



## Analysis

## The impact of climate change mitigation policies on European labour markets

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## ABSTRACT

We study the impact of climate change mitigation policies intended to reach the Paris Agreement's two-degree target on the structure of European labour markets. Employing a three-sector macro-econometric model with a rich labour market extension, we show that the measures targeted at shrinking the use of fossil fuels in electricity generation and the road transport sector – both of which have an overall modest, positive impact on GDP and total employment – could make occupational structure less unequal and polarised in 2030, the target deadline. This could occur in more than half of the European Union's member states, particularly where the industries most affected by the transition to a low-carbon economy (i.e., mining and quarrying, utilities and manufacturing of coke and refined petroleum products) remain most important.

## 1. Introduction

Although there is wide agreement on the urgency of addressing the challenges posed by global warming, climate change mitigation policies might harm some segments of the population in the short term. Determining the impact of any sort of public sector intervention is not only in the best interest of citizens but also helps to deal with any potential resistance by the sectors most affected by these actions. Events such as the yellow vests protests in France, partly associated with a remarkable hike in fuel taxes, bring up the importance of addressing the political economy of the measures for carrying out the so-called ecological transition (Douenne and Fabre, 2020; Milanovic, 2018).

In fact, concerns over the equity implications of climate change mitigation policies are at the core of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2022). Sharing this worry, the European Union (EU) Just Transition Mechanism aspires to mobilise €100 billion over the 2021–2027 period in the most affected regions to alleviate the socio-economic impact of the transition. Similarly, ensuring an effective and fair transition to a low-carbon economy represents one of the main priorities of the International Labour Organization (2015).

This paper sheds light on the effects of climate change mitigation policies that aim to maintain the increase in global temperature below 2 °C by 2030 on European labour markets.<sup>1</sup> We use a global macro-econometric model that integrates a range of social and environmental

processes, a set of modules that allow us to translate the impact of these types of measures into employment implications by occupation and sector of activity, and a ranking of jobs derived from labour force surveys—a simple and rough way of approaching job quality. Specifically, we assess where employment creation and destruction occur, whether the new or lost jobs are good or bad ones, and the impact on labour market inequality and polarisation by country.<sup>2</sup>

The paper's main finding is that the overall impact on employment is generally positive and the impact on occupational structure is limited. On average, in those countries where mining and quarrying, utilities and the manufacturing of coke and refined petroleum products still hold a relevant weight nowadays (i.e., some Eastern European states), the transition to a low-carbon economy might make the labour market less unequal and polarised.

Measures targeted at reducing CO<sub>2</sub> through diminishing the use of fossil fuels in electricity generation and the road transport sector might imply a process of creative destruction, with employment losses and gains located at different places in the employment distribution. Knowing these types of consequences thus becomes essential for designing compensatory mechanisms that can improve the political feasibility of these mitigation policies.

A wide range of studies, inspired by very different modelling strategies, explores the implications of this green shift on both income and employment. According to a survey by the IPCC (2022), most works

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<sup>1</sup> At the time of conducting this research, the UK was still part of the EU. Hereafter, for brevity, when using the term EU, the UK is included.

<sup>2</sup> Labour market polarisation and inequality have attracted much attention in other domains, such as, but not exclusively, the assessment of the impact of technological change (see, e.g., Barbieri et al. 2019 and Jerbashian 2019).

suggest a negative impact of mitigation on GDP growth and a nearly null impact on employment, with a net destruction of low-skill jobs. Models with Keynesian ingredients, like the one used in this paper, tend to offer a more optimistic picture.<sup>3</sup>

An exhaustive literature review of ex-ante assessments of climate change mitigation policies by [García-García et al. \(2020\)](#) suggests overall modest, positive effects on both magnitudes due to the ecological transition. Unsurprisingly, the distributional consequences of mitigation seem contextual; i.e., they can widely vary depending on the country. [García-García et al. \(2020\)](#) document the striking scarcity of studies due to the ecological transition addressing issues like job quality or gender equality.<sup>4</sup>

Nevertheless, due to the undeniable distributional implications of environmental policy, a sizeable number of works address equity concerns using a wide range of methodologies ([Bento, 2013](#); [Fullerton, 2011](#); [IPCC, 2022](#)). This fertile literature highlights not only the relevance of the national context and the specific instruments – many of which are likely to be regressive – when assessing the distributional issues of climate mitigation but also the key role of compensatory interventions that can shape the overall balance of the ecological transition (e.g., targeted subsidies funded by environmental taxes).

To the best of our knowledge, no previous research focuses on the same outcome as ours, i.e., the impact on occupational structure, particularly labour market inequality and polarisation. While the former concept refers to the unevenness of the distribution of workers across jobs of different quality, the latter captures the decline of the middle-class working population. Several studies carry out an ex-ante evaluation of the impact of different models of ecological transitions on overall inequality (see, among others, [Bernardo and D'Alessandro 2016](#), [D'Alessandro et al. 2020](#), [Ravigné et al. 2022](#) and [Vona 2023](#)). Nevertheless, overall inequality levels are the result of many factors (like capital-labour conflict, unemployment, wage structure, taxes or public policies), of which occupational structure is only one of them. Therefore, this previous research does not allow distinguishing the specific role of our object of interest (i.e., occupational structure).

The closest study to ours is [Château et al. \(2018\)](#), who simulates the impacts of the green transition with policy measures that are not very different from those considered in this paper. These authors use a CGE model (ENV-Linkages) to estimate the impact of climate change policies on employment, and they also simulate their impact by occupational group. In particular, they consider five types of jobs (managers and officials, professionals, clerical workers, service and sales workers, and blue-collar and agricultural workers).

Their findings, only available for the Organisation for Economic Co-operation and Development (OECD) members as a whole, suggest a negligible decrease in the employment of manual workers and agricultural workers and an increase of around 0.05% for the other four

<sup>3</sup> The surveys of [Godinho \(2022\)](#) and [Pestel \(2019\)](#), centred on ex-post evaluations of climate change mitigation policies conclude that these kinds of measures have a small positive impact on employment.

<sup>4</sup> Although our work belongs to the body of literature of ex-ante studies, it is worth mentioning the work of [Godinho \(2022\)](#), who performs an excellent and up-to-date literature review of ex-post evaluations of mitigation policies. She points out modest positive effect of employment, and overall, non-negative impacts on equity. In contrast to ex-ante evaluations, these types of works allow analysing the actual performance of policies, implementation problems, political economy issues and power relations. However, ex-ante studies tend to focus on the impact of a single measure and often have a limited spatial coverage. This limits their ability to capture indirect effects. Furthermore, one should bear in mind that the joint effect of several interventions on inequality is not necessarily the sum of the separate individual effects of those policies computed by distinct studies. Last, the consequences of a certain policy measure in the future may not be the same as the one detected by an ex-post evaluation today, since both the production structure and the labour force may change or adapt to the pioneering and early policies.

categories. They do not conclude anything about how these shifts may impact occupational structure.<sup>5</sup>

The contribution of this paper is twofold. First, it expands our understanding of the consequences of policies aimed at curbing global warming on the labour market. Particularly, it focuses on changes in occupational structure, identifying the niches where job creation and destruction occur. This rather crude approach to job quality allows us to evaluate the impact of energy transition on both inequality and polarisation on European labour markets. Second, to the best of our knowledge, this study is the first to apply rigorous measures of ordinal inequality and polarisation to explore changes in occupational structure. The paper's main added value is not providing one more projection of the impact of the ecological transition on economic output and total employment but rather exploring the distributional consequences on the labour market of a certain reasonable path, which follows a model widely used in previous research.

Overall, previous research does not provide a clear-cut hypothesis about the impact of the transition in terms of the labour market structure. Given European citizens' growing concern over climate change ([European Commission, 2019](#)), widening economic disparities ([European Commission, 2014a](#)), and the relatively limited empirical evidence on the topic, the equity implications of the measures required for carrying out the transition constitute a hot topic nowadays.

The final outcome in terms of labour market equity is the result of the consideration of different simultaneous mitigation and eventually compensatory policies. Whereas the specific package of mitigation measures is key, previous research suggests that their impacts operate through different channels ([Château et al., 2018](#)).

First, mitigation policies imply changes in production modes. Overall, the economy shifts from “brown” (energy- and capital-intensive) activities to “green” sectors. Such a process often involves a degree of deindustrialisation, with redundant workers absorbed mainly by services ([Fullerton and Heutel, 2007](#)), which rank lower in the occupational structure ([Autor and Dorn, 2013](#)).

Second, we should observe shifts in demand patterns (including final and intermediate demand) as a logical consequence of policy-induced changes in the relative importance of polluting goods. This development should lead to net job creation in “green” sectors and net job destruction in “brown” ones, with inevitable consequences for the structure of employment.

Third, green policies can naturally affect growth. These changes in macroeconomic conditions have multiplier effects that affect employment and shape occupational structure ([Barker et al., 2016](#)). Typically, policies that integrate these packages change the fiscal balance of governments (e.g., carbon taxes). Governments have different ways of dealing with these imbalances (e.g., reducing different types of taxes or implementing spending plans), with inevitable effects on the demand for goods and services and, consequently, on the distribution of jobs.

Fourth, the interventions resulting from the ecological transition may well have an impact on international trade. Changes in production patterns and prices may affect countries in different ways, altering their relative competitiveness and hence labour demand ([Lanzi et al., 2013](#)). Such a channel is particularly relevant in the case of activities related to the export and import of fossil fuels.

Fifth, new “green” jobs may require specific skill sets, the availability of which may vary across countries ([Saussay et al., 2022](#);

<sup>5</sup> Their model only comprises five occupational categories, a much lower degree of detail than ours, which can accommodate until more than 2,000 different jobs, defined by any combination of 41 occupations and 63 economic activities. Their tool of analysis does not offer any disaggregation by country. At most, they can provide individual information for the big four EU countries (France, Germany, Italy and the United Kingdom), the rest of the OECD EU countries and the non-OECD EU countries. In any case, they only present the employment changes by occupation for OECD and non-OECD countries as a whole.

Vona et al., 2018). Last, the concrete set of compensatory policies adopted by governments to correct some the impacts outlines above play a substantial role (e.g., the use of government revenue raised from carbon taxes) (D'Alessandro et al., 2020; Fullerton and Metcalf, 2001; Fullerton, 2011).

This picture becomes even more complex when we consider that asymmetries in emission intensity and job type composition exist not only across sectors but also across countries. As a result, many qualified voices and ex-ante studies of the distributional consequences of the environmental transition consider that it is difficult to determine a priori the expected direction and intensity of the effects on inequality outcomes (Château et al., 2018; Fullerton, 2011; Ravigné et al., 2022; Vona, 2023). The final outcome of this type of macroeconomic ex-ante evaluation exercise is therefore essentially an open empirical question.

The final outcome of our quantitative exercise is also – and critically – context specific. First, it depends on the position of the shrinking and thriving industries within the occupational structure in each country. Even if these jobs were similar in terms of pay across Europe, the location of a particular job in each country would depend on the rest of the employment structure. Second, it has to do with the extent to which countries can take advantage of the opportunities offered by transition. The jobs potentially created may require a labour force with a certain level of skills.

Similarly, the carbon intensity and capital-labour ratio of the national industry, the electricity mix and the environmental policies adopted before the reference year will affect the outcome of decarbonisation. In this respect, it is reasonable to hypothesise that the higher the relevance of “brown” sectors in terms of employment, the more disruptive the impact of green growth policies on the occupational structure (regardless of the direction of the effects). Specifically, as workers' compensation in these activities tends to be relatively high, it is possible that reducing the weight of these sectors will reduce inequality and polarisation if their employment importance is high.

The rest of the paper is as follows. Section 2 describes the main features of the model and the tools employed for measuring ordinal inequality and polarisation. Section 3 presents and discusses the main findings. In Section 4, we draw several conclusions from the modelling exercise and summarise the main implications of our work.

## 2. Methodology

### 2.1. Modelling strategy

Our simulation of climate change mitigation policies draws on the skills forecasting model of the European Centre for the Development of Vocational Training (Cedefop in its French acronym) (Cedefop, 2009; Cedefop, 2012; Cedefop and Eurofound, 2018). The Cedefop model provides comprehensive projections on future trends in the labour market structure (Fig. 1). In its 2018 projections, among other outcomes, the model anticipates the number of jobs by occupation and sector of activity from 2015 to 2030. This forecasting exercise involves the use of the Energy-Environment-Economy Global Macro-Economic (E3ME) multi-sectoral macro-econometric model and six modules, forming the Cedefop Skills Forecast framework, to translate its results into implications for skills supply and demand (Cedefop, 2009).

Overall, the forecasting exercise draws on data from Eurostat, including population projections (with specific forecasts on migration and ageing), national accounts and the European Labour Force Survey (EU-LFS). Module 1 consists of the E3ME model, developed and maintained by Cambridge Econometrics, and allows forming projections of labour demand by industry and labour supply by demographic group. This model includes a demographic module for estimating active labour force by age group and gender from the effect of economic activity, real wage rates, unemployment and benefit rates on the working-age population stocks projected by Eurostat. Forecasting focuses on stocks and is composed of rather simple models that fit trends of aggregate

qualification patterns among population and/or labour force to provide more sophisticated econometric strategies based on the exploitation of individual-level data (mainly from the EU-LFS) (Cedefop, 2012).

The E3ME baseline 2015–2030 is calibrated to match a set of external projections for both economic and energy trends. That baseline is calibrated to the official European Commission projection used at the time of the analysis: the EU Reference Scenario 2016 (European Commission, 2016). This scenario focuses on the EU energy system, transport and greenhouse gas emission developments, given a certain level of economic development (i.e., population and GDP growth). The Reference Scenario acts as a benchmark of current policy and market trends.

The population and long-term GDP growth assumptions in the EU Reference scenario are consistent with the 2015 Ageing Report (European Commission, 2014b). In terms of energy and climate policies the EU Reference Scenario includes all policies and measures adopted at EU level and in the Member States by December 2014, as well as the amendments to three Directives agreed in the beginning of 2015 (European Parliament, 2015b,a). In order to calibrate E3ME the population, GDP, energy balances trends (i.e., growth rates) from the EU Reference Scenario are used to extend the E3ME historical data to 2030. In addition, the actual levels for carbon and energy prices from EU Reference Scenario are used directly in E3ME. Any policy analysis in the scenarios refers to the addition of new policies on top of those reflected explicitly or implicitly in the baseline.

Modules 2–7 are not full models in the sense of the E3ME model, and they use the EU-LFS microdata to estimate trends of changes in occupations within sectors or for qualifications. Modules 2, 3 and 4 cover the demand for skills. Their forecasting draws on fitting trends of aggregate qualification patterns among the population and labour force, combined with more sophisticated approaches based on econometric analyses of microdata on individuals (mainly using the EU-LFS). Modules 2 and 3 deals with employment levels and expansion demand for occupations (EDMOD) and qualifications (QMOD), respectively. The forecasting module designed to calculate changes in employment (expansion demand) by occupation (EDMOD) draws on trends of occupations within each industry derived from the EU-LFS microdata. Using econometric techniques, it estimates such trends by economic activity and applies them to the E3ME sectoral employment results. The estimation of employment by qualification level (QMOD) follows a similar approach.

The fourth module focuses on replacement demand (RMOD), job openings due to workers leaving a job because of retirement, migration or mortality. This module applies models and information on the probability of leaving employment (owing to retirement, migration or other reasons) to the output of the two previous modules to forecast job openings by qualification and by occupation. It uses population stocks to ascertain trends in the data, and its estimation of replacement demand draws on the stocks of age cohorts by occupation and qualification and excludes transitions from one occupation to another. In addition, the EU-LFS data that it uses allow us to analyse the demographic composition of each occupation and, consequently, specific rates of retirement for each occupational class. The data source also enables us to estimate flow rates between categories.

Modules 5 and 6 focus on the modelling of skills and analyse working-age population stocks and flows by the highest level of qualification held, respectively. The last module reconciles skills supply and demand, exploring the resulting imbalances. A group of individual country experts review and validate this model's results.

To explore the consequences of the ecological transition on inequality and polarisation in the labour market, we extend this framework in two ways. First, the E3ME model can project employment from 2015 to 2030 by occupation and sector of activity, so it is possible to integrate them within the jobs-based framework of the European Job Monitor (EJM). Developed by the Eurofound, the EJM provides a ranking of jobs – defined as combinations of occupations and industries

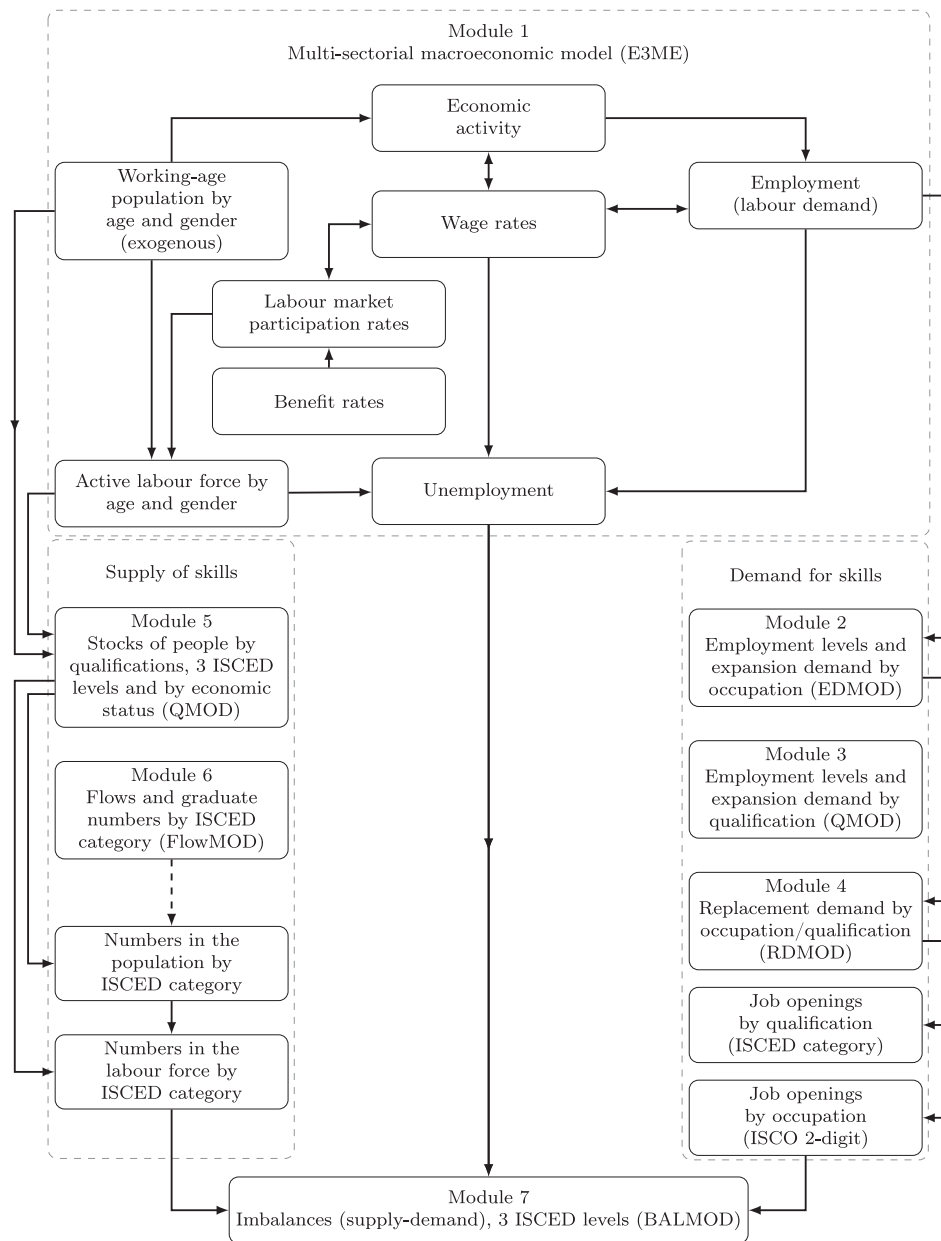


Fig. 1. Cedefop skills forecasting model.

Source: Authors' elaboration

–based on the mean hourly wage by country. It makes it possible to carry out an exhaustive assessment of employment changes across the earnings distribution. Second, we explore the consequences of policies aimed at holding the global average temperature below the 2 °C above pre-industrial levels, achieving the target set in the Paris Agreement (hereafter “the two-degree scenario”). (United Nations, 2015). The model solves annually from 2015 to 2030. However, 2018 is the first year when the scenario inputs are introduced (so it diverges from the baseline).

The E3ME model is widely used to evaluate the impact of climate and energy policy during two decades (Barker et al., 2007, 2016; Ekins et al., 2012; Foley et al., 2016; Mercure, 2012; Mercure et al., 2018b,a, 2019; Pollit et al., 2015). It represents one of the most advanced models of its kind since it allows for an integrated treatment of national economies, energy systems, emissions and material demands, capturing two-way linkages and feedback among these components and providing highly disaggregated results by country and industry

(Cambridge Econometrics, 2014). The model has some features of post-Keynesian inspiration since it does not assume that economies work at their full capacity (with not totally flexible prices and output determined by aggregate demand) and agents' behaviour does not come from optimisation under perfect information but from parameters estimated from macro-econometric analyses of historical time series.<sup>6</sup>

The two-degree scenario consists of achieving a level of global CO<sub>2</sub> emissions in 2030 associated with a 66% probability of limiting the temperature increase to below the two-degree target (IPCC, 2014), which requires stronger climate change mitigation policies and a different technological trajectory than those currently in place.<sup>7</sup> Such a

<sup>6</sup> See Pollit et al. (2015) for a thorough comparison between CGE models and this sort of strategy in this area of research.

<sup>7</sup> The Nationally Determined Contributions of the states, including the 40% reduction in CO<sub>2</sub> emissions committed by the EU, are not enough for achieving this target.

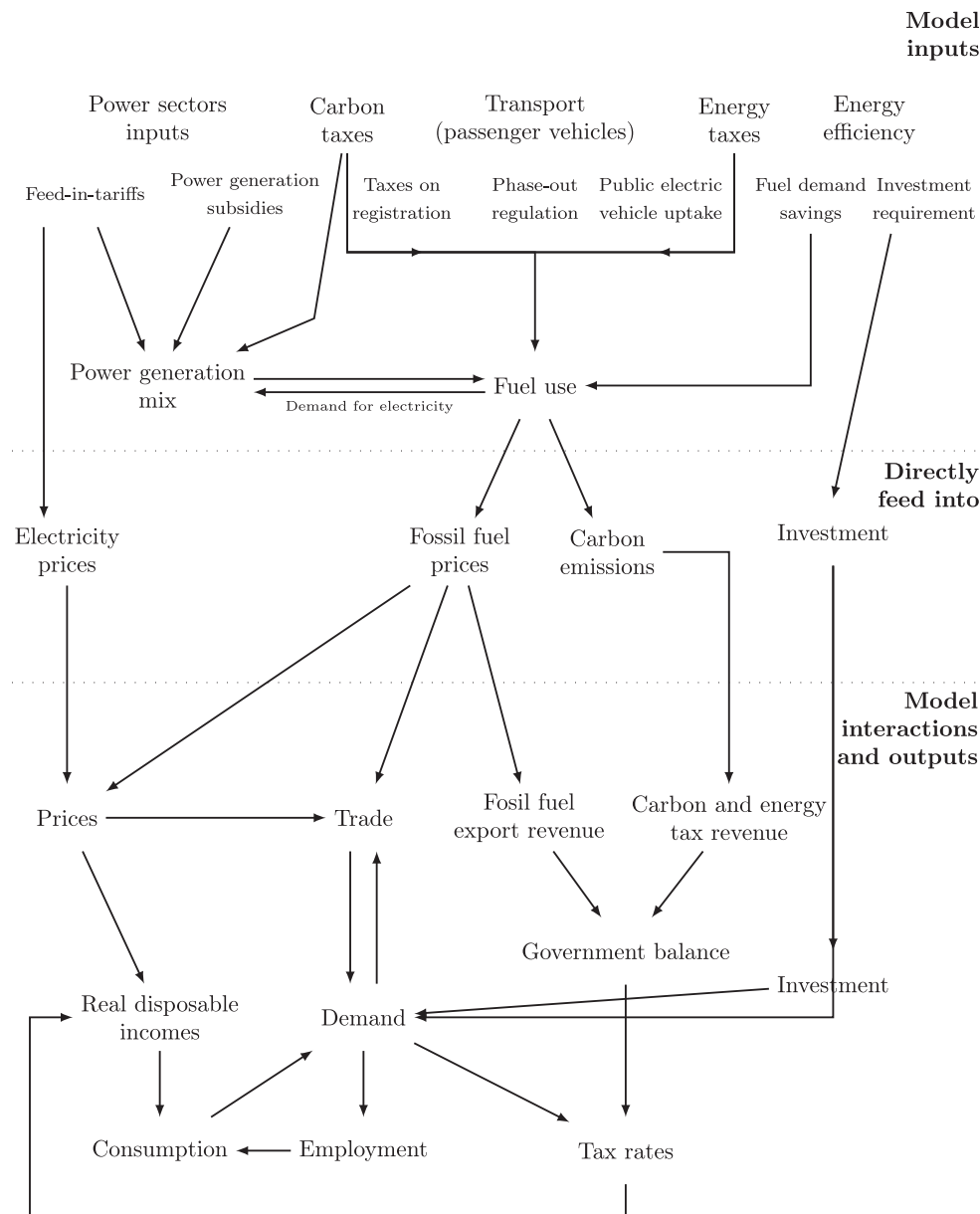


Fig. 2. Model inputs and links. Source: Authors' elaboration

policy scenario includes some carbon pricing mechanisms already in place (e.g., the EU Emissions Trading System) as well as continued support for renewables and energy efficiency, an expansion of carbon pricing and a partial removal of fossil fuel subsidies.<sup>8</sup> The E3ME is a suitable tool for simulating the impact of these kinds of policies

<sup>8</sup> The implementation of fossil fuel subsidy removal can be understood as an energy tax in the E3ME modelling. With the subsidy the household/industry pays a reduced price in terms of euro/toe, so its removal would lead to a higher final energy price which in the model is introduced as tax of euro/toe. The partial removal refers to a gradual phase-out, with developing countries taking longer to phase out their subsidies compared to developed ones. This is to allow households/industry more time to adjust and be able to switch to alternative fuel sources. The information on fossil fuel subsidies comes from the International Energy Agency (IEA) Fossil Fuel database (IEA, 2022), which offers information on fossil fuel subsidies by country and energy carrier. This information, together with the energy balances is used to calculate the subsidy value per toe which then is introduced as an energy tax in the model. The

because it computes energy demand by sector and fuel type. Overall, this scenario targets those sectors that produce the most CO<sub>2</sub> emissions – electricity generation and road transport – and tries to reduce any use of fuel with a high content of carbon.

The implementation of this strategy in the model develops in an iterative way, with the establishment of additional measures until achieving the two-degree target. Specifically, the model in this scenario deploys the following policies:<sup>9</sup>

interaction mechanism is then the same as for any other energy tax (higher energy prices leading to reduction in fuel use and fuel switching).

<sup>9</sup> This range of measures applies to the 59 global regions covered by the E3ME model, although some countries (e.g., China, Russia, Ukraine and some states from Latin American and the Association of Southeast Asian Nations) demand further regulations to reduce the use of coal outside the power generation sector.

- A carbon emission price of \$155 in constant 2012 values in 2050 per ton of CO<sub>2</sub>. This carbon price is set globally but is applied at a national level through cap-and-trade systems and/or carbon taxes.<sup>10</sup>
- Public programmes, funded by the revenue from carbon pricing, to improve the energy efficiency in households, industry and commerce consistent with the recommendation of the IEA (2016).<sup>11</sup>
- A biofuel mandate applied to aviation with the effect that about 18% of fuel in this sector will come from biofuel by 2050.
- Power generation policies aimed at promoting renewables, particularly wind and solar power, that comprise feed-in tariffs (which guarantee the price received by producers) and direct subsidies decreasing over time (around 10%–15% of the additional investment costs and up to 60% in some circumstances).<sup>12</sup>
- Road transport policies for promoting the shift to low-carbon vehicles that include a proportional tax on vehicles depending on carbon emissions per kilometre, higher road fuel taxes, regulation after 2018 to phase out the least fuel-efficient vehicles, limitation after 2020 of high-polluting luxury vehicles in some countries, electrification of the public vehicle fleet (as a way of fostering charging facilities), setting higher emissions standards for new cars after 2018 and a biofuel mandate in several countries to reach the emissions reduction target.<sup>13</sup>

The E3ME model incorporates all of these policies through its inputs, as Fig. 2 illustrates. The seven policies detailed above unfold on power sector inputs, carbon taxes, transport, energy taxes and energy efficiency. They induce a decline in the demand for coal, oil and gas, lowering the global prices of fuel and reducing carbon emissions. The model allows for feedback between energy prices, carbon revenue

<sup>10</sup> This figure is towards the lower end of the range considered in the Fifth Assessment Report. (IPCC, 2014). The design of the package of measures is such that it allows reaching the two-degree target. Obviously, one could have set a higher carbon price. Nevertheless, the modelling indicates that such a policy is ineffective compared to other cheaper alternatives and would imply a quite substantial increase in the living costs of low-income individuals, making it politically infeasible. The carbon price level and evolution over time are consistent with the *World Energy Outlook 2018 Sustainable Development Scenario* (IEA, 2018) and covers the power sector, industry and aviation. The *World Energy Outlook 2018 Sustainable Development Scenario* only provides a carbon price for 2025 and 2040, so the values in-between are interpolated. After 2040 the values are extrapolated to 2050. For countries that already have carbon pricing in the baseline (e.g., EU-ETS) the price is increased gradually until it reaches the global price level in 2025. For countries that currently do not have one, it is introduced from 2018 onwards.

<sup>11</sup> These programmes are implicit in some of the assumptions we bring in. The public action also unfolds through the financing assumption, with the government covering the cost of the energy efficiency investment (by using the extra carbon revenues and other sources).

<sup>12</sup> The subsidies and feed-in-tariffs are introduced as a proportion of investment requirement and electricity price, respectively. The implementation of these measures across countries depends on the current market structure and suitability for deployment of alternative technologies. The subsidies represent a proportion of the capital cost investors need to build the power plants. In the modelling, we assume that investors recover their capital cost via electricity prices over the lifetime of the plant they have built. The feed-in-tariffs act as a price guarantee to investors, making it more competitive for a specific type of plant (e.g., solar) to be built. Both the subsidies supporting investment and the feed-in-tariffs act as support for a new technology to establish market presence by removing some of the risks investors perceive.

<sup>13</sup> Transport-specific interventions were required in some countries as the technology was not at all on the market and further incentives were needed to encourage some deployment. While electric vehicles are specifically encouraged (2030 is too short of a horizon for hydrogen-powered vehicles), both the energy and carbon pricing would encourage efficiency in the model based on estimated parameters.

and investment, affecting real disposable incomes and consumption expenditure.

Power sector inputs (feed-in tariffs and subsidies) foster a shift of the power generation mix towards renewables, leading, at least initially, to an increase in electricity prices unless greater degrees of adoption of this technology result in cost reductions. This composition change leads to a decrease in the demand for conventional fuel, with an impact on electricity prices.

Carbon taxes drive the price of carbon-intensive fuel up, which lowers their demand and affects the power generation mix. The transport sector interventions described above, which favours the uptake of more efficient or electric vehicles, reduce the demand for petrol and diesel by road transport in favour of electricity.

The target of publicly funded energy efficiency policies (e.g., better household insulation and more efficient appliances) is to diminish the demand for fuel. This scenario is neutral in terms of the fiscal budget balance in all countries through adjustments in the income tax, the value added tax and social security contributions when needed. If the revenue raised by carbon pricing measures do not cover the whole cost of those policies, the model allows the governments to use the mentioned tools to fill such a gap. If the resources collected exceed investment costs, the E3ME model assumes the usage of the surplus in reducing taxes.

The investment in energy efficiency and the electricity supply sector stimulates the demand for domestic and foreign goods and services, raising production, employment, disposable income and consumption expenditure.<sup>14</sup> Conversely, large fossil-fuel-exporting countries might require tax hikes to compensate for the loss of fiscal resources. The model allows price changes to affect differently the countries' competitiveness – thus impacting the demand for its production – and the outcome of carbon taxation translates into tax rate changes that, in turn, alter consumer spending and the demand for goods and services.<sup>15</sup>

The overall effect of this set of policies is complex, with different implications from country to country. On the one hand, one expects that the higher investment associated with renewable technologies and energy efficiency will foster economic growth when countries produce the capital goods associated with this strategy domestically (and no stimuli if the economy must import them). On the other hand, these measures are very likely to drive energy prices up, with a negative impact on consumer disposable income and external competitiveness. This probably leads to a decrease in the demand for fossil fuels, inducing a reduction in both the extraction- and processing-associated activities and their global demand. Given that the EU – plus the UK – represents a net importer of fossil fuels, the overall impact of this change on GDP and employment might end up being positive. Nevertheless, non-negligible differences can exist across states depending on their economic structures.

## 2.2. Inequality and polarisation measurement

The key output provided by the model outlined above consists of a large matrix comprising the distribution of employment across 41

<sup>14</sup> Note that the E3ME considers direct, indirect and economy-wide rebounds effects, i.e., the decrease in savings due to efficiency measures because of the reduction in energy prices (Colmenares et al., 2020).

<sup>15</sup> Carbon pricing results in a reshuffling of the energy sector mix, which lead to shifts in domestic energy prices in the modelling. Global commodity prices for fossil fuel (coal, oil and gas) do change in the model based on global demand and built-in cost supply curves. The reduction in both fossil fuel prices and demand means that fossil fuel exporting countries face a loss of revenues. If they are going to maintain current expenditure patterns, they would need alternative sources of income (e.g., increase taxes in the economy elsewhere, likely on top of the carbon pricing).

occupations and 63 industries by each EU country.<sup>16</sup> In this context, as mentioned above, the definition of a job corresponds to a combination of an occupation and an economic activity, which results in almost 2600 potential categories. This number is much smaller in practice as many occupations only exist in certain industries. Since the model does not provide earnings, the next step is to order this set of jobs according to an ordinal wage ranking built by the Eurofound (2021) for the year 2015 that draws on several EU-level databases.<sup>17</sup>

As a result, the main output of interest in terms of labour market structure consists of a distribution of employment across such an ordinal ranking.<sup>18</sup> There is a large body of literature in Economics and Sociology using this type of approach, with slight variations, to monitor middle- and long-term changes in job quality (see, among many others, Autor et al. 2003, Fernández-Macías 2012, Goos and Manning 2007 and Oesch and Rodríguez Menés 2011). Within this framework, the relative position of a job in the ranking serves as a proxy for its quality.<sup>19</sup>

The translation of the measures due to the transition to a low-carbon economy into consequences on the occupational structure will depend on the countries' sectoral composition and on the position of the jobs affected by the climate change mitigation policies across the wage distribution. Apart from the pay-based order, the Eurofound database also provides two additional rankings that we use to assess the robustness of the main results. The first one considers the average educational level by cell, and the second relies on a non-pecuniary job quality index based on 38 variables that capture the amenities in different dimensions of work (Eurofound, 2013).

As argued by Jenkins (2021), it is inappropriate to use tools developed for measuring cardinal inequality and polarisation to analyse data of this nature. Therefore, to evaluate the labour market implications of the measures adopted to achieve the two-degree target, we draw on measures of ordinal inequality and polarisation proposed in the welfare economics literature. Intuitively, whereas inequality pertains to the existence of differences in the distribution of variables within a group of individuals (any departure from a situation where two or more given quantities are the same size) (Cowell, 2011), polarisation, widely associated with conflict by the specialised literature, refers to the degree of clustering of a population into groups, where each one is very "dissimilar" in terms of its members' attributes but where different clusters comprise members with very "similar" attributes (Esteban and Ray, 1994). Specifically, bipolarisation concerns the reduction of the middle class (Wolfson, 1994; Foster and Wolfson, 2010). Although the economics literature has used them interchangeably in the past – particularly in informal settings – they represent distinct phenomena.<sup>20</sup> Regarding the interest of using polarisation measures here, it is noteworthy that a large body of research links polarisation to conflict

<sup>16</sup> The taxonomies of occupations and sectors of activity consist of a slightly aggregated version of the International Standard Classification of Occupations 2008 and the Statistical classification of economic activities in the European Community Revision 2 at the two-digit level.

<sup>17</sup> See Eurofound (2019a) for details on the ranking's construction.

<sup>18</sup> The ranking built by Eurofound is only available for the year 2015 and is ordinal (rather than cardinal) because of data limitations. Even though the ranking contained labour income, it would be unappealing to use it in a cardinal way to study earnings inequality and polarisation. One would need to assume that the whole earnings distribution across jobs remains the same over the whole period considered in the analysis. It is much less likely that this assumption holds than that the ordinal ranking does not change. Furthermore, as mentioned above, non-negligible strand of literature the focus here is on the structure of the labour market, which pertains to where job creation and destruction occurs.

<sup>19</sup> Apart from being quite popular in this body of literature, it is worth mentioning the positive correlation between pay and non-monetary job amenities and the lower dispersion of the latter compared to the former (Muñoz de Bustillo et al., 2011).

<sup>20</sup> The pioneering works of Esteban and Ray (1994) and Wolfson (1994) present extremely useful and intuitive examples where decreasing inequality

(Esteban and Ray, 1994; Esteban and Schneider, 2008; Esteban and Ray, 2011) and previous research has also established the relevance of potential social problems due to climate change mitigation policies (Douenne and Fabre, 2020; Sælen and Aasen, 2023).

The indicator of inequality employed here comes from Cowell and Flachaire (2017), whereas we select the polarisation index proposed by Apouey (2007). These two measures allow us to compare distributions whose medians might differ (Jenkins, 2020; Sarkar and Santra, 2020), as is the case of the job distributions in 2015 and 2030 under two different scenarios that represent the inputs of the analysis. Specifically, the indicator of inequality we employ hereafter is as follows (Cowell and Flachaire, 2017):

$$I(\alpha) = \begin{cases} \frac{1}{\alpha(\alpha-1)} \left( \frac{1}{N} \sum_{i=1}^N s_i^\alpha - 1 \right), & \text{if } 0 < \alpha < 1 \\ -\frac{1}{N} \sum_{i=1}^N \log s_i, & \text{if } \alpha = 0, \end{cases} \quad (1)$$

where  $s_i$  is the share of population/sample with a job ranked less than or equal to individual  $i$ ,  $N$  denotes the population/sample size and  $0 \leq \alpha < 1$  is a parameter that captures the sensitivity of the inequality index  $I(\alpha)$  to different parts of the distribution. The larger the  $\alpha$ , the smaller the weight put on high-ranked jobs relative to low-ranked ones.

The study of polarisation in the context of occupational structure has certainly not fulfilled very high formal standards when compared to the developments in Public Economics. This literature has tried to determine whether there is a relative decline of jobs in the middle of the wage distribution relative to the top and the bottom. In contrast with the literature discussed above, this strand of works often employs the term polarisation interchangeably with inequality. The assessment of polarisation, expressed in a vague and informal way, has relied on verifying the existence of a U-shaped relationship between the observed employment change and the job rank – by including a quadratic polynomial in the rank variable in a linear regression and focusing on the estimated coefficient of the second-order term – and the graphical visualisation of the patterns of employment growth across the job distribution using a certain number of quantiles (see, among many others, Goos and Manning 2007 and Fernández-Macías 2012).

These approaches neither discuss nor state explicitly their value judgements and, at best, only allow one to determine whether there is a change in the polarisation of labour market structure since they do not put a number on this phenomenon. Nevertheless, building on the pioneering contributions of Esteban and Ray (1994) and Foster and Wolfson (2010), several solid proposals for measures of ordinal polarisation has emerged in the public economics field (see, e.g., Jenkins 2021 or Sarkar and Santra 2020 for a review). However, just some few of these indexes allow for comparisons between distributions with different medians (the key statistic when exploring ordinal inequality and polarisation), a circumstance very likely to be present in the type of data explored here.

Therefore, our analysis relies on one of the indexes that is suitable for this task, the  $P_2(e)$  polarisation index, proposed by Apouey (2007) and expressed as follows:

$$P_2(e) = 1 - \frac{2^e}{K-1} \sum_{k=1}^{K-1} \left| F_k - \frac{1}{2} \right|^e, \quad (2)$$

where  $F_k$  represents the proportion of individuals allocated in category  $k$  or lower,  $K$ ; the total number of classes; and  $e$  is a parameter that determines how concentration within the groups below the median and within the categories above the median contributes to polarisation.

can lead to an increase in polarisation. Using the Gini index (the most popular inequality measure), Foster and Wolfson (2010) show that inequality and polarisation move together when inequality between groups increases and they evolve in opposite directions when within-group inequality widens.

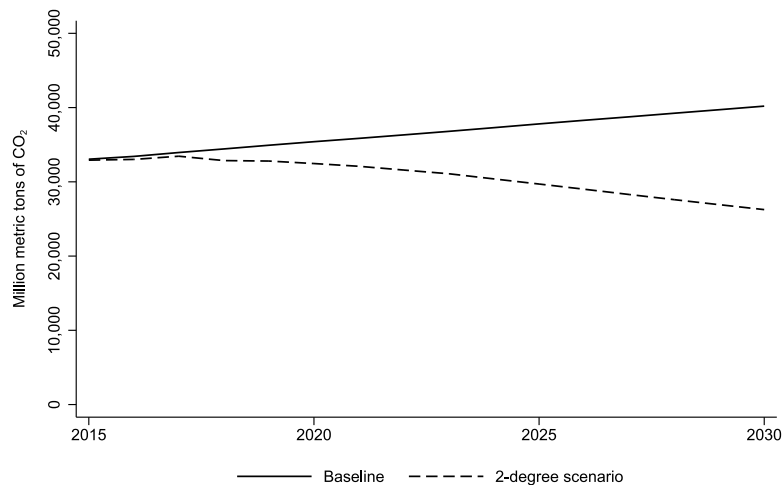


Fig. 3. Global CO<sub>2</sub> emissions (million metric tons, 2015–2030).  
Source: Authors' analysis

For instance, the index aggregates the distances between  $F_k$  and 0.5, employing the square root of absolute distances if  $e = 0.5$ , a linear distance function under  $e = 1$  or a Euclidean distance metric if  $e = 2$  (Jenkins, 2020). As in the case of our indicator of ordinal inequality, the calculation of this measure just requires the proportion of the population in each job cell.

### 3. Results

The deployment of the measures for curbing global warming described above results in a reduction of more than a third of CO<sub>2</sub> by 2030 compared to the business-as-usual scenario (Fig. 3), in line with previous research such as IEA (2016), Mitchell et al. (2016) and Peters (2016). Table 1 shows that the EU decreases its carbon emission level by more than 20% compared to the baseline, a less marked decline than the one required for China, India or the US, which are more dependent on fossil fuels.<sup>21</sup> The higher level of investment necessary to transform the electricity generation sector and energy efficiency measures results in a GDP and employment that is 0.5 and 1.1%, respectively, higher than in the baseline scenario. This outcome is much more positive than, for instance, in the US, harmed by the decline of oil and gas production, and smaller than the one in China or India, who have a longer way to walk in terms of embracing – and a larger potential of profiting from – renewable energy technologies.

This positive, modest impact is not at odds with most of the other forecasts addressing the social dimension of the ecological transition in the specialised literature (García-García et al., 2020) and in line with those reported by models comprising elements of Keynesian inspiration (IPCC, 2022), such as Bulavskaya and Reynès (2018), Landaa Rivera et al. (2016) or the E3ME itself. The latter kinds of methodological approaches tend to yield more positive scenarios than others (e.g., CGE ones) since the investment required for mitigation boosts GDP rather than partially crowding out productive investment elsewhere.<sup>22</sup>

Fig. 4 summarises the impact of these policies on GDP and employment in the EU by country. Unsurprisingly, in line with previous

<sup>21</sup> We show the evolution of CO<sub>2</sub> emissions over the period of analysis relative to the baseline scenario in Figure S1 in Supplementary Appendix A. The impact on the transport sector occurs in two main ways: the production of alternatively-powered vehicles and the addition of these vehicles to the fleet. We assume that car manufacturing capacity is maintained within the EU (e.g. if they were able to manufacture conventional vehicles, they would be able to switch to production of electric vehicles—so there would be no large shifts in market shares). However, the switch to electric vehicles means more use of

Table 1

CO<sub>2</sub> emissions, GDP, consumption, investment and employment in 2030 (% change over the baseline).

Source: Authors' analysis.

	Global	United States	China	India	European Union plus the United Kingdom
CO <sub>2</sub>	−34.7	−45.5	−26.5	−53.2	−20.3
GDP	0.1	−3.4	4.7	0.6	1.1
Consumption	0.4	−2.0	11.2	−1.1	0.7
Investment	1.0	−2.5	3.2	1.1	1.7
Employment	0.5	−1.6	2.3	0.1	0.5

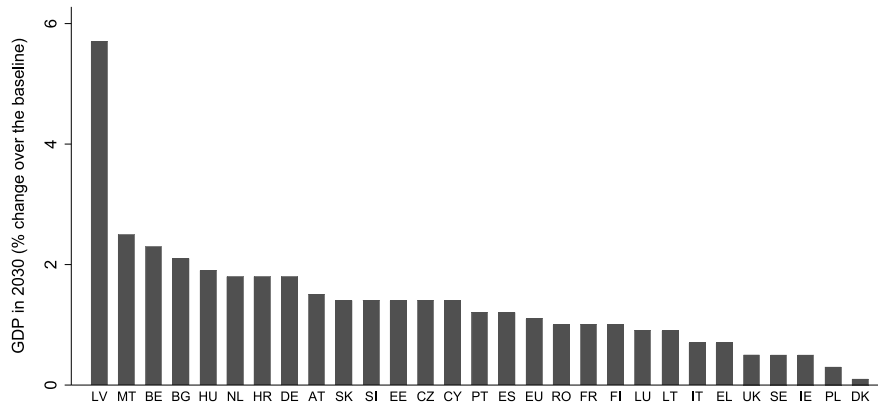
literature, the macroeconomic implications of the ecological transition varies across EU member states. As argued above, the effect on output responds to the investment associated with decarbonisation and energy efficiency measures and a lower dependence on fossil fuel imports and their reduced prices. In this line, Latvia experiences the largest economic boost in the EU given its lag in these sorts of policies and the relevance of fossil fuel imports in 2015. On the opposite side of the spectrum, the Danish case exemplifies that the potential gain is lower in the most advanced countries in the ecological transition – the level of investment required to meet the decarbonisation target is smaller – but also suggests a more modest effect in those national economies where coal production still plays a non-negligible role, such as Poland or, to a much lower extent, Romania.

The effects on employment are of a smaller scale and are coherent in most of the cases with the output impact. Nevertheless, there are non-negligible deviations in some countries. The positive evolution of job creation in Spain is due to the decrease in energy prices – driven by the development of the photovoltaic sector – that fosters household incomes and thus the demand for consumer services, largely labour intensive. In Latvia, the large GDP rise mainly accrues to the much less labour-intensive equipment supply firms. Last, decarbonisation in Cyprus results in energy price increases, which negatively

charging points rather than specific petrol stations, so retail activity (where these are located) would be expected to decline as a result.

<sup>22</sup> Nevertheless, it is noteworthy that the results in terms of aggregate output and employment are very similar to those obtained by Château et al. (2018). For reasons of brevity, a detailed comparison of the aggregate results of our modelling with other studies is beyond the scope of this work.

(a) % change in GDP over the baseline



(b) % change in employment over the baseline

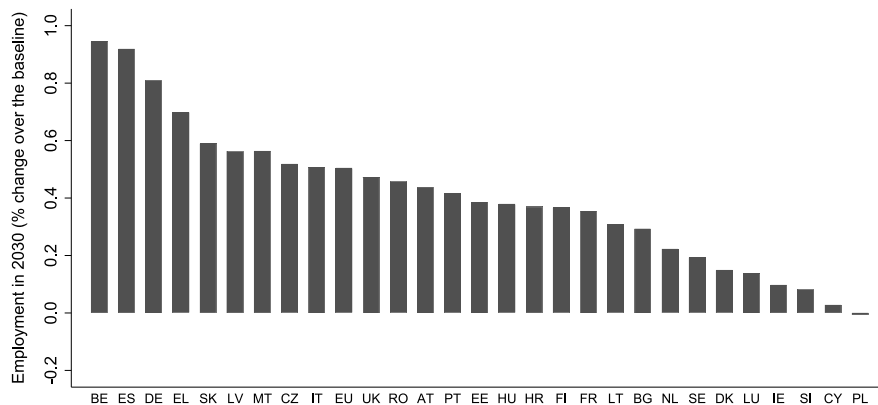


Fig. 4. GDP and employment in the EU in 2030 (% change over the baseline).  
Source: Authors' analysis

affects consumer expenditure (which tend to trigger the demand for labour-intensive goods and services) and external competitiveness.<sup>23</sup>

Fig. 5 shows the impact of the transition to a low-carbon economy on employment by sector of activity and occupation in the EU as a whole. The industries concentrating the job losses are mining and quarrying and utilities (and a more fine assessment reveals that the closely related activities like manufacturing of coke and refined petroleum products also exhibits a negative evolution). The behaviour of employment in the former sectors reflects the shrinkage of extraction activities, whereas job creation in the latter suffers from the energy efficiency measures that reduce the demand for gas.

It is worth commenting on the higher volume of jobs in the construction sector, which benefits from the modernisation enhanced by energy efficiency measures and the building of renewable plants. Although many parts of the economy enjoy a demand boost because of the growth in consumer expenditure, sub-sectors of manufacturing and business services also profit in terms of employment from being part of the supply chain of construction, renewables and energy efficiency equipment. The outcome in terms of occupation is much less appealing since the differences with the baseline are remarkably small. The most salient finding is the slightly above-average positive impact reported among craft and related trade workers that reflects the boosted production of

<sup>23</sup> We summarise the most salient findings of the aggregate impacts of the whole package of climate change mitigation policies, those that stand out from the average behaviour, in Supplementary Appendix A.

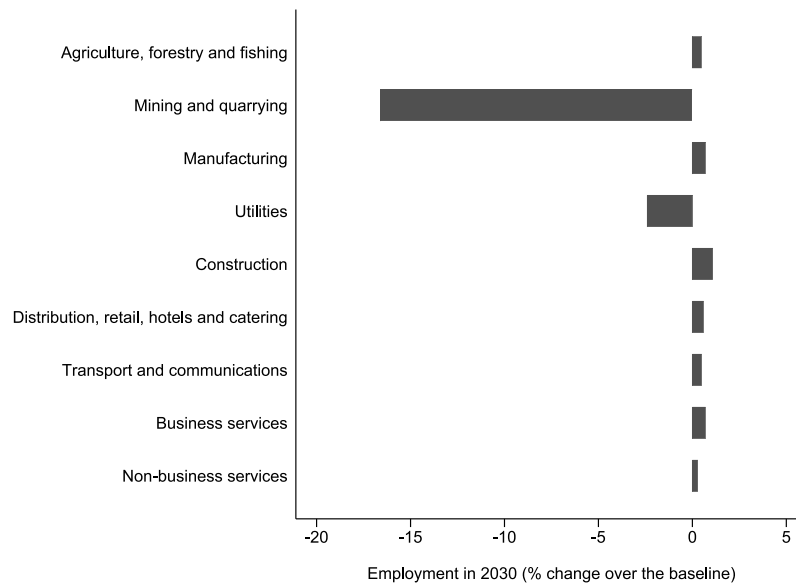
investment goods. In Supplementary Appendix A, we present the same information by country using broad group occupational and sectoral categories (Table S1) and the top 10 occupation and industries at a very disaggregate level with the highest and lowest growth in the EU (Table S2).

Using locally weighted scatterplot smoothing (Cleveland, 1979; Cleveland and Devlin, 1988), we show the pattern of job creation and destruction across the occupational structure by country as a consequence of the climate change mitigation policies (Fig. 6). This allows us to observe whether jobs created and destroyed in net terms belong to the lower or the upper tail of the distribution; i.e., they are good or bad ones. Not only do we find remarkable differences in the scope of the changes in employment, as shown above, but there is also a wide diversity in the way that the transition to a low-carbon economy shapes the labour market. Whereas employment change decreases across the wage distribution in countries like Austria, Belgium, Bulgaria, Finland, Poland, Slovakia, Sweden and the United Kingdom, other countries like Malta, the Netherlands and Slovenia exhibit an increasing pattern.

The figure also shows a roughly uniform pattern in Germany, France, Ireland, Luxembourg and Portugal. We observe also cases where the change follows a U-shaped (Croatia and Cyprus) or an inverted U-shaped pattern (Denmark, Estonia, Greece, Italy, Lithuania and Spain). The evolution in some states (like Czechia, Hungary or Luxembourg) is not easy to characterise just through eyeballing.

Therefore, the use of tools for measuring ordinal inequality and polarisation becomes particularly attractive considering the limited

(a) % change in employment by sector of activity over the baseline



(b) % change in employment by occupation over the baseline

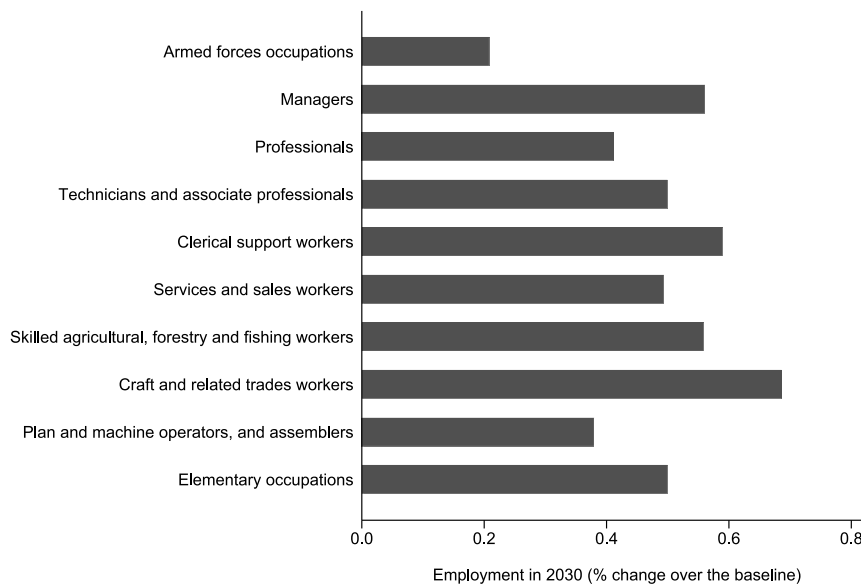


Fig. 5. Employment by sector of activity and occupation in 2030 (% change over the baseline)  
 Source: Authors' analysis

magnitude of the changes, the existence of such diverse – and not-as-easy-to interpret – national profiles and the appeal of comparing across countries. One should also bear in mind that the impact of those changes on these magnitudes depends not only on where job creation and destruction occur but also on the initial distribution of workers across jobs.

The application of such types of measures (Fig. 7), described in Section 2.2, confirms the reduced size of the effect of the policies associated with achieving the two-degree target on ordinal polarisation and particularly on ordinal inequality. Decarbonisation seems to raise inequality in the labour market for Estonia, Slovenia, Hungary, Lithuania, Sweden, Portugal, Italy, Spain, France, Greece and Romania and seems to augment polarisation in Croatia, Austria, the Netherlands, Sweden, Denmark, Luxembourg, France, the United Kingdom, Czechia and Belgium. Interestingly, the EU as a whole experiences a decrease in

the levels of ordinal inequality and polarisation. The existence of a far from perfect, though remarkable, correlation between the variation in both indicators (the Pearson correlation coefficient,  $\rho$ , equals 0.33) and the change in the position of many countries depending on the measure considered indicates that one stands in front of different phenomena. This issue is worth mentioning given that the terms (inequality and polarisation) are (imprecisely) used interchangeably in some of the labour market literature.

Since the model includes a wide set of mechanisms of linkages and each national economy possesses its own peculiarities within industries (e.g., different intensities in the use of fossil fuels), it is inherently quite difficult to determine the drivers of these outcomes. Nevertheless, several findings arise. The first one is that the larger the share of employment in the most affected sectors (mining and quarrying, utilities and manufacturing of coke and refined petroleum) in the baseline, the

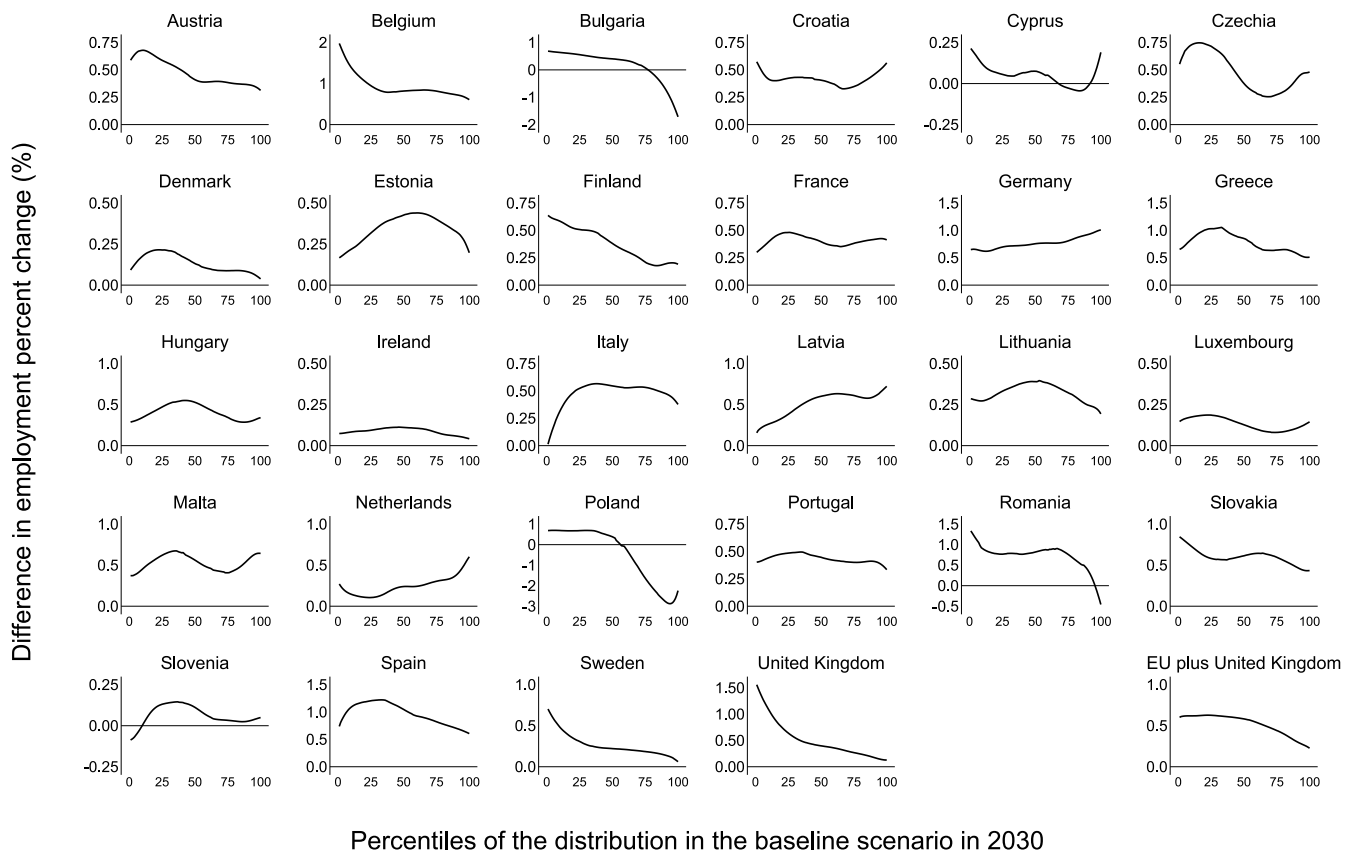


Fig. 6. Changes in employment across the occupational structure by country in 2030 (% change over the baseline).

Note: Locally weighted scatterplot smoothing with a bandwidth of 0.75.

Source: Authors' analysis

lower the increase in ordinal inequality and polarisation ( $\rho = -0.31$  and  $-0.49$ , respectively). There are not so large differences in the position of the jobs associated with these activities across the labour market structure in the baseline: they are mainly concentrated in the upper part of the earnings distribution (see Figure S2 in Supplementary Appendix A). However, whereas the proportion of employment in these industries located in the top quintile of the job structure exhibits a weak correlation with inequality ( $\rho = -0.02$ ), the relationship with the evolution of polarisation seems stronger ( $\rho = -0.19$ ).<sup>24</sup>

There are cases that do not fit this pattern, like Romania – which, unlike the Bulgarian or Polish economy, the most affected sectors also mean more than 3% of total employment – where the job decline observed in these industries is less marked ( $-2.8\%$  change in the former compared to more than  $-10$  and almost  $-8\%$  in the latter countries).<sup>25</sup> There is actually a positive correlation between the change in employment in those industries and the variation in ordinal inequality and polarisation ( $\rho = 0.53$  and  $0.51$ , respectively).

These results are unsurprising and are in line with our discussion on the expected effects of climate policy mitigation measures in the introduction. As hypothesised there, first, we do not find a uniform pattern of results. This heterogeneity of outcomes highlights how much context-specific the occupational outcomes of the ecological transition can be. Second, as argued above, we find that the relevance of mining

<sup>24</sup> The initial proportion of employment in these sectors in the middle tercile of the distribution only shows a weak relationship with both inequality and polarisation ( $\rho = -0.01$  and  $-0.08$ , respectively).

<sup>25</sup> Nevertheless, in the case of Romania, mining and quarrying activities are much more diversified than in other Eastern European countries where this sector has a relevant employment weight. Particularly, they go much beyond the extraction of coal and gas.

and quarrying activities, largely placed at the top of the job ranking, is highly negatively correlated with the change in both inequality and polarisation.

To assess the stability of the results presented above, we perform two types of robustness checks. The first one refers to the specification of different values for the parameters embedded in the indexes of ordinal inequality and polarisation that capture the sensitivity to inequality in different parts of the distribution ( $\alpha$ ) and how concentration within the groups below and above the median contributes to polarisation ( $e$ ), respectively. The evolution of both magnitudes remains basically unchanged when varying the values for the mentioned parameters (Table B3).

The second sensitivity analysis consists of evaluating how the main results in terms of inequality and polarisation vary when using an alternative measure of job quality. With that purpose, we redo the previous calculations and consider a job ranking based on the mean educational level and the mean value of an index of non-monetary job amenities by cell. Reassuringly, the main results seem to hold in both qualitative and quantitative terms (Tables B4 and B5).

#### 4. Conclusions

While EU citizens and international organisations have expressed a large and growing concern over both climate change and economic disparities, our knowledge on the impact of policies intending to curb global warming on labour market outcomes is still limited. This paper attempts to fill this gap by studying the impact of climate change mitigation policies intended to reach the two-degree target set in the Paris Agreement on the structure of European labour markets. Using a three-sector macro-econometric model linked to a rich set of labour market modules and equipped with new inequality and polarisation

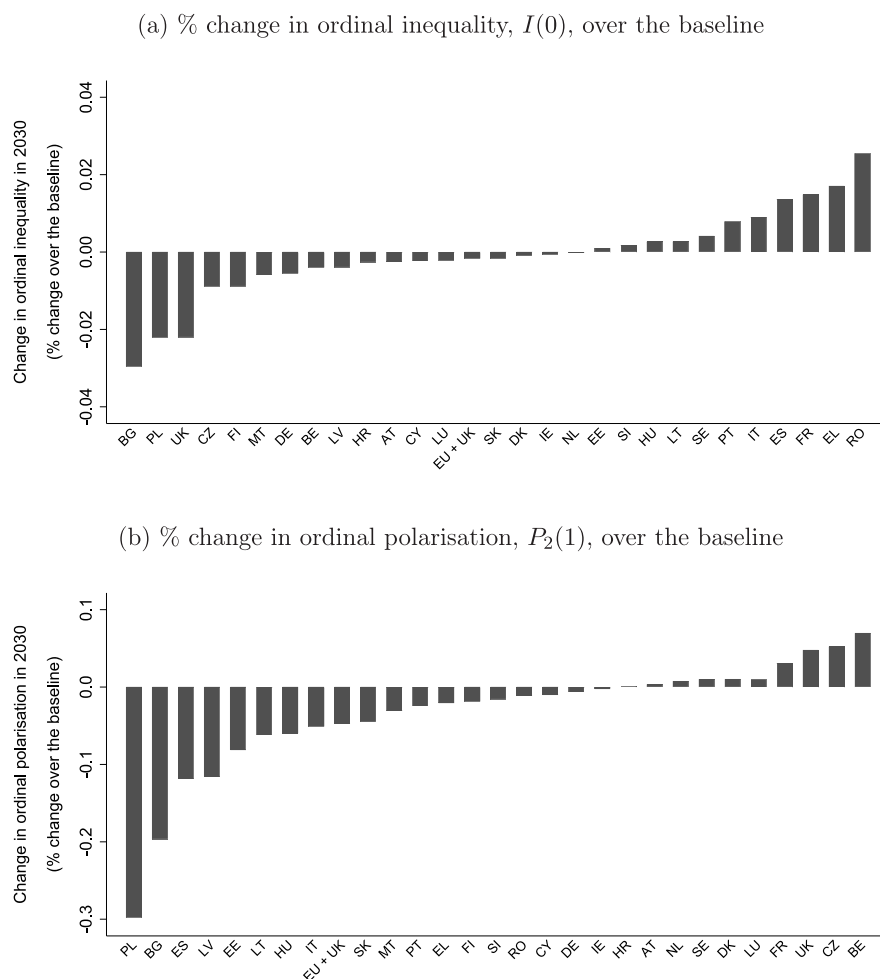


Fig. 7. Change in inequality and polarisation in 2030 (% change over the baseline)  
Source: Authors' analysis

measures, we find that the effects of these policies is overall modest and should not represent a wide source of concern.

We also find that the EU-wide impact on both GDP and employment is positive and these actions slightly reduce inequality and polarisation in employment. Nevertheless, the outcomes remarkably differ by country. They mainly depend on the economic structures of national economies and their current levels of progress towards low-carbon ones. Overall, those countries most affected by the shrinking of industries associated with the production of fossil fuels would also profit from the largest declines in ordinal inequality and polarisation in their labour markets. These findings are robust to a wide series of robustness checks regarding the value judgements embedded in the measurement indexes of these magnitudes and the method of ranking jobs within domestic labour markets.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

The authors do not have permission to share data.

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#### Appendix A. Supplementary data

Supplementary material related to this article can be found online at <http://doi.org/10.1016/j.ecolecon.2023.108022>.

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