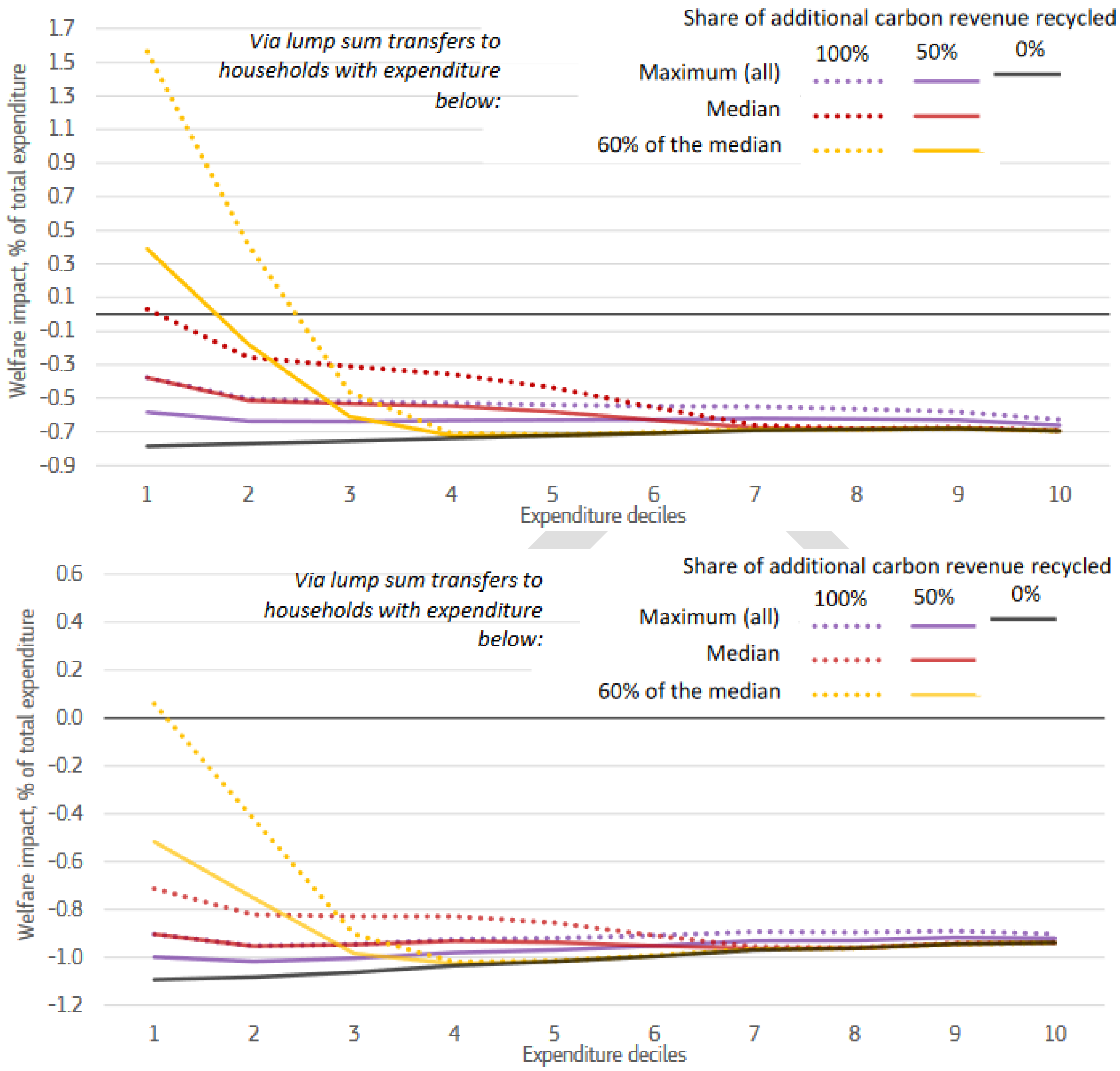
Table 3: Share of sectoral employment in S3

	S3			
	2020	**2030**	**2040**	**2050**
Fossil fuel industries	0.13%	0.11%	0.05%	0.05%
Energy intensive industries	6.7%	6.5%	6.2%	5.9%
Transport equipment	2.1%	2.0%	1.9%	1.8%
Other equipment goods	6.3%	6.2%	6.1%	6.1%
Consumer goods industries	4.4%	4.2%	4.0%	3.9%
Transport	3.6%	3.9%	3.7%	3.7%
Construction	7.8%	7.6%	7.7%	7.7%
Market services	34.0%	34.6%	34.9%	35.3%
Non-market services	26.6%	27.1%	27.3%	27.5%
Agriculture	3.5%	3.2%	3.1%	2.8%
Forestry	0.4%	0.3%	0.5%	0.4%
Other	4.4%	4.3%	4.6%	5.0%

The findings on the distributional analysis are in line with previous results. Carbon pricing can have regressive effects, however, this can be mitigated by (targeted) use of revenues from carbon pricing. Taking into account that households will be richer in 2040 and have shifted their consumption patterns (e.g. lower expenditure shares for food and energy than today) reduces the regressive effect on the expenditure side compared to an analysis based on static shares of consumption expenditures.

Figure 2 shows the change in relative change in welfare by expenditure decile for S2 (top part of the figure) and S3 (bottom part of the figure). When all additional revenues are used for lump-sum redistribution, the regressive effect can be offset, this becomes more pronounced with targeted recycling, e.g. by allocating revenues only to household between the median expenditure or 60% of the median. In this case, the bottom deciles may even benefit from the decarbonization policy. When moving to the most ambitious policy pathway S3, this may just be barely achieved as carbon revenues are eroded due to a lower tax base. In this scenario, the welfare effects prior to redistribution of revenues are larger and thus the lower revenue then limits the potential for making certain groups of the population at least as well of as in the less ambitious scenarios.

Figure 2: Change in relative welfare by expenditure decile, S2 (top) and S3 (bottom)



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