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# The Possible Implications of the Green Transition for the EU Labour Market

Anneleen Vandeplas, Istvan Vanyolos, Mauro Vigani and Lukas Vogel

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# The Possible Implications of the Green Transition for the EU Labour Market

Anneleen Vandeplas, Istvan Vanyolos, Mauro Vigani and Lukas Vogel

## Abstract

With policy ambitions at an all-time high, the green transition is set to accelerate over the next decade and trigger significant structural change in EU labour markets. While aggregate employment impacts of the green transition may remain contained, shifts are likely to occur between sectors, firms, occupations, and regions. This calls for policymakers to anticipate and address the distributional risks of climate policy. Three types of jobs ('green', 'white' and 'brown') are distinguished that would be differently affected. Brown jobs would be most negatively affected. While on aggregate, their share is relatively small, impacts may be concentrated in sectors and regions. As the ease of labour reallocation will crucially depend on the similarity of location and skills of the jobs that are newly created, demographic characteristics of workers in brown sectors are discussed. It is argued that with the right policy support, transition costs can be mitigated, particularly at the current juncture, where labour markets are tight. At the same time, regional socio-economic specificities need to be accounted for. Policy action should focus on providing inclusive social protection, education and training, individualised re-employment support, temporary job subsidies, and effective regional development policy. Acting in anticipation can improve policy effectiveness. Lessons should be drawn from past structural transformations aimed at economic diversification. At the same time, care should be taken to counter political backlash against climate policies based on job-killing arguments with evidence of positive employment effects in well-managed cases and clear communication on policy strategies to address distributional consequences.

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**Keywords**: Green transition, labour market, reallocation, changing skills requirements.

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# 1. INTRODUCTION

**In July 2021, the Commission adopted its flagship climate initiative (‘Fit for 55’).** It aims at making the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas (GHG) emissions by at least 55% by 2030, compared to 1990 levels.[1] The target of net zero GHG emissions (i.e., taking into account carbon captured in sinks and through any industrial processes) is to be reached by 2050. Curbing GHG (particularly $CO_2$) emissions (“decarbonisation”) is to be achieved through higher energy efficiency and increasing reliance on (low-emission) renewable energy. It implies important changes in the composition of final demand (towards less emission-intensive goods and services) as well as supply (technological change). Changes triggered by the green and the digital transition are likely to mutually reinforce each other.[2] While there are potential synergies between the twin transitions, in some respects, they might also reinforce some of the challenges brought about by one another, such as the acceleration of changes in skills demand.

**Most research seems to converge on the idea that the impact of the green transition on aggregate employment will be limited, but that shifts are likely to occur between sectors, firms, occupations and regions**. This calls for policymakers to anticipate the distributional consequences of climate policy and address possible social and employment risks and adjustment frictions through appropriate policy action, as also highlighted in the Council Recommendation on ensuring a fair transition towards climate neutrality.[3]

**This paper looks into the existing evidence on the labour market impact of the green transition and discusses potential variations across sectors and regions**. The note starts out by examining the expected impact of the green transition on potential employment (Section 2). Along with the equilibrium capital stock and total factor productivity (TFP), potential labour input determines potential output. Other internal analysis by ECFIN has addressed how the green transition may affect the other two factors, i.e., the capital stock and productivity.[4]

**Subsequently, the note considers in more detail, which types of economic activities and jobs are likely to be most affected by the green transition**. For this, a simple framework is used laying out three types of jobs:[5]

- *Green jobs*, which involve tasks aiming at reducing the impact of economic activity on the environment, ranging from waste recycling to R&D in green innovation. These jobs are expected to grow, and to have on average higher skills requirements than other jobs. However, they are estimated to concern only a few percentages of total employment.

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[1] COM(2021) 550 final.

[2] See Strategic Foresight Report, COM/2022/289 final.

[3] See 2021/0421 (NLE); 9107/22 (https://ec.europa.eu/social/main.jsp?langId=en&catId=89&newsId=10297).

[4] See Varga et al. (2022) on capital obsolescence and reallocation, and Nikolov et al. (2022) on decarbonisation and productivity.

[5] Note that the classification of jobs into ‘green’, ‘brown’ and ‘white’ jobs is used in this paper for ease of presentation. In reality, these jobs are not always easy to distinguish. For example, there are many ‘green’ jobs in ‘brown’ sectors, aiming at reducing the negative environmental impact of polluting activities.

- *Brown jobs*, which concern highly polluting activities (e.g. in mining, manufacturing, agriculture). These jobs are set to face a contraction in labour demand (and in some cases, such as coal and lignite mining, even a full phase-out), or significant structural change related to the greening of these sectors. At present, these jobs are estimated to cover around 5% of employment in the EU.

- *White jobs*, which are relatively neutral in their environmental impact, are expected to see only moderate changes in task content, related to the broad greening of activities. They correspond to the large majority of jobs in the EU. Some of these white jobs may also experience an expansion in labour demand as a result of the green transition, in spite of not involving directly 'green tasks'.

**The remainder of the paper is organised as follows.** Section 3 discusses the present state of knowledge around new 'green jobs' that would be created. As brown activities are likely to undergo the strongest and, in absence of mitigating policies, possibly most painful adjustment, Section 4 discusses evidence on the distribution of brown jobs by country, region and selected demographic characteristics of workers. Insights in where the burden of the adjustment will fall can help policymakers anticipate, where and which type of targeted support will be most needed to safeguard social cohesion and trust in institutions. Section 5 reviews results from model-based simulations of the green transition on employment. Section 6 looks at past examples of adjustment processes and effective policy action in the context of large shocks, such as mine closures. Section 7 sets out conclusions and policy implications.

# 2. HOW DOES THE GREEN TRANSITION AFFECT POTENTIAL EMPLOYMENT?

**The accelerated obsolescence of some technologies and products will affect the structure of labour demand and may result in the obsolescence of some jobs and human capital.** This is a first-round or direct effect, but not the ultimate effect on potential labour input. While some sectors may be adversely affected, people working in these sectors may find jobs in others. If the demand for certain skill sets diminishes, workers may be able to find employment in other occupations. Therefore, if potential labour input is measured as the number of people who are ready and able to work, the impact of the green transition on potential employment ultimately equals the number of people leaving or entering the labour market (if any) as a result of the structural economic change. This will crucially depend, inter alia, on the ease with which displaced workers can be re-integrated into other sectors (and/or occupations) of employment, and the ability of employment policies to support people during possible unemployment spells in reskilling and finding new jobs.

**Available estimates point to only small and transitory aggregate employment effects of environmental policy in general, and decarbonisation policies in particular.** For the EU, the impact assessment of the 'Fit for 55' initiative projects an aggregate employment growth of somewhere between -0.3% and 0.5% by 2030, based on simulations with different macro-economic modelling tools (JRC-GEM-E3, E3ME and E-QUEST).[6] CEDEFOP (2021) predicts 1.2% additional

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[6] Notably, it is argued that with the right accompanying polices in place, such as employment-friendly carbon-tax revenue recycling, the transition could create around 1 million jobs in the EU by 2030 (ca. 0.5% of current employment), and 2 million jobs by 2050 (ca. 1% of current employment) – including middle-skilled, middle-paying jobs in energy and construction. However, the impact will vary across countries and sectors. For more details, see European Commission (2020) and Asikainen et al. (2021). Results from macro-economic model simulations are also discussed in more detail in Section 5.

employment growth by 2030 associated with the implementation of the European Green Deal. Similar results are obtained when drawing on empirical analyses of the impact on employment of past episodes of tightening environmental regulations. Niggli and Rutzer (2021) present a study on the manufacturing sector in 19 EU countries over the period 1992-2010, when environmental policy stringency (EPS)[7] almost tripled, and find an insignificant impact on aggregate employment, but shifts between jobs with low and high green potential. Drawing on a panel of (up to) 5300 firms from 31 countries over the period 2000-2015, Mohommad (2021) similarly finds that the net effect of EPS tightening on total employment has been small and temporary, with a peak after two years, and a coinciding reallocation of employment from high- to low-emission firms and sectors. Looking at green subsidies in the American Recovery and Reinvestment Act (ARRA) of 2009, instead of policies that directly increase the costs of polluting, Popp et al. (2020) also find an increase in green jobs – raising in particular the demand for manual labourers in construction and waste management, together with very modest aggregate employment effects. Vona et al. (2018) shows that environmental regulations in the US have had no causal impact on aggregate employment over the period 2006-2014 but raised the demand for green skills. Marin and Vona (2019) examine the impact of increasing energy prices (as a proxy for climate policies) on employment, using a panel of 14 EU countries over a period of around 15 years. They find that, while aggregate employment effects are limited, climate policies have promoted (high-skilled) technician jobs (ISCO3) and reduced (low and medium-skilled) manual worker jobs (ISCO7-9).[8]

**A word of caution is needed in interpreting these results as they generally do not take into account the cost of inaction**. Notably, there is increasing evidence that climate change might also cause important damage to productive systems, with notable impacts on labour markets and working conditions, which is not accounted for in the studies above.[9] The costs of climate change are likely to vary widely across Member States, with southern and coastal member states being affected more negatively.

**The small effect on total employment is explained because most jobs in the EU are in so-called 'white' sectors, generating few $CO_2$ emissions.**[10] Activities such as electricity production, transport, manufacturing, agriculture and mining sectors together produce about 90% of all $CO_2$ emissions in the EU, but account for less than 25% of employment.[11] Conversely, construction, wholesale, retail and other services together employ more than 75% of the workforce, while generating less than 12% of $CO_2$ emissions.

**While aggregate employment effects are likely to be small, a more significant and heterogeneous impact of the green transition is expected to unfold at sector, occupation and task levels**. As mentioned above, shifts are likely to take place between high- and low-polluting sectors and firms and

[7] See https://www.oecd.org/economy/greeneco/how-stringent-are-environmental-policies.htm for details (method and coverage) on the OECD's environmental policy stringency (EPS) index on which many empirical studies are based.

[8] Other analyses of relative shifts in skills demand triggered by climate policies are presented by Bowen et al. (2018) and Consoli et al. (2016).

[9] See for instance Giordani (2014).

[10] IMF (2022). The IMF includes EU countries and quantifies a range of 2-3% of total employment.

[11] European Commission (2019).

to involve changes in occupational structure and skills requirements, with possibly relevant distributional implications.[12]

**First, the green transition is expected to lead to the creation of new 'green' jobs**, i.e., jobs that reduce the environmental impact of economic activity, such as energy efficiency renovations or research and development for green innovations.[13] In terms of volume, however these occupations account only for a small share of total employment. Studies have estimated their current incidence at merely a few per cent of total EU employment.[14]

**Second, 'brown' jobs are likely to come under pressure, or at least observe significant transformation in the workplace**.[15] Jobs in highly polluting activities concern around 5% of total EU employment at present. Among these, the prime example of activities that are set to be fully phased out over the medium term is coal and lignite mining, which represents just around 0.1% of total EU employment. At the same time, it is unlikely that all brown jobs would be phased out, as even the green transition may still require certain inputs from sectors such as metal mining and chemical/metal manufacturing.

**Finally, the green transition is expected to affect a major share of 'white' jobs through the adoption of more environmentally friendly work practices**. The green transition does not only take place through employment reallocation towards greener activities and away from brown activities, but also -and probably to an even larger extent- through 'greening' and reduction of emissions within existing activities.[16] Research suggests that most people work in 'white' jobs, which are neutral in terms of their impact on the environment. These would be expected to encounter only some changes at the task level, as production processes are greening.[17] Moreover, some white jobs might see growth as a result of the green transition (e.g. bus drivers, if the demand for public transit grows), even if they cannot directly be classified as 'green' jobs.[18] Figure 1 visually represents the job classification used. Figure A.1 in Annex presents approximate data on changes in green, white, and brown jobs in the EU over the last decade.

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[12] See e.g. Hofmann and Strietska-Ilina (2014).

[13] For more details on how green jobs are defined and identified in employment data, see Section 3 and Box 1.

[14] See e.g. IMF (2022).

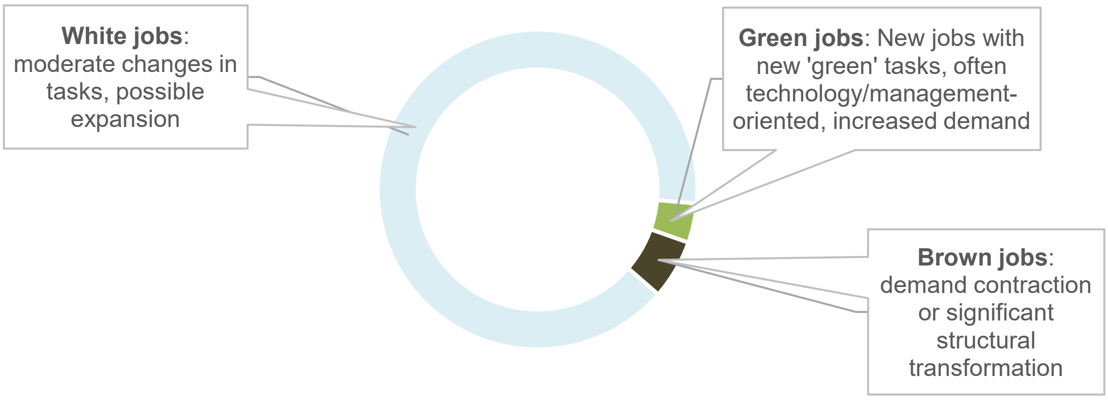
[15] See European Commission (2019) and IMF (2022).

[16] Copeland et al. (2022) show that a large part of emission reductions that occurred in advanced countries over the period 1995-2009 were due to changes in technology within industries, rather than due to a change in the composition of industrial activities.

[17] For instance, Vona (2021) argues that "most occupations are neither green nor non-green, and often transitioning towards greener task configurations."

[18] Bowen and Hancké (2019) distinguish "green increased demand" jobs (white jobs for which demand increases), "green enhanced skills" jobs (existing jobs requiring significant changes in tasks, skill, and knowledge) and "green new and emerging" jobs, referring to new jobs (with new skills requirements) created to meet the needs of the green economy, in line with a classification proposed by Dierdorff et al. (2009) for the O*NET database. They further distinguish non-green jobs in "green rival jobs" and "other non-green jobs", whereas the former category refers to jobs that imply similar tasks or skills requirements than green jobs, also based on O*NET data (see also Bowen et al. (2018).

Figure 1: **The differential impacts of the green transition on the labour market**




Source: Authors' own presentation based on e.g. Bowen et al. (2018), Vona (2021), Vona et al. (2018), Dierdorff et al. (2009).

**The labour market effects of the green transition are likely to unevenly affect sectors, regions, and population groups**, with possibly important economic and distributional impacts at the local level, also related to associated up- and downstream industries, and support services.[19] At the sectoral level, highly polluting sectors would experience strong structural transformation and/or (partial) phase out while green sectors would potentially see strong job creation. While the geographical distribution of green jobs tends to be more diffuse, regions in which brown jobs are currently concentrated would be disproportionally affected by employment losses. Data presented in this paper suggest that the destruction of brown jobs is likely to fall most heavily on medium-skilled male workers, who were already at higher risk of job losses as a result of the digital transition and the progressive de-routinisation of employment.[20]

**The green transition could negatively affect aggregate employment if labour market frictions stand in the way of labour reallocation**. If new jobs created are in geographically distinct areas or require significantly different skills, it will be more difficult for workers, who lose their jobs, to move into new positions. They may have to migrate to other areas or face long-term earnings losses. The proportion of the labour force that would be directly concerned by a phase out of specific activities, such as coal and lignite mining, is relatively small on a European or national scale. Nevertheless, at the level of local communities the impact could be significant.

**Experience indicates that policy support will be needed to help workers make a smooth transition**, diversify the economy towards less polluting activities, and avoid that job destruction, where it occurs, translates into structural unemployment and a deterioration of social cohesion. On the positive side, research indicates that the skill composition of workers in brown sectors is relatively similar to skill sets used in the wider economy, so there is scope to reintegrate workers in the labour market, especially at the current juncture of unusually tight labour markets in most parts of the EU. Thus, conditional on effective policy action, the negative impacts from job destruction for specific groups and regions could be kept at bay.

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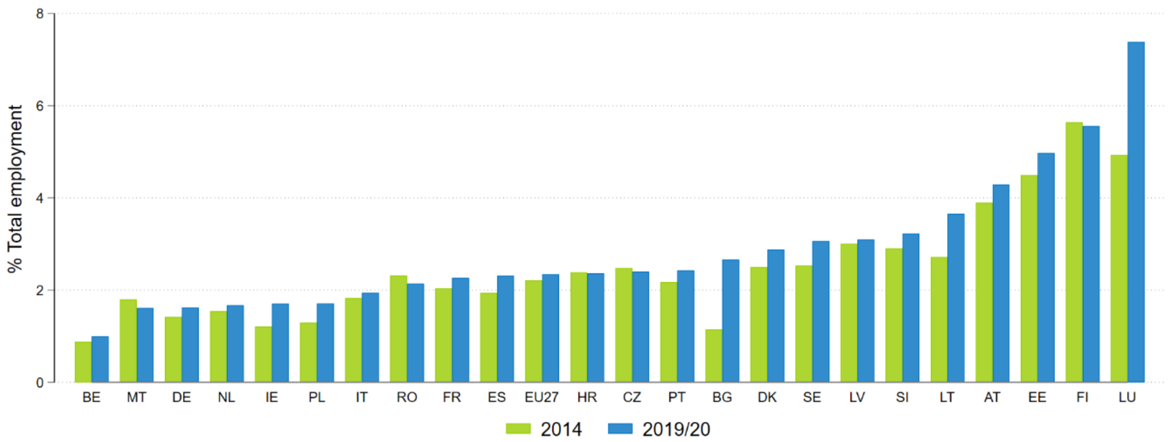
[19] Given the spatial concentration of certain industries, the transitions can also have broader regional effects, e.g. related to local identities, with implications for the political economy of green transition policies.

[20] An important qualification to this statement is that it only considers brown job destruction; it does not consider job creation in other sectors. Hence, job losses in brown sectors could be counteracted by job creation elsewhere.

# 3. WHAT DO WE KNOW ABOUT 'GREEN' JOBS IN THE EU?

**'Green' jobs are an elusive concept in the academic and policy literature.**[21] Researchers have examined different dimensions of greenness of a job to arrive at estimates, often driven by data availability. The most common way to measure green jobs is by drawing on the US-based Occupational Information Network (O*NET), for which Dierdorff et al. (2009) have elaborated a detailed 'tagging' of skills related to the green transition.[22] Nevertheless, as pointed out by Vona (2021), transferring the information provided by O*NET to data for EU countries is not without challenges, especially since "green jobs" typically concern relatively small occupational groups, which must be identified at a more granular level than Eurostat's current data collection allows for.[23] Yet, Eurostat provides a classification of employment in "environmental goods and services" across different industrial activities based on national accounts data, which also seems useful in this context (See Figure 2 and Box 1 for more details).

Figure 2: **Employment in environmental goods and services, 2014 and 2019/20**




Source: ESTAT data on Employment in the environmental goods and services sector from national accounts data (online data code: ENV_AC_EGSS1). 2015 data for FI are used instead of 2014 due to missing data for 2014. Blue bars reflect the most recent available data (2019 or 2020). Data missing for CY, EL, HU, SK.

**As a result, earlier studies on the incidence of 'green' jobs in the EU have reached diverging conclusions.** Very broad definitions (e.g. Bowen and Hancké, 2019) lead to the conclusion that up to 40% of EU jobs would be promoted by the green transition. More commonly, however, analysts have opted for a narrower definition of green jobs and estimated the current incidence of green jobs (jobs directly involving green tasks) at just a few per cent of total employment.[24] For example, IMF (2022) finds that the employment-weighted green intensity of occupations ranges between 2-3% for most

[21] See an extensive discussion by Bowen and Hancké (2019).

[22] See e.g. Niggli and Rutzer (2021), Bowen and Hancké (2019), IMF (2022).

[23] A green tagging for the EU occupational classification ISCO is under development by the European Skills/Competences, Qualifications and Occupations (ESCO) project; see Box 1.

[24] For instance, Vona et al. (2015) focus on jobs involved in the design, production, management and monitoring of environmental technologies.

advanced economies, and that these occupations are concentrated in the water supply, construction and professional services sectors. ESTAT's data on employment in environmental goods and services put its share in total employment at around 2% on average in the EU at present, with most of the jobs in water supply, manufacturing and construction. Over the last 10 years' time, the share rose by around 10%, from 2.1% to 2.3% of total EU employment (not shown below). At present, the share of green jobs ranges from around 1% in Belgium to almost 8% in Luxembourg. It has generally increased over the last 5 years (Figure 2).

BOX 1. **HOW TO MEASURE THE INCIDENCE OF "GREEN JOBS" AND "BROWN JOBS" IN THE EU?**

**In the narrowest sense, green jobs can be defined as jobs in (sub)sectors that directly relate to green technologies and processes.** For instance, Eurostat defines a subset of industries producing environmental goods and services, based on national accounts data. Employment in these industries concerns jobs that involve developing, producing or maintaining green technologies (e.g. renewables) and processes (e.g. recycling and reusing).[25] Alternatively, jobs can be defined according to their pollution intensity. This would yield a relatively broad range of 'green' jobs, as most service jobs have low carbon emissions. This paper considers jobs with a low pollution intensity, but no specific green task content, as 'white' jobs. Conversely, brown jobs can be defined as jobs in (sub)sectors with a high pollution or emissions intensity in process or product.[26]

**Another way to define green jobs is by considering the pollution content of the final product, or the potential of a product or service to harm the environment**.[27] Indeed, the production of cars with combustion engine is, by itself, a relatively 'clean' activity and therefore considered as a 'white' job, but some of its inputs and outputs contribute significantly to carbon emissions. It is therefore likely to be subject to significant structural change over the next years. A definition based on final products would better take into account relevant supply chain linkages, but also lead to additional challenges in data availability and measurement, especially outside of agriculture and manufacturing where there are no physical outputs.[28] Therefore, the literature has mostly turned to alternative definitions of green jobs.

**A common approach taken in the literature is to identify 'green' and 'brown' jobs at the occupational level**. This approach is relevant especially in view of the strong occupational dimension of the green transition, which does not only involve shifts across sectors, but also across occupations. A methodology that is very prominent in the literature is the green occupational labelling provided in O*NET for the US Standard Occupational Classification by Dierdorff et al. (2011). This methodology assumes that the green transition will promote employment particularly for three categories of jobs: (i) jobs with new tasks and skill requirements, created to meet the needs of the green economy ("Green New and Emerging" jobs); (ii) existing jobs that require significant changes in tasks, skills, or knowledge ("Green Enhanced skills" jobs); and (iii) existing jobs that do not involve any green/new tasks ("white jobs"), but that see demand grow as a result of the green transition.[29] Vona et al. (2018) evaluate the "greenness" of jobs according to the proportion of "green" tasks in an occupation, based

[25] See Vona (2021).

[26] See Vona et al. (2018), and IMF (2022).

[27] As an example, fuel-based car manufacturing is by itself not a sector with high greenhouse gas emissions; but using a fuel-based car does lead to considerable greenhouse gas emissions.

[28] Sato (2014).

[29] The methodology has been applied to EU LFS data by Bowen et al. (2018) and, more recently, by Bowen and Hancké (2019). See also European Commission (2019).

on green task labelling provided in O*NET by Dierdorff et al. (2011). Such task-based approach is, however, not available for "brown" jobs. Therefore, Vona et al. (2018) propose to identify 'brown' jobs as occupations that occur at least 7 times more frequently in "brown" sectors than in the rest of the economy, to examine whether there are certain types of occupations that are rather typical to "brown sectors", as this could complicate the transition to other sectors. IMF (2022) uses the same approach and complements it by an analysis at the sectoral level, where sectors are considered 'brown' based on their emissions intensity, similar to the approach in Section 4 of this paper.

**The application of these occupational-level methodologies to EU data is not without challenges, however.** The approach makes use of the job classification of the Occupational Information Network (O*NET), which uses information at a highly disaggregated occupational level. To apply it to EU LFS data, the information must be aggregated to a higher level, as crosswalks from the US occupational classification (SOC) to the EU occupational classification (ISCO) are only available at a relatively high level of aggregation. Moreover, cross-country comparable information on employment by occupation across the EU is also available at the ISCO 3-digit level at most, depending on the context. This obstacle can sometimes be solved using national-level employment data, firm-level data, or matched employer-employee data.[30] At the EU level, a European Classification of Occupations, Skills and Competences (ESCO) has been elaborated. ESCO is an occupational information system along the same lines as O*NET, more adapted to the (heterogeneous) EU labour market. Recently, a classification of green skills and competences has been developed,[31] and future work will examine its usefulness to identify green jobs in EU-LFS data. Moreover, CEDEFOP will launch a Green Observatory for mapping needed skills in the EU job market in 2022.

# 4. WHAT DO WE KNOW ABOUT 'BROWN' JOBS IN THE EU?

**Economic adjustment due to the green transition will be felt hardest in 'brown' jobs.**[32] These jobs will see outright labour demand contraction, or significant structural transformation towards greener production processes. Having better insights into where the brunt of the adjustment cost will fall, helps policymakers anticipate losses and design targeted policies to address these costs. Therefore, this section examines the distribution of 'brown' jobs, defined as jobs in economic activities with a high pollution intensity. It also zooms in on the coal and lignite mining sector as an emblematic example of an activity that is set to be entirely phased out.[33] At the same time, it is important to keep in mind the methodological challenges faced in defining and projecting the size of the adjustment cost, as the impact of the green transition on the structural transformation at the sectoral level remains highly uncertain for most sectors.

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[30] For example, Elliott et al. (2021) use Dutch LFS data, which provides employment data by ISCO-4 digit level.

[31] https://esco.ec.europa.eu/system/files/2022-03/Green%20Skills%20and%20Knowledge%20-%20Labelling%20ESCO_0.pdf.

[32] While employment in the car industry is not considered "brown", as mentioned earlier in the text, the switch from internal combustion engines (ICE) to electric vehicles (EV) will most probably have profound implications also on its labour force. Arguably, there will be less work in car manufacturing (ICEs have around 1400 parts, EVs have 200 parts), but more demand for higher skilled labour (there will be less work in the field of cleaning and mechanical machining, but there more in the field of testing and assembly). For a discussion see Casper and Sundin (2021).

[33] Coal miners are the most emblematic examples of losers from climate policies (see e.g. Vona 2021). Employment in coal and lignite mining is also a key variable to assess the scale of adjustments costs in the allocation method of the Just Transition Fund.

**Past events have shown that effects may concentrate in certain sectors, regions, and demographic groups.** In the case of regionally concentrated collective dismissals, the time and expenses required to reallocate workers to other jobs may be substantial.[34] In the absence of policy action, frictional unemployment may then evolve into long-term and structural unemployment.[35] If they find a new job, displaced workers may still face substantial wage losses.[36]

**As is standard in the literature, a data-driven method is used to identify 'brown' activities.** Notably, data from ESTAT's Air Emission Accounts (AEA) by economic activity are combined with data on employment levels from the European Labour Force Survey (LFS) to arrive at the intensity of greenhouse gas (GHG) emissions per worker (kg/per worker).[37] While the level of GHG emissions per worker varies strongly across Member States, the ranking of sectors appears relatively stable. Those sectors that are most often top-ranked based on their GHG emission intensity are considered to be 'brown'. This is in line with other approaches in the literature. For instance, Vona et al. (2018) label the 5% sectors with the highest GHG emissions among the list of NAICS 4-digit industries as "pollution intensive industries". Figure 3 shows the resulting selection of sectors identified as 'brown' sectors.[38]

**In these 'brown' sectors, the green transition can be expected to lead to substantial structural transformation**, with impact on labour demand, even if for most of the activities production would still continue to take place. Some of the production is likely to be downscaled, and labour demand would then likely follow suit. Furthermore, some of the production processes would see substantial change, which could lead to changing skills requirements. Among the identified 'brown' activities, special emphasis will be placed on coal mining as a prime example of an economic activity that is due to being phased out entirely.[39] The descriptive data analysis that follows looks at how important brown sectors are in Europe in terms of employment. It also discusses cross-country differences, and - to the extent possible - characteristics of occupations and workers concerned.

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[34] For example, Greenstone (2002) finds, based on firm-level data, that in the 15 years after the introduction of the Clean Air Act Amendment in the US, counties that were subject to greater regulatory oversight as a result of the Amendment lost jobs, capital stock, and output in pollution-intensive industries. At the same time, these losses were modest compared to the scale of the entire manufacturing sector. In addition, the analysis does not provide information on the extent to which the lost labour and capital was easily shifted to other activities or counties. Walker (2011) presents similar findings. In a follow-up paper, he provides evidence that, in spite of being significant for a subset of workers, on aggregate, these one-time adjustment costs are relatively modest compared to the estimated benefits of the policy (Walker 2013).

[35] See e.g. Maivali (2006).

[36] See e.g. Jacobson et al. (1993).

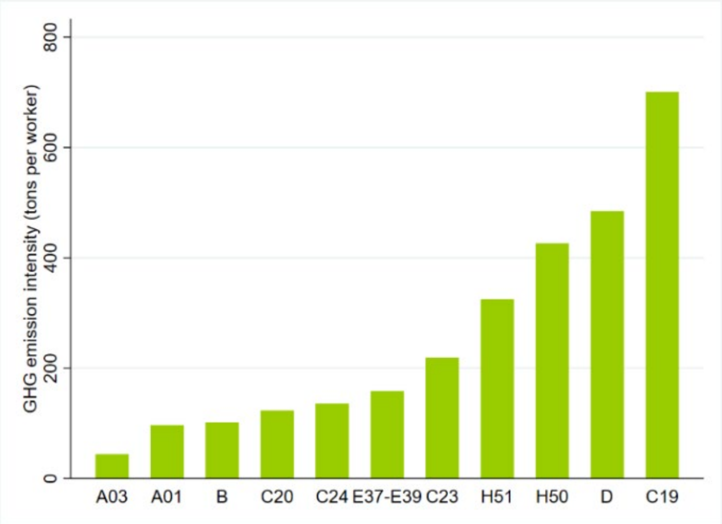
[37] Sectors are defined at the NACE 1- or 2-digit level, according to the availability of 2-digit level data in the LFS and the AEA data.

[38] An alternative definition of 'brown' sectors can be based on the energy-intensity of production. Notably, Commission SWD(2021) 277 final defines 'energy-intensive industries' as composed of the chemicals, steel, pulp and paper, paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, non-ferrous metals, glass and ceramics sectors (NACE 2-digit sectors C16, C17, C19, C20, C22, C23, C24). These industries supply the basic materials in the economy, are strongly interlinked with each other, and also with downstream sectors, energy providers, and waste and recycling industries. According to the SWD, the green transition in these industries is characterised by high upfront investment costs to save fuel and carbon in the long term and a need to rethink business models.

[39] It is defined as NACE 2-digit sector B05.

**It is important to note, nevertheless, that the identification methodology has some drawbacks**. As it groups together very different sectors, the impact of the green transition is likely to vary across the different sectors. In some industries, there would be more scope for innovation towards green technologies to protect employment than in others. Also, some activities such as waste management could as well grow in importance as a result of increased recycling needs for the green transition.

Figure 3: **Economic activities with the highest greenhouse gas emissions per worker, EU27, 2020**




A03: Fishing and aquaculture
A01: Crop and animal production
B: Mining and quarrying
C20: Manufacture of chemicals and chemical products
C24: Manufacture of basic metals
E37-E39: Sewerage, waste collection & treatment, remediation activities
C23: Manufacture of other non-metallic mineral products
H51: Air transport
H50: Water transport
D: Electricity, gas, steam and air conditioning supply
C19: Manufacture of coke and refined petroleum products

Source: Air Emissions Accounts, ESTAT.

**Employment in brown sectors and in coal mining in particular has been on a longer-term decline in the EU27.** Employment in brown sectors declined from around 8.2% of total EU employment in 2008 to around 5.7% in 2021, around one-third less in a bit more than 10 years. Employment in coal mining declined at an even slightly higher pace, from 0.17% to 0.11% of total EU employment over the same period (Figure 4).[40]

**The strongest reduction in employment in brown activities and in mining has taken place during recessions**. During the recession following the global financial crisis, a steep decline was witnessed in these activities. In contrast to other sectors, no employment growth was observed during the economic upturn as of 2015. This is in line with broader employment dynamics for routine occupations: these occupations have been observed to show strong reductions during recessions, without recovering during economic upturns.[41] In this respect, the impact of the green transition on brown job destruction resembles the impact of the digital transition. In the context of the digital transition, automation has affected particularly jobs with a high routine content, which concern mostly low- and medium-skilled jobs in agriculture and manufacturing.[42] As brown activities are concentrated in these sectors as well, both trends are likely to reinforce each other to some extent. Moreover, the secular shift from manufacturing to services, which has taken place over the last decades, has contributed to reducing emissions in advanced countries. Sectoral reallocation notwithstanding, empirical research still

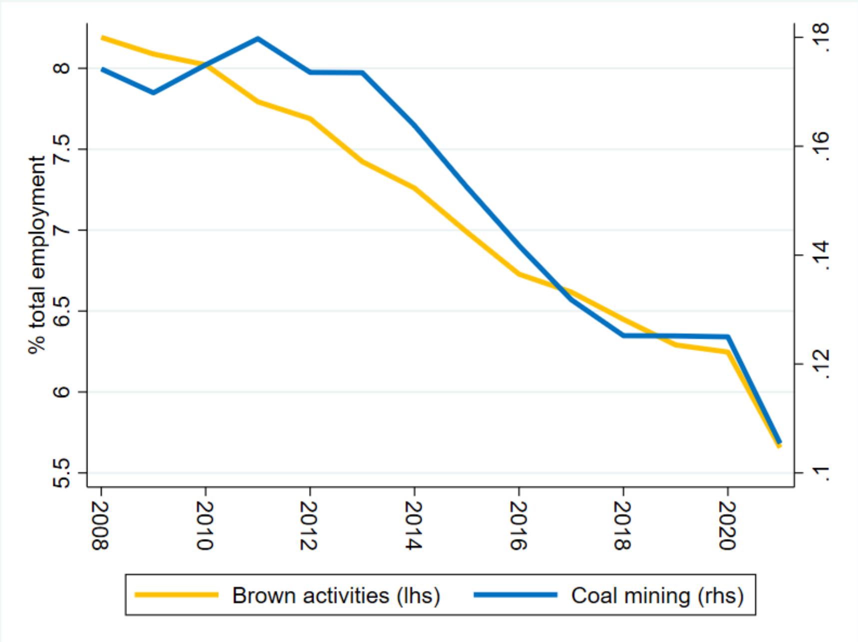
[40] See Figure A.2 in Annex for employment dynamics in brown sectors and coal mining by Member State.

[41] See also Jaimovich and Siu (2020).

[42] See OECD (2021). The skills implications of the green transition are discussed in more detail below.

suggests that an important part of the emission reduction that took place over recent decades was the result of within-sector reductions (the use of greener technologies and processes, and in particular the use of cleaner energy) rather than the phasing out of polluting activities.[43] Box 2 provides a more in-depth analysis of the relationship between unemployment and (the decline in) brown activities.

Figure 4: **Employment in brown activities and in coal mining, EU27 (2008-2021)**




Source: Authors' own calculations based on LFS and AEA data (ESTAT).

**Employment in broader brown activities reaches 3-10% of total employment in most Member States,** with higher shares being observed in Bulgaria (11%), Croatia, Poland, Greece and Romania (16%). Substantial reductions in these activities have been observed over time, particularly in Romania and Portugal (Figure 5).[44] By far the largest contribution to this decline has come from employment in crop and animal farming.

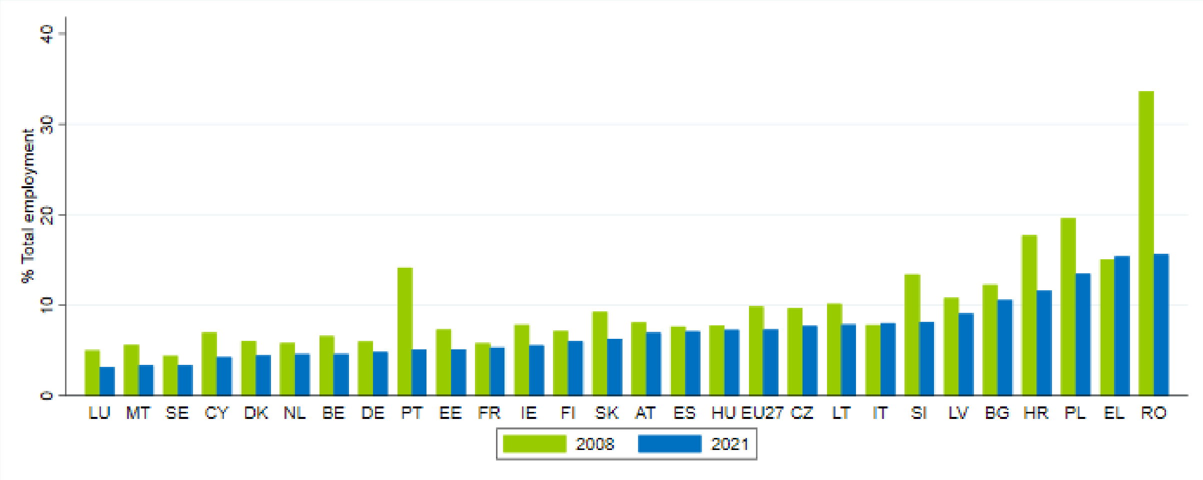
**At the regional level, employment in brown activities reaches more than one quarter of employment in some regions.** In about 5% of EU NUTS-2 level regions, more than 20% of

[43] Analysis by Copeland et al. (2022) suggests that especially countries in Eastern Europe saw significant progress in the within-sector use of greener production technologies over the period 1995-2009, dwarfing the impact of changes in the sectoral composition for emission reduction. IMF (2022: Figure 3.1) suggests that sectoral reallocation accounted for only about a quarter of emissions reductions in advanced countries over the period 2005-2015. Yet, the relatively low contribution of sectoral reallocation could relate to the fact that industries are considered at a relatively aggregate level (NACE-1D). As a consequence, sectoral reallocation that takes place at a more granular level (e.g. shifts within manufacturing towards less emission-intensive industrial activities) would be captured as a change in 'sectoral efficiency'. Moreover, Copeland et al. (2022)'s results also suggest considerable variation between advanced countries. For instance, in the US improvements in sectoral efficiency have indeed been the dominant driver of reductions in emissions.

[44] The classification of brown sectors follows the definition developed above and shown in Figure 3.

employment is in brown activities. In seven regions, brown activities concern 25-31% of all jobs. These regions are all located in Greece and in Romania.[45]

Figure 5: **Employment in brown activities by Member State, 2008 and 2021**




Source: Authors' own calculations based on LFS and AEA data (ESTAT).

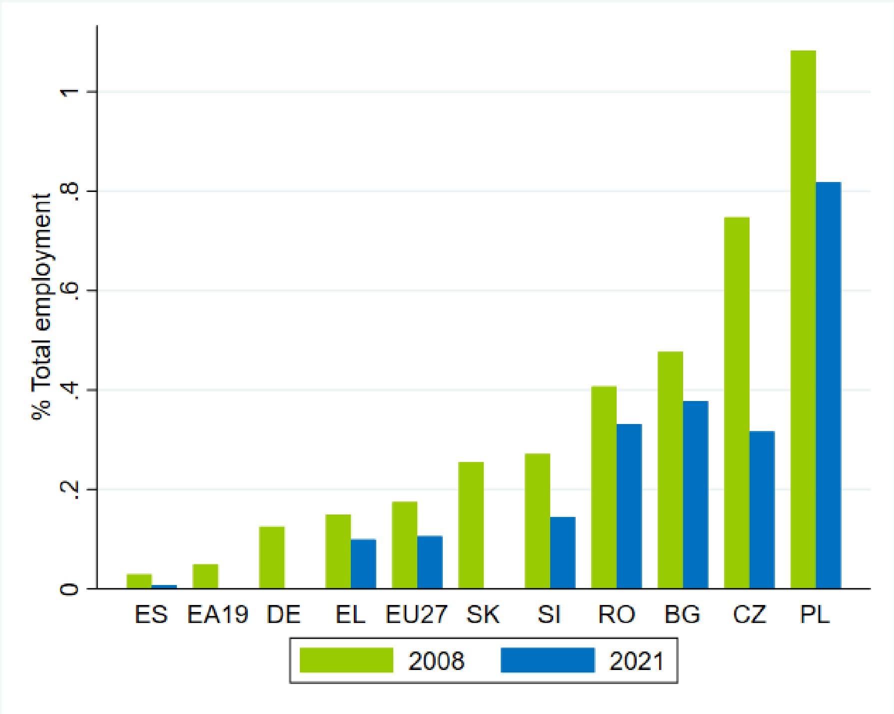
**Employment in coal and lignite mining remains concentrated in a few Member States** (Figure 6). Notable cases are Poland, where it comprises around 0.8% of total employment (136.000 jobs), and Bulgaria, Romania, and the Czechia, where it comprises a bit less than half of that. Some employment in coal mining is still reported in Slovenia, Greece and Spain as well. Over time, all Member States have, however, seen a significant decline of employment in the sector.

**While coal mining activities have become relatively limited compared to national employment levels, at the regional level they can still be important**. While coal mining does not reach 1% of total employment in any EU Member State, employment shares at the regional level can be much higher due to the local concentration of activities. In 2011, there were still three EU regions in which coal mining covered more than 3% of total employment (Silesia Province, PL: 7.5%; Western Macedonia, EL: 5.2%; Moravian-Silesian region, CZ: 3.7%). By 2021 this has come down to just two: while the share of coal mining had declined to 1.2% in the Moravian-Silesian region in Czechia, in Western Macedonia (Greece) and in Silesia Province (Poland) it still stood at 4.2% and 5.1%, respectively (see Annex Figure A.5).[46] As will be argued in Box 3, the labour market situations in each of these regions is quite distinct, underlining the necessity to consider regional heterogeneity and needs in the design of policies to promote the transition.

[45] The following regions are concerned: Eastern Macedonia and Thrace, Western Macedonia, Western Greece, Central Greece, and Peloponnese in Greece, and Nord-Est and South-West Oltenia in Romania.

[46] In all other EU NUTS2 regions, the share of employment in coal mining has dropped below 3% of overall employment. At a more granular level (e.g. EU NUTS3), the concentration of coal mining activities is likely to be even higher.

Figure 6: **Employment in coal mining by Member State (% total employment), 2008 and 2021**




Source: Commission calculations based on EU-LFS.

**Data on the gender and age distribution of employment in brown sectors suggest that the brunt of the adjustment cost will fall upon core age men** (25-49). Women and young people are underrepresented in brown activities (Figure 7 and Figure 8). While older workers are overrepresented in brown sectors in general, this is not the case in the coal and lignite mining sector, possibly due to earlier retirement patterns in that sector. While older workers typically also face a lower risk of job loss, they would still be of specific concern as they are more at risk of leaving the labour force upon job loss.[47] LFS data suggest that out of around 250,000 workers currently working in coal and lignite mining in the EU, around 54,000 are older than 50. Almost half of these are in Poland; around 5,000 are in Bulgaria; 7,000 in Czechia and almost 9,000 in Romania. Given the lower job finding probability of older workers, some of these older workers may not find a new job after being dismissed anymore. Some may qualify for early retirement.[48]

**Data on the skills distribution of jobs and workers suggests that 'brown' jobs require, on average, lower skills than jobs in the aggregate economy.** Patterns of job-specific skill requirements suggest that there are less high-skilled jobs, but more medium- and low-skilled jobs in brown sectors than in the aggregate economy (Figure 9). In coal mining, medium-skilled jobs prevail, and there are less high- as well as low-skilled jobs (and workers) than in the aggregate economy. Fairly similar results obtain when considering workers' qualification levels instead of jobs' skill requirements (Figure 10).

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[47] See e.g. Quintini and Venn (2013); Deelen et al. (2018); Flek et al. (2020).

[48] Coal miners often have earlier official retirement ages than other workers. As Baran et al. (2018) report, in Poland underground miners can retire at the age of 50 or 55 under certain conditions. Early retirement packages are often used for workers in collective dismissals that are less than 3 years away from their pensionable age.

BOX 2: **LABOUR MARKET CONDITIONS IN REGIONS WITH STRONG ADJUSTMENT NEEDS**

**An analysis of cross-sectional variation suggests that within a country, regions with higher shares of 'brown' employment tend to have higher unemployment rates**, underlining the relative vulnerability of these areas in terms of labour market conditions (models (1) and (2) below and Figure A.3 in Annex).

**Nevertheless, over the last decade, the reduction of employment in brown activities and coal mining took place mostly in a context of declining unemployment**.[49] Especially in countries such as Poland and the Czechia, the strong decline in unemployment is likely to have cushioned the labour market impact of the reduction of employment in coal mining. Fixed effects regressions at the regional level (models (3) and (4)) suggest a positive relationship between the aggregate unemployment rate and the employment share in brown activities (and coal mining), which suggests that a decline in 'brown' employment has been broadly associated with a decline in unemployment rates at the regional level. Adding time dummies to control for common time trends and economic shocks reduces the strength of the relationship, in particular for coal mining (models (5) and (6)). But the data provide no prima facie evidence that a phase out of 'brown' activities would put substantial or potentially long-lasting upward pressure on unemployment rates at the NUTS-2 level.

Table 1: **Regression results, dependent variable: regional unemployment rate**

| | (1)<br>OLS | (2)<br>OLS | (3)<br>FE | (4)<br>FE | (5)<br>FE | (6)<br>FE |
|---|---|---|---|---|---|---|
| % Brown empl | 0.090*** | | 0.535*** | | 0.204*** | |
| | (0.016) | | (0.035) | | (0.032) | |
| % Mining empl | | 0.360*** | | 1.935*** | | 0.442 |
| | | (0.114) | | (0.485) | | (0.376) |
| Constant | 3.942*** | 9.673*** | 4.217*** | 9.429*** | 7.247*** | 10.395*** |
| | (0.440) | (0.552) | (0.332) | (0.157) | (0.355) | (0.261) |
| Country dummies | ✓ | ✓ | | | | |
| Time dummies | ✓ | ✓ | | | ✓ | ✓ |
| Observations | 2,665 | 1,330 | 2,665 | 1,330 | 2,665 | 1,330 |
| R-squared | 0.672 | 0.774 | 0.086 | 0.013 | 0.376 | 0.435 |
| Nr of regions | | | 237 | 115 | 237 | 115 |

Source: Authors' calculations based on LFS and AEA data (ESTAT).

Note: Data are annual and reflect the period 2009-20. Standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Results should not be interpreted as reflecting causal relationships. Regressions (2), (4) and (6) only include countries with a non-zero share of employment in coal mining.

[49] See e.g. Figure A.4 and Figure A.5 in the Annex. A report by Szpor and Ziolkowska (2018) shows that employment in Upper Silesia (with the most important coal basin in Poland) has followed broadly the same trends as Poland on aggregate over the period of contraction in coal mining employment.

BOX 3. **LABOUR MARKET SITUATION IN THREE MAJOR COAL MINING REGIONS IN THE EU**

In 2021, **Western Macedonia** is the NUTS-2 region with the highest unemployment rate (19.8%) in Greece (national average: 14.7%), underlining the relative economic vulnerability of the region. Long-term unemployment (as % of active population) is also among the highest of Greek regions. Nevertheless, unemployment had improved considerably since its peak at 31% after the financial crisis. In 2021, 5.2% of employment is in coal mining. Over the last decade, jobs have disappeared particularly in coal mining, the manufacturing of food products and wearing apparel, and construction. At the same time, jobs were created especially in the retail sector. While women historically experience higher unemployment rates than men in this region, unemployment remains higher than in the first decade of the 2000s especially for men – and more so for men with medium than for those with low qualifications.

In **Silesia Province**, unemployment is very low, and below the Polish national average in 2021 (2.9% versus 3.4%). Long-term unemployment is at less than 1%, as in most regions in Poland. Over the last two decades, unemployment has continuously declined, coming down from around 20% in the early 2000s. Since 2011, the size of the population has been on a more rapid decline in the region than in the rest of the country. In 2021, 7.5% of employment is in coal mining. Over the last decade, jobs have disappeared particularly in agriculture, coal mining, specialised construction activities, and wholesale and retail trade. Over the same period, jobs were created especially in manufacture of rubber and plastics and of motor vehicles, warehousing, computer programming, and public administration. Unemployment rates are low across all qualifications groups. The majority of the workforce in Silesia Province is medium-skilled.

In 2021, unemployment stood at 4.6% in the **Moravian-Silesian region** of Czechia: relatively low, even if it was the highest rate in all Czech regions (national average: 2.8%). Long-term unemployment stood at 1.4%, also the highest rate in Czechia (national average: 0.8%). Unemployment has declined swiftly over the years, from more than 12% in the early 2000s, but saw a slight uptick in 2021. Employment in coal mining remains at 3.7% in 2021. Over the last decade, jobs have disappeared primarily in coal mining, manufacture of basic metals, and public administration. Jobs were created in manufacture of motor vehicles, computer programming, architectural and engineering activities, education, and health and care services. Unemployment rates remain high among low-qualified people (and more so among women than men).

Source: Regional statistics, LFS, ESTAT.

**These findings are in line with the broader literature.**[50] Existing analysis finds that green jobs are highly dispersed across sectors, but they are likely to concern higher skills.[51] Several of these studies have already been mentioned earlier (Section 2). Consoli et al. (2016) suggest, based on a study on US data, that green jobs require higher levels of education. Bowen and Hancké (2019) arrive at a similar conclusion using EU data.

**Typically, workers with low and medium qualifications encounter more difficulties in taking up training or transitioning to new jobs than workers with high qualifications**. OECD research suggests that low-qualified workers tend to face the highest risk of job loss, take longer to transition

[50] See e.g. Vona et al. (2018) and IMF (2022). Marin and Vona (2020) find that climate policies promote in particular technician jobs (ISCO 3-level: high-skilled), at the detriment of manual worker jobs (ISCO 7-9 level: low-medium skilled).

[51] IMF (2022), Vona et al. (2018), Marin and Vona (2018), Bowen and Hancké (2019), ESDE (2019), Consoli et al. (2016).

into new employment, and are more likely to face wage losses upon taking up a new job.[52] While the proportion of low-qualified workers is extremely low in the sectors most at risk (coal mining), they are overrepresented in broader 'brown' activities that are likely to undergo considerable structural transformation. The OECD study also suggests that medium-qualified workers are more likely to transition into new jobs with different skills requirements than low- or high-qualified workers, underlining the value of training. More broadly, with the majority of workers in brown activities exhibiting low and medium qualifications, policy efforts for upskilling and reskilling will need to be stepped up to increase workers' resilience in face of the likely structural transformation that these sectors would be facing - either to adapt to greener work processes, or to make the shift to other sectors in the economy.

Figure 7: **Gender distribution of employment in brown activities and total employment**

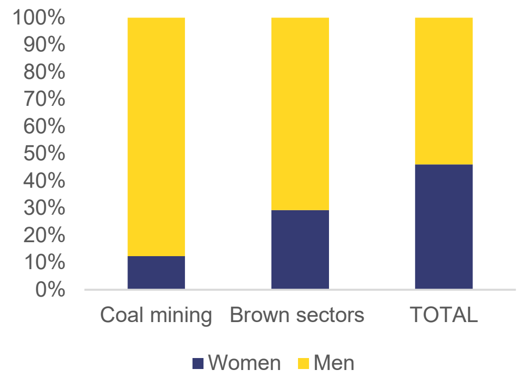



Figure 8: **Age distribution of employment in brown activities and total employment**

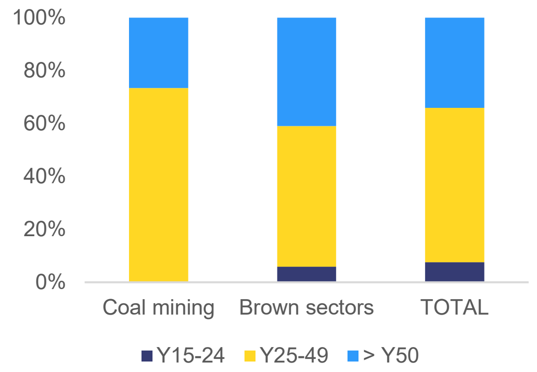



Figure 9: **Distribution by skills requirements of jobs**

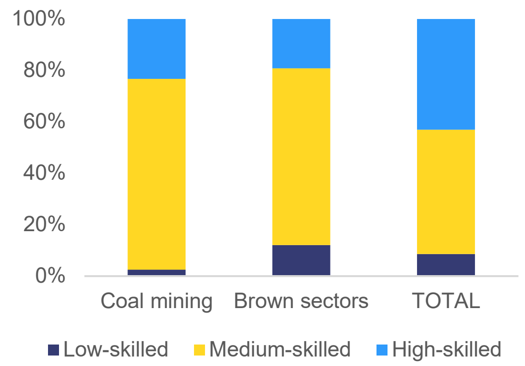
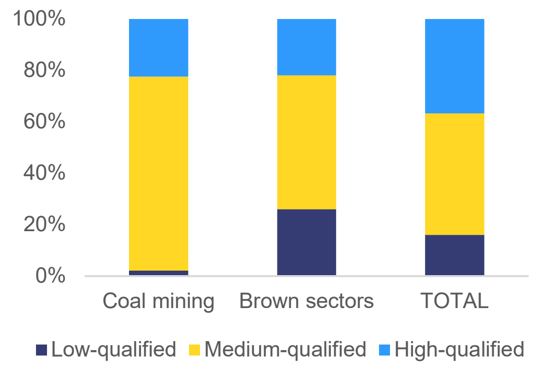



Figure 10: **Distribution by workers' qualification levels**




Source: Authors' own calculations based on LFS and AEA data (ESTAT).

**Transitions to new occupations and across regions are generally more challenging than transitions within occupations or the same region.** Research by IMF (2022) suggests that generally, environmental properties of jobs are 'sticky', meaning that workers are more likely to find new jobs with similar environmental properties as their previous jobs. Their analysis suggests that on average, around 4-7% of workers in polluting jobs who change jobs in a given year switch to green jobs and

[52] Quintini and Venn (2013).

around 11% to white jobs. Workers in neutral ('white') jobs have a slightly higher probability to switch to a green job (9-11%) when they change jobs. Nevertheless, after controlling for individual worker characteristics, there remain no differences in the transition probability to a green job from a brown or a white job. The low transition probabilities reflect broader challenges to switch between occupations. Curtis and Marinescu (2022) find that the growth of renewable energy in the US has led to the creation of relatively well-paying jobs across the skills spectrum, but usually not in the same areas where brown jobs are destroyed. In other words, geographic mismatch may compound possible problems related to skills mismatch.

**At the same time, however, studies also suggest that a large part of the skill characteristics of brown sector jobs is transferrable to the green economy**.[53] For example, Vona et al. (2018) suggest that the skill gap between brown and green jobs is small overall, and often the general skills requirements of brown jobs are closer to those of green jobs than to other ('white') ones. With the right support, reintegration in local labour markets should thus be possible.[54] At the same time, Vona et al. (2018) point at notable exceptions such as extraction workers (included those employed in coal mining). These workers have very specific skill profiles that seem to be different from those required by green and white skills, which could lead to more substantial challenges in finding new employment. An outstanding challenge is that brown jobs are often highly unionised,[55] and relatively well-protected and well-remunerated relative to their skills requirements. For instance, it has been argued that in Poland, miners that have lost their jobs have found it difficult to find jobs with similar skill requirements that offered equivalent working conditions.[56]

**A back-of-the-envelope calculation suggests that Romania, Poland and Bulgaria would face the highest potential costs of re- and upskilling their workers.** Figure 11 and Figure 12 show estimated training costs per worker (in PPS) and as a percentage of GDP. The underlying assumptions are that (a) there is no overlap between green and brown jobs,[57] (b) that those jobs that are not green nor brown are white jobs; (c) that white and green jobs would require 500 EUR PPS per worker for on-the-job training to apply greener work practices, while mining jobs require 10,000 EUR PPS for reskilling and reorientation towards other sectors, and other brown jobs require 1,500 EUR PPS.[58] The results suggest that on average in the EU, the cost per worker of training would be 573 EUR PPS, with the costs being notably higher in RO, PL, EL, and BG, where they range from around 600-750 EUR PPS.

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[53] See e.g. Vona (2021). Bowen and Hancké (2019) also find that many of the activities associated with environmental sustainability can be integrated into existing tasks and jobs, or built up from existing skills.

[54] See also the [2022 Council Recommendation] on ensuring a fair transition towards climate neutrality for dedicated policy recommendations in this context.

[55] See Bowen and Hancké (2019).

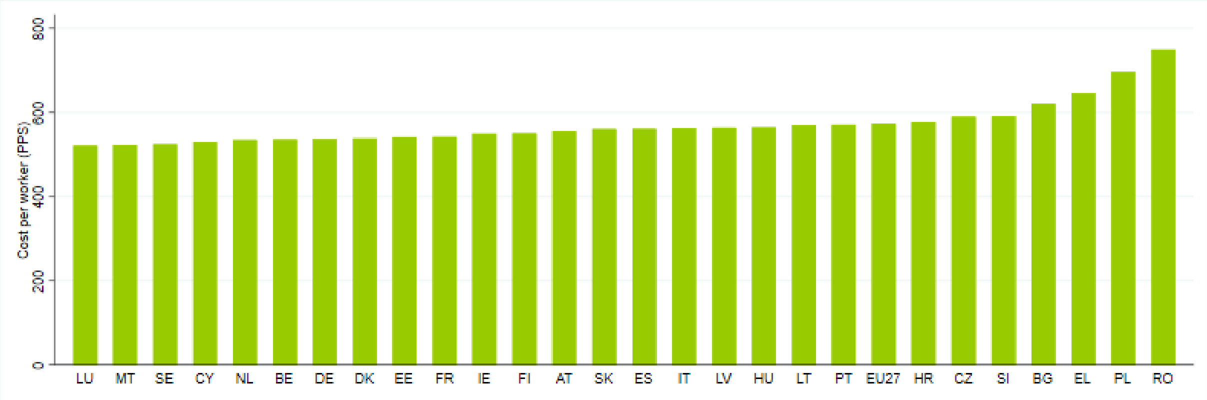
[56] See e.g. Caldecott et al. (2017), Szpor and Ziolkowska (2018), Vona (2019), Sniegocki et al. (2022).

[57] Calculations on the shares of green and brown employment are taken from different data sets, so in principle some overlaps can occur. Green, white and brown jobs are defined as explained earlier.

[58] Evidence on costs of comparable training programs across EU countries is very thin. Therefore, the indicated figures should be taken as purely illustrative. Moreover, training costs are likely to diverge between countries more strongly than what can be corrected for by PPS, and therefore the results should really be interpreted as a simple back-of-the-envelope calculation. As a result of our assumptions, the differences in costs of labour force training shown can be considered as an upper bound. For instance, in Bulgaria and Romania, training costs are likely to be cheaper than what has been assumed through the adjustment based on PPS, as wage levels (which can be thought of as the main determinant of training costs) tend to diverge more strongly than price levels across EU.

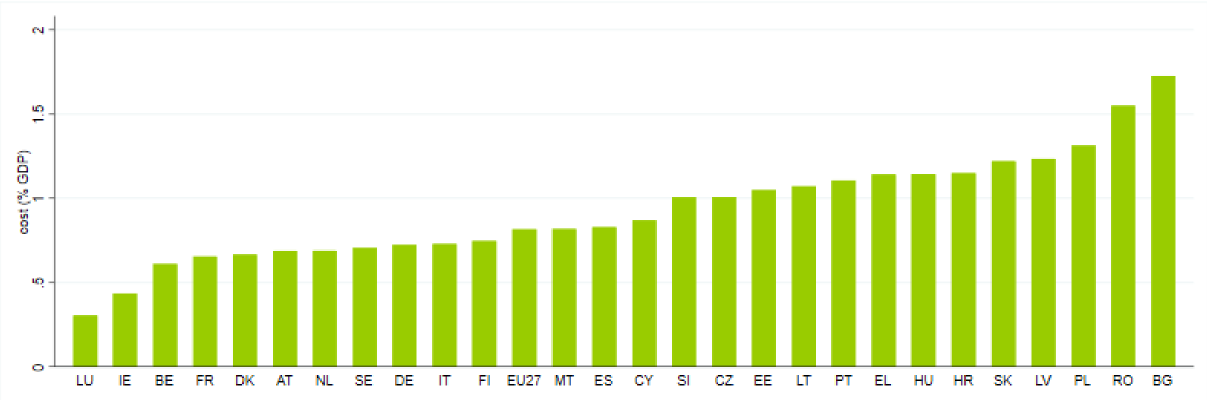
When expressed as a % of GDP, the costs range from 0.3% of GDP (Luxembourg) to 1.3-1.7% of GDP for Poland, Romania and Bulgaria. The calculation assumes a one-off cost of training.

Figure 11: **Average costs per worker of training for the green transition (EUR PPS)**




Source: Authors' own calculations based on LFS and EAE data. For methodological details: see text.

Figure 12: **Total costs of labour force training for the green transition (% GDP)**




Source: Authors' own calculations based on LFS, EAE and national accounts data. For methodological details: see text.

**While training costs per worker do not vary substantively from country to country, the highest aggregate costs are likely to fall upon countries that are relatively poorer**. The calculation makes clear that even if costs per worker do not vary substantially between countries, the burden of the training cost as a percentage of GDP will be substantially higher in already poorer EU countries than in richer EU countries. In addition, the countries that are affected more strongly also tend to have (on average) weaker institutions for adult learning than richer countries.[59]

**As discussed below, the costs of training will be only one element of the transition costs.** Public support will also be needed to provide temporary income support and different types of employment support to dismissed workers, early retirement schemes for some, and, importantly, for regional development programs to promote economic diversification.

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[59] See for instance 2022 Joint Employment Report: https://ec.europa.eu/info/publications/2022-european-semester-proposal-joint-employment-report_en

# 5. MODEL-BASED ASSESSMENTS OF THE IMPACT OF THE GREEN TRANSITION ON EMPLOYMENT

**Structural macroeconomic models play an important role in the analysis of climate policies.** Model simulations provide guidance where empirical evidence is scarce, such as on the effects of carbon pricing, given the unprecedented size and scope of measures. At the same time, they also rely on certain assumptions that need to be made in highly uncertain environments. Structural models emphasise the interdependence between markets and policies in general equilibrium.[60] Macroeconomic models used to analyse the energy transition and policies (such as carbon pricing, green subsidies, R&D support) typically comprise several production sectors, such as brown versus green energy production, and the production of brown versus green investment goods. The latter are the combined with brown or green energy as well as labour in the production of final goods.[61]

**Scenario analysis with the E-QUEST and G-Cubed models suggests non-negligible shifts in employment from brown to green sectors, together with broadly stable aggregate employment**.

- In particular, E-QUEST simulations for the EU climate target suggest transitory aggregate job losses of no more than 0.1% on the way to 2050, and a return of employment to baseline by the end of this 30-year period.[62] The policy scenario is a path for carbon taxes calibrated to reach the target of net zero GHG emissions by 2050. The carbon tax increases the relative price of brown energy and leads to substitution away from brown energy to green one, and from brown capital goods to green ones. Final output is then produced with a cleaner energy mix.

- G-Cubed simulations for decarbonisation policies suggest an initial increase in EU employment by up to 2% during the first decade, followed by a decline of up to 0.5% relative to baseline, and a return to baseline by 2050.[63] The G-Cubed model is more complex than E-QUEST in its geographic (10 regions versus two in E-QUEST) and sector (20 compared to seven) structure. Contrary to Varga et al. (2022), the G-Cubed scenario combines carbon taxes with (over a 10-year

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[60] In the case of "Integrated Assessment Models" this includes the interaction between economic activity and GHG emissions.

[61] See e.g. Barrett et al. (2021), Jaumotte et al. (2021), and Varga et al. (2022).

[62] See Varga et al. (2022). The carbon pricing, or equivalent regulation, reduces the profitability of brown capital ("stranded assets"). As green capital builds up only gradually, the capital intensity of production and labour demand (at given wages) can be expected to fall temporarily. More private and public investment demand during the transition leads furthermore to an increase in the rental rate/financing cost of capital in general equilibrium, which dampens the investment increase. In simulations, negative employment effect can be offset by carbon-tax revenue recycling that, e.g., reduces the labour tax wedge, or strengthens aggregate demand, resulting in modest employment gains Hence, net employment effects remain close to zero, or slightly positive (up to 0.2% in the 2030s with targeted labour tax reduction) in the scenarios of employment-friendly revenue recycling in Varga et al. (2022). Note that carbon tax revenue goes to zero as the economy approaches the net-zero emission target, which also removes the scope for revenue recycling in the long term. It should also be noted that E-QUEST scenarios in Varga et al. (2022) are not identical to those in European Commission (2020), which can explain modest differences in the numerical results.

[63] See Jaumotte et al. (2021). For the global economy, they find an initial increase in aggregate employment by around 0.5%, followed by a similar decline, and a return to baseline by 2050, as well as a permanent shift in employment from high-carbon to low-carbon sector by about 2% of the jobs.

horizon) green subsidies and a green fiscal stimulus, which leads to strong private and public investment demand on impact (including labour-intensive construction) that explains the initial increase in output and employment.

**Macroeconomic models are simplifications of reality and tend to generate rather smooth employment adjustment.** In particular, the examples provided (E-QUEST, G-Cubed) do not distinguish between green and brown skills and their limited convertibility. Green versus brown activity is defined only at the sector level (green versus brown energy and capital goods production), not at the level of occupations or skills. The skill decomposition of labour demand tends to be the same across sectors by assumption, and workers transferring from one sector to the other are not subject to (temporary) productivity shocks that may proxy for skill mismatch and training needs.[64] By implication, aggregate employment losses during the transition remain contained, and long-run potential employment remains largely unaffected. In light of the emphasis, earlier in this paper, on job transitions and related adjustment and reskilling needs, the lack of more detailed information on labour substitutability across and within industries is a limitation to the use of macro models for evaluating the temporary employment effects of the green transition.

**Carbon pricing generates fiscal revenue, which can be recycled in employment friendly ways.** In 2019, the revenue from EU ETS auctioning reached 0.1% of EU GDP. The peak revenue effects in the green transition could be in the order of magnitude of 1-2% of GDP per year.[65] The additional revenue can, e.g., be used to lower the tax burden on households and firms by reducing taxation on labour or capital, subsidise green R&D to accelerate the green transition, or increase government spending, notably on green infrastructure. The simulations with E-QUEST show significant employment gains from revenue recycling through labour tax reduction. In particular, a tax rebate through targeted labour tax reductions for low-skilled workers leads to up to 2.5% increase in low-skilled employment over a two-decade horizon. Revenue from carbon pricing can be used to support and facilitate the transition in particularly concerned sectors. The revenue and positive employment effects from revenue recycling are temporary, however. Once the economy has moved towards net zero GHG emissions, the revenue from carbon taxes or emission trading equals zero.[66]

[64] E-QUEST distinguishes between low-skilled, medium-skilled and high-skilled labour (proxied by educational attainment). This distinction allows, in principle, for some differentiation in relative skill demand in brown versus green industries. The scenarios in Varga et al. (2022) keep the skill composition of labour demand across production sectors constant, however.

[65] See IMF/OECD (2021), in particular Figure 7. Note that the more successful carbon pricing is at shifting energy use from brown to green sources, the lower will be the fiscal revenue (trade-off between incentive and revenue effects).

[66] See Varga et al. (2022). Conversely, the simulations in Barrett et al. (2021) for the U.S. show temporary employment losses for green energy subsidies financed by higher wage taxes.

# 6. LESSONS FROM SECTORAL TRANSFORMATION IN ADVANCED ECONOMIES

**Structural breaks in the market environment often occur fast, and they can be highly disruptive.** Therefore, there is a strong argument for the anticipation and proactive management of such transitions.[67]

**Past coal transitions tended to have a significant impact on the labour market.** The coal transitions that took place since the second part of the 20th century (transition from coal to oil and gas) could provide useful examples. A meta-analysis of the literature review[68] shows that of the 167 studies examined, 130 report negative labour market effects[69] – by far the most frequently reported negative impact (the next is demography with 33 studies).

**The concentrated impact of the green transition on parts of the labour market calls for a more comprehensive policy response.[70]** While the green transition on a macro-level may have limited employment effects, there is much more concern about the potential for significant impact on some sectors, regions and groups of workers. Particularly out-of-coal transitions appear with strong geographical and sectoral concentration and can therefore have a significant impact on local and regional economies. The geographical concentration is also conducive to the creation of strong cultural identities related to the predominant activity, which in turn complicates the political economy of the transition. Lessons from past regional economic shocks can inform policymakers on a holistic policy response to large-scale dismissals. Box 4 provides an overview of the support required at the individual worker level.

BOX 4. **KEY ELEMENTS OF LABOUR MARKET INTERVENTIONS TO FACILITATE ADJUSTMENT AFTER A MAJOR DEMAND SHOCK**

1. Pre-transition (pre-layoff planning, assistance)
   a. Identify workers to be affected.
   b. Conduct skills audit that would assess the skill levels of the workers in order to design a proper up-skilling programme.
   c. Review labour regulations to understand the rights and responsibilities of laid-off workers.
   d. Set-up institutions/partnerships to manage the labour marker transition. Participation of employment services and social partners are crucial.
   e. Begin provision of certain services, such as providing early job search assistance.
2. During and after transition (post-layoff assistance)
   a. Providing temporary income support (severance payments, role of unemployment benefit, minimum income schemes, and early retirement) is essential to cushion the sudden loss of income. Sequencing and tailoring various income supports makes a

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[67] Caldecott et al. (2017).

[68] Diluiso et al. (2021).

[69] The impacts are most often measured at the local level (e.g. coal mining regions) or at the sectoral level (e.g. jobs in coal mining).

[70] See again the 2022 Council Recommendation on ensuring a fair transition towards climate neutrality for dedicated policy recommendations in this context.

huge difference in the long-term labour market reintegration. Generous early retirement can create disincentives to return to the labour market.

b. Providing active labour market policies will depend on the nature of the transition (frictional or structural unemployment, lack of labour demand).

c. Access to enabling services, such as continuous healthcare, childcare, social services.

Source: Based on Reitzenstein et al. (2021).

**In addition to providing support to individual workers, governments may also need to develop longer-term strategies to revive and diversify economic activity** in areas with high economic dependence on 'brown' activities. Regional economic development programmes have not always been successful in the past, but there are positive examples to draw on (see e.g. Box 5).

BOX 5. **SUCCESSFUL TRANSITIONS: THE CASE OF RUHR REGION**

In 1957, employment in the Ruhr's coal, iron and steel industries peaked at about 800,000 (around 70% of the region's total employment). Around 475,000 worked in coal mining. By 2007, there were only 24,000 still employed in Ruhr coal mining, accounting for less than 2% of total Ruhr employment. Despite the dramatic loss of over 400,000 jobs in coal mining, economic development and structural policy for the Ruhr area during this period managed to keep the total number of jobs in the region almost constant. The road to this relative success, however, was not straightforward.

Early attempts (up to the 1970s) supported the existence of the traditional industries in the region, because the relevant stakeholders (local businessmen, politicians, trade unions) regarded the decline of the coal and steel industry as a temporary crisis. Structural policy measures mainly aimed at preserving the coal industry through technological modernisation and by supporting workers, who faced continues income losses. Initial attempts focused on trying to find only one alternative (i.e., health sector) that would replace the coal and steel industry, which never really materialised.

The approach changed only towards the end of 1980s, with a refocusing of structural policy towards a sector-expertise oriented approach, in which different regions had differentiated areas of expertise. One key component was the development of the so-called "knowledge region" by establishing higher education institutions (first university opened in 1965) and creating technology centres. The repurposing of old and creation of new infrastructure in education, traffic, leisure (including culture) have improved the quality of life in the region.

Policies that contributed to the successful transition include:

- Consistent engagement of state and federal governments.
- Strong participation of social partners helped managing consensus and legitimation during times of major economic and societal changes.
- Public sector investment in supportive infrastructure, higher education and training, and fostering private sector innovation and entrepreneurship.
- Institutional cooperation (federal, state, local governments, employers, and unions) in managing the restructuring (especially since the mid-1980s).
- Effective active labour market policies, based on job transfer within companies, requalification, and support of transitioning into the service sector.

Despite the relative success of the transition, challenges remain. There are socio-economic differences between the southern Ruhr, where structural change started earlier and therefore is more developed, and the northern Ruhr, which is still characterised by higher long-term unemployment and a weaker economy. Furthermore, data on the total cost of the transition policy measures are not easily available.

Source: Based on Reitzenstein et al. (2021), Galgoczi (2014), Sheldon et al. (2018).

**There are cases where the transition was less successful.** The closure of the coal mines in the Belgian province of Hainaut left a lasting scar on the region's economy which once was the richest province but by 2010 it became the poorest in Belgium.[71] Mining was a significant contributor both to the enrichment of the province and its subsequent economic decline. Nowadays, the region is plagued by stubbornly high unemployment rates. The reasons for the failure are manifold - including persistent labour market rigidities[72] - that ultimately rendered regional policy efforts futile.

**Nevertheless, every transition experience is different, with local economic conditions playing a crucial role** (see also Box 3). In a tight labour market, where new jobs created are similar in skill requirements than the jobs that are destroyed, lower adjustment costs would be expected than in regions in which unemployment rates were already high before the closure of the mines.

**Even the type of previous brown industry has consequences on the transition.** For example, in case of coal, the risk of job losses is higher for lignite mining regions, because lignite is unprofitable to transport over long distances, so the consumption of coal has to happen also in the proximity (often in the form of power plants).[73] This means that the closure of mines would have an immediate impact on the downstream industries in the region, exacerbating the economic and labour market impact. The type of brown industry can also have a bearing on the skills sets of the workers in that industry, with relevant implications for the transferability of those skills to other industries.

**Soft location factors, such as connectivity, healthcare, education, culture, and leisure, can increase the attractiveness of regions in transition** to reduce outmigration or even attract new people, firms and industries.[74] Investment in these sectors can soften the sudden impact caused by the closure of a dominant sector in the region. Important connectivity investments include investment in transport, energy and telecommunication infrastructure.

**Involvement of policymakers at all levels is considered crucial** given that the impact of the green transitions is mainly felt at subnational levels, whereas the financial resources and expertise to address the transition are usually at national level (or higher).[75] Negative past experiences of insufficient support can increase mistrust and opposition against upcoming transitions. In general, a well-designed governance of change across the different levels of government and various stakeholders (including social partners) is essential in the transition processes.[76] Sniegocki et al. (2022) provide a review of public policies aimed at supporting the coal transition in Poland.

**The cost of these transition policies can be significant, but the cost of inaction is even higher.** Financing the transition can be expensive - in the order of magnitude of several billion euros - and a large part of the cost is born by central or regional governments. At the same time, the cost of not supporting the transition can be even costlier. For instance, evidence from Spain suggests that around 22 billion EUR have been spent in government subsidies just to support the profitability of mining activities during 1992-2014. Early retirement schemes also tend to be rather costly since they

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[71] Buyst (2019).

[72] The historically high wages prevailing in coal mining have pushed up labour costs in other industries and it proved very difficult to adjust these wages after the collapse of coal mining.

[73] Reitzenstein et al. (2021).

[74] Diluiso et al. 2021.

[75] Diluiso et al. 2021.

[76] Reitzenstein et al. (2021).

permanently remove active workforce. For example, in Spain the average age of retirement for former miners was 44 years, which would imply that such workers would cost half a million euro more to the state, compared to someone who would find another job.[77]

# 7. CONCLUSIONS AND POLICY IMPLICATIONS

**The green transition is set to be a driver of accelerated innovation and structural change towards a more environmentally friendly economy and society**. Brown sectors are likely to face reduced demand or will need to undergo structural transformation towards greener production processes. Green sectors and jobs are likely to expand. Most sectors are relatively neutral in terms of their environmental impact, however, and are expected to observe some changes at the task level at best to contribute to ambitions towards higher energy efficiency and reduced emissions per employee.

**Policy measures can accelerate the green transition by imposing regulation or introducing subsidies**. For example, recent evidence from the Netherlands suggests that the encouragement of green innovation through subsidies or regulations can bring about a shift from non-green to green jobs.[78]

**On aggregate, the number of jobs that would be lost in high-emission activities and with little chance of re-absorption of workers in other sectors is relatively small**. Likewise, the demand for new jobs that are specific to low-emission industries may remain relatively contained. The reason is that the vast majority of jobs are emission neutral, i.e., they are not highly specific to either green or brown activities.

**However, the gains and the costs of adjustment are likely to be unequally distributed.** Newly created green jobs are often more skills-intensive than brown jobs that are disappearing. Also, the phasing out of specific activities employing workers with skills hardly usable in other sectors, notably coal mining, is likely to have strongly concentrated regional impacts that need to be catered for by forward looking policy measures, that are decided on before the onset of economic disruption.[79]

**Understanding better which groups and regions are going to be particularly affected, is important to inform effective policy measures, targeted to where the highest needs arise.** It also helps policymakers anticipate possible tensions in society, which, if unaddressed, may lead to undesirable political outcomes (e.g. backlash against climate policy) and reduced trust in institutions (see for instance Vona 2019). Political backlash should be countered with evidence of positive health and employment effects of well-managed transitions and clearly communicated commitments on strategies to address distributional consequences.

**The green transition implies massive industrial transformation processes beyond brown and green jobs as defined in this paper.** Examples include the automotive sector where white jobs dominate according to our classification. There is unprecedented pressure for a rapid green transition – a much faster transition that we have seen in the past, therefore making it difficult to extrapolate into the future. In addition, transformation related to the green transition coincides with other structural

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[77] Caldecott et al. (2017).

[78] Elliott et al. (2021).

[79] See e.g. Healy and Barry (2017).

changes, such as the digitalisation of the economy. The latter may facilitate adjustment, but may also reinforce the obsolescence of certain occupations and skills. Improving the methodologies to classify green /brown jobs with a view on adjustment needs will refine the assessment of the green transition's labour market effects in the future.

**To facilitate the green transition, adequate and effective investment in education, training and skills will be key**. Young graduates will need to be equipped with strong transversal skills to navigate changes in their career and adjust to innovations. The demand for technical skills is expected to grow, due to an increased demand for innovation (research and development as well as implementation). In addition, to make the climate transition broad-based and impactful, reinforcing environmental awareness among citizens, workers and businesses will be key.[80]

**In addition, many workers that are already in the labour market may need to upgrade their skills to adopt more environmentally friendly practices or move away from brown jobs.** Public and private support is needed to help workers upskill and reskill. While certain forms of training can be done on the work floor, with support of employers, other types of training will need to be provided by public employment services, along with individualised matching support. In those regions that are particularly hit by structural change and extensive lay-offs (e.g. due to the closure of coal mines), effective collective dismissal policies should be in place, including early notification to regional public employment services. This would allow public employment services to start with skills audits and individualised job search assistance already at the time of notification (during the notice period). Targeted and temporary employment subsidies can help dismissed workers re-integrate more easily in other sectors and occupations.

**For workers who lose their jobs, inclusive social protection systems should be in place to help smoothing incomes, along with access to enabling services and support for activation.** Targeted income support schemes will also play a crucial role to help households cope with possibly high or less predictable energy prices in the energy transition.

**In those regions in which coal mines (or other brown industries) played a major economic role (geographic concentration), regional economic development policies may be needed to diversify the economy towards other sources of income.** Lessons from past transitions highlight the need to adapt to specific territorial assets, and the importance of strategies to strengthen investment (including public investment and public-private partnerships) and attractiveness (by providing access to healthcare, culture, education, etc.), optimising complementarities, efficient multi-level governance systems (with strong national level presence), and stakeholder involvement (including strong social dialogue). The new regional State aid Guidelines also offer an opportunity to Member States to support their least favoured regions and reduce regional disparities, while ensuring a level playing field between Member States.[81]

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[80] For more details, see e.g. GreenComp: the European sustainability competence framework (europa.eu). Furthermore, Martinez-Fernandez et al. (2013) define green skills as "the skills needed by the workforce, in all sectors and at all levels, in order to help the adaptation of products, services and processes to the transformations due to climate change and to environmental requirements and regulations." See. CEDEFOP (2022) defines skills for the green transition as the "the knowledge, abilities, values and attitudes needed to live, work and act in economies and societies seeking to reduce the impact of human activity on the environment". The ESCO database gives a classification of green skills that are market oriented: https://esco.ec.europa.eu/en/home.

[81] See EUR-Lex - 52021XC0429(01) - EN - EUR-Lex (europa.eu).

**The 2022 Joint Employment Report highlights remaining weaknesses in policy institutions that are crucial to support the transition.**[82] For example, significant differences remain across Member States with respect to participation in adult learning, particularly for unemployed. Participation in early activation measures among registered unemployed and collective dismissal regulations vary widely as well. Moreover, often, these institutions are less well developed and/or resourced in those countries with higher remaining adjustment needs than in others, creating a rationale for EU policy support to alleviate the social impact of the green transition.

**The Commission has put in place various instruments to support Member States in making an inclusive transition.** In particular, there is the Just Transition Fund and the European Globalisation Adjustment Fund that are particularly aimed at helping workers make the transition to new jobs after collective dismissals. The programming of territorial plans is currently ongoing. The Modernisation Fund supports ten Member States to meet 2030 energy targets by modernising energy systems and reinforcing energy efficiency.[83] Other European Structural and Investment Funds can also help in different ways (e.g. ESF to fund active labour market policies, ERDF to finance necessary public infrastructure and training). The Commission has also provided technical support to help regions transition out of coal, e.g. through the Structural Reform Service,[84] the Initiative for Coal Regions in Transition,[85] or through Horizon2020 support to develop new development strategies for coal-intensive regions.[86]

**More recently, the Recovery and Resilience Facility, reinforced by RepowerEU, offers support for the green transition, in particular support to accelerate the conversion to renewables**. For example, the Czech national recovery and resilience plan includes investments to replace part of the coal-fired energy sources by photovoltaic power plants, alongside measures to better target active labour market policies to vulnerable groups, promote up- and reskilling, and set up regional innovation and business hubs to promote entrepreneurship. The Romanian plan includes measures to promote renewables and alternative energy sources, such as green hydrogen, to accelerate the decarbonisation of the energy sector, along with the reinforcement of active labour market policies, social protection, and education and training systems.[87] In the short term, nevertheless, efforts to reduce fossil fuel dependency on Russia, in view of the war in Ukraine, could involve delays in the phasing out of coal plants in some Member States.

**Finally, while adjustment costs may be high, non-action is also likely to be costly.** Costs would not only arise in terms of immediate climate and health effects, but also because of postponing a conversion towards higher-value activities, which is set to benefit the economy in the longer run. The urgency of policy action is not only underlined by the ambitious climate-related objectives that the

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[82] See https://ec.europa.eu/info/sites/default/files/economy-finance/2022_european_semester_proposal_for_a_joint_employment_report_0.pdf.

[83] https://modernisationfund.eu/.

[84] See e.g. https://ec.europa.eu/info/files/supporting-transition-coal-energy-slovakia_en for an example for Slovakia’s Horna Nitra region. Other regions receiving assistance along these lines include Greece's Western Macedonia region and Romania's Jiu Valley.

[85] See https://energy.ec.europa.eu/topics/oil-gas-and-coal/eu-coal-regions/initiative-coal-regions-transition_en.

[86] See e.g. TRACER (https://tracer-h2020.eu/) or CINTRAN (https://coaltransitions.org/projects/cintran/).

[87] See https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/assets/thematic_analysis/1_Clean.pdf and https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/assets/thematic_analysis/4_Employment.pdf.

Commission has committed too, but also by economic conditions. In particular, the adjustment costs are set to be lower during periods of tight labour markets (as at the current juncture) compared to economic downturns.[88] In many Member States, and particularly in those that still have remaining coal mining activities, unemployment is currently at an all-time low, even if there are risks on the downside in view of the consequences of the Russian war in Ukraine and increased economic uncertainty. The tight labour market creates a window of opportunity for phasing out highly polluting activities.

[88] See e.g. Hardoy and Schone (2014).

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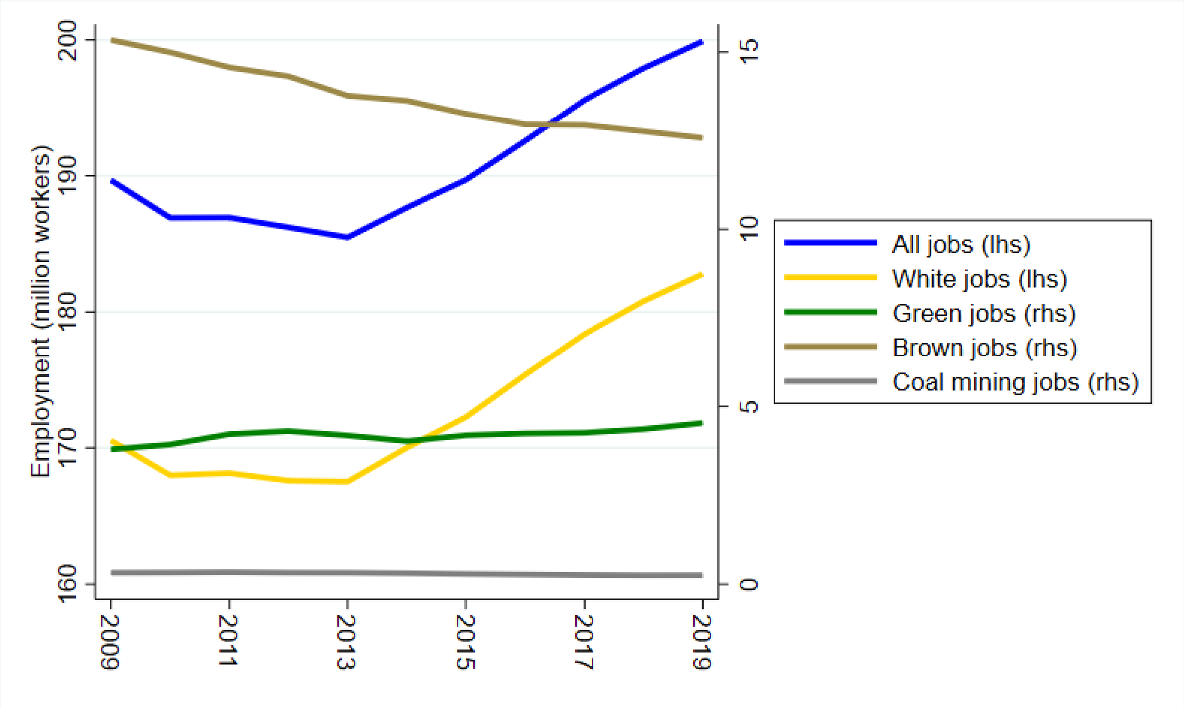
# ANNEX

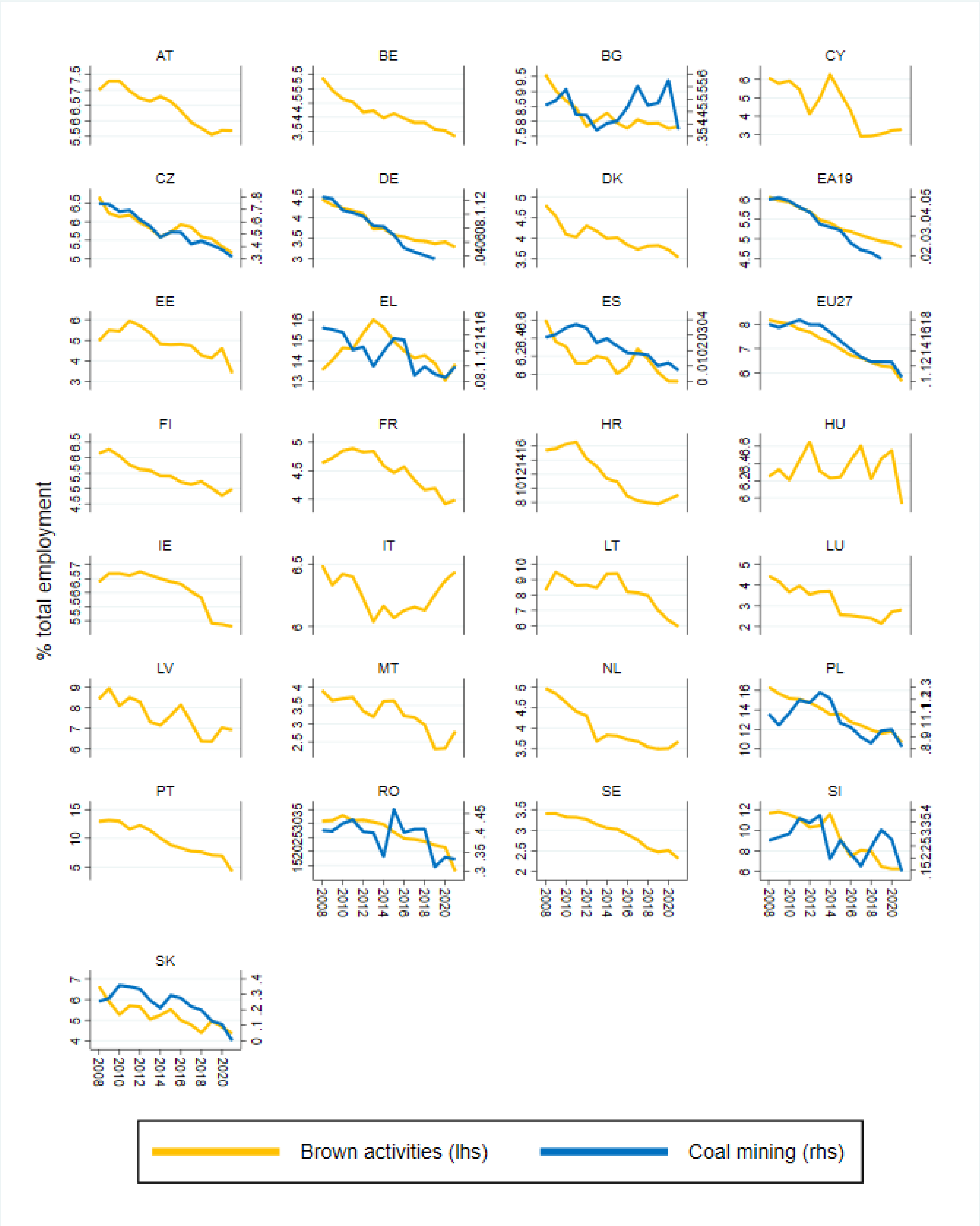
Figure A.1: **Evolution of white, green, brown, and coal mining jobs, EU27, 2009-2019**




Note: Figures shown are merely approximate, as data on different job types originate from different data sources. As a result, there could be overlap between different types of jobs, which is not corrected for in this figure. Future work is planned to develop a methodology to identify green jobs based on occupational categories in the EU-LFS. This will allow for better comparisons of employment dynamics in the different categories.

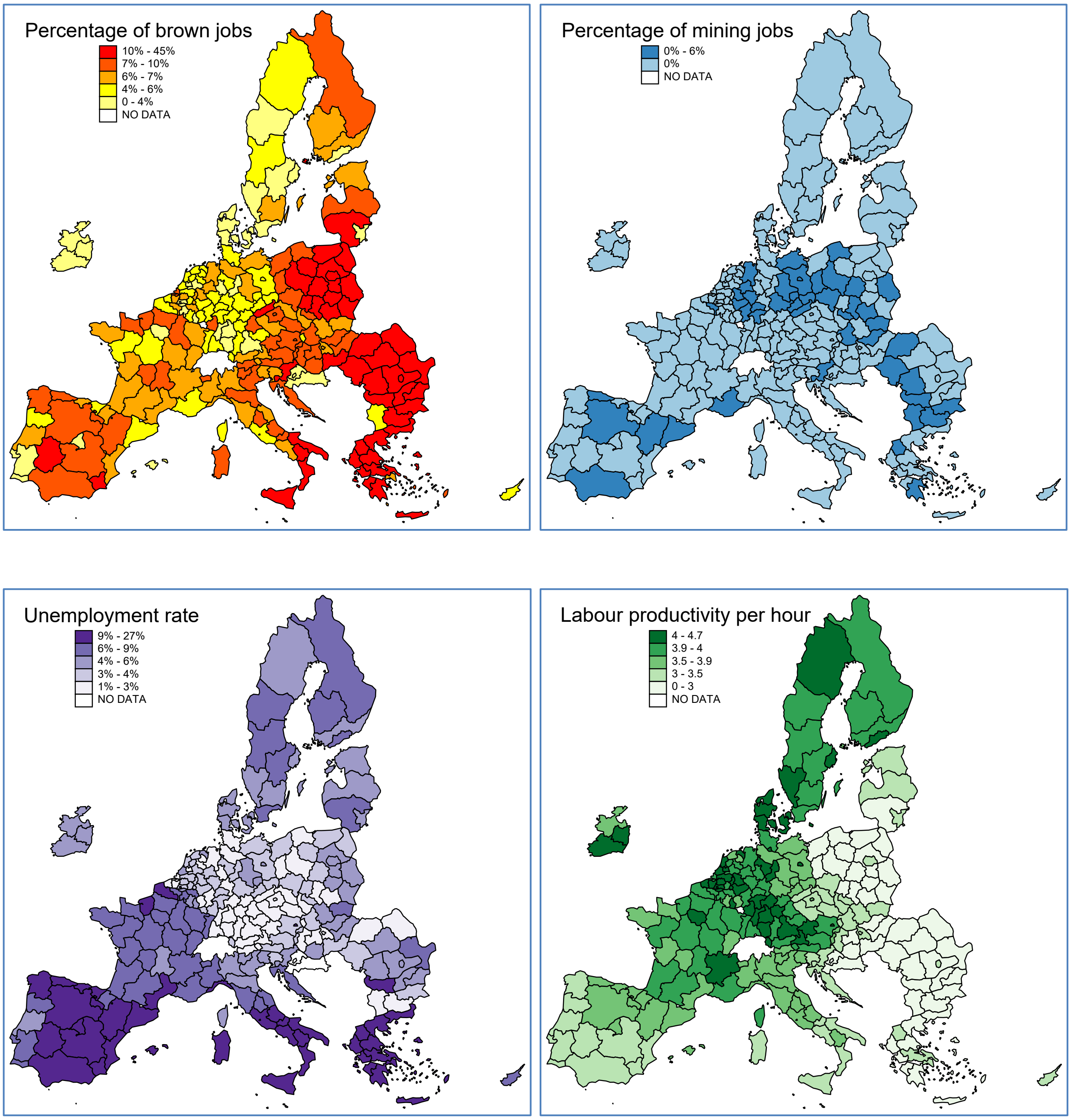
Source: EU-LFS [lfsa_egan22d], AEA.

Figure A.2: **Employment in 'brown industries' and coal mining across Member States**




Source: EU-LFS [lfsa_egan22d], AEA.

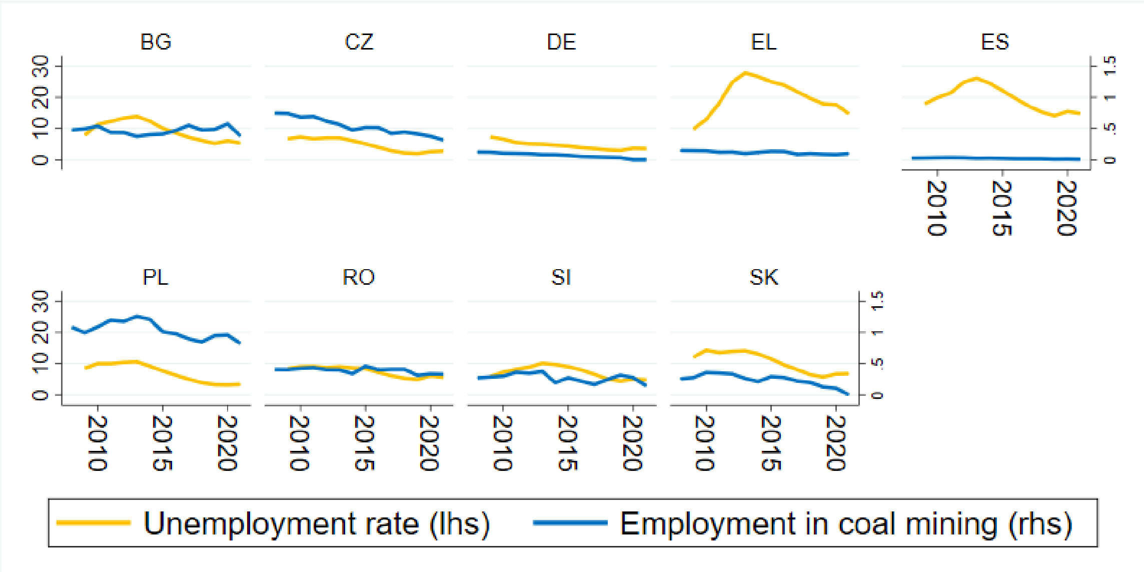
Figure A.3: **Regional distribution of 'brown' job and labour market conditions**




Note: The graphs present the regional distribution of brown jobs, of coal mining jobs, and of labour market conditions (unemployment rate, log(nominal labour productivity per hour worked)). Brown jobs are defined according to the definition presented in Figure 3. Mining jobs refer to jobs in coal and lignite mining. Data refer to the share of brown (resp. mining) jobs out of total employment. The unemployment rate follows the standard definition (age group 15-74, ESTAT variable lfst_r_lfu3rt). Labour productivity is expressed as the log of nominal hourly labour productivity and based on national accounts data (ESTAT variable nama_10r_2nlp).

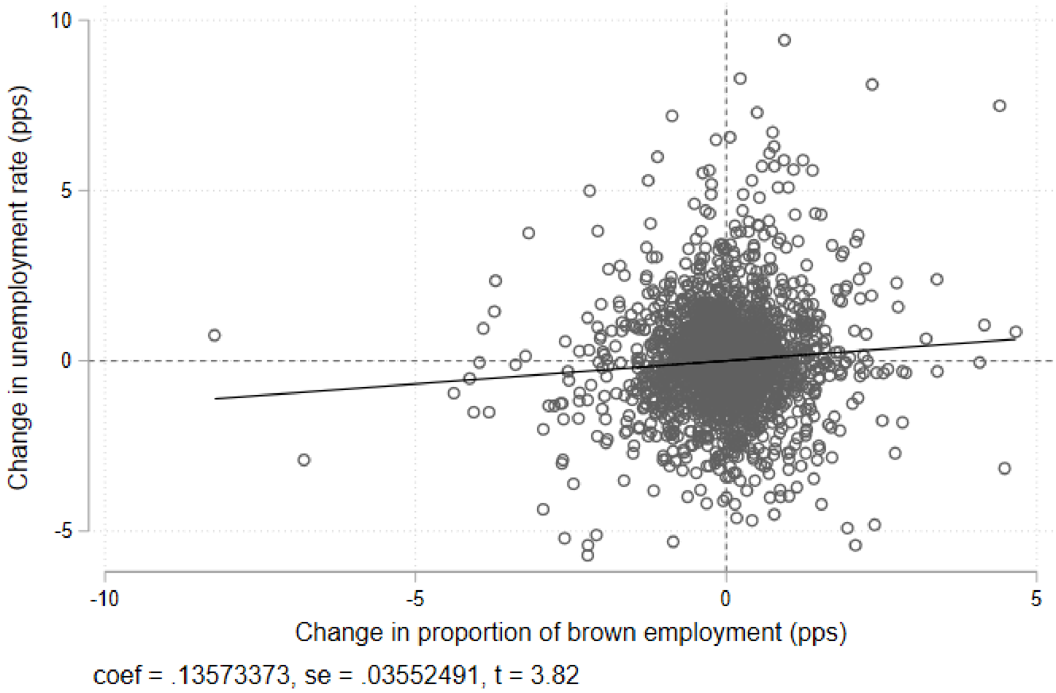
Source: LFS, AEA, national accounts data provided by ESTAT.

Figure A.4: **Evolution of unemployment rate and employment in coal mining**




Source: EU-LFS.

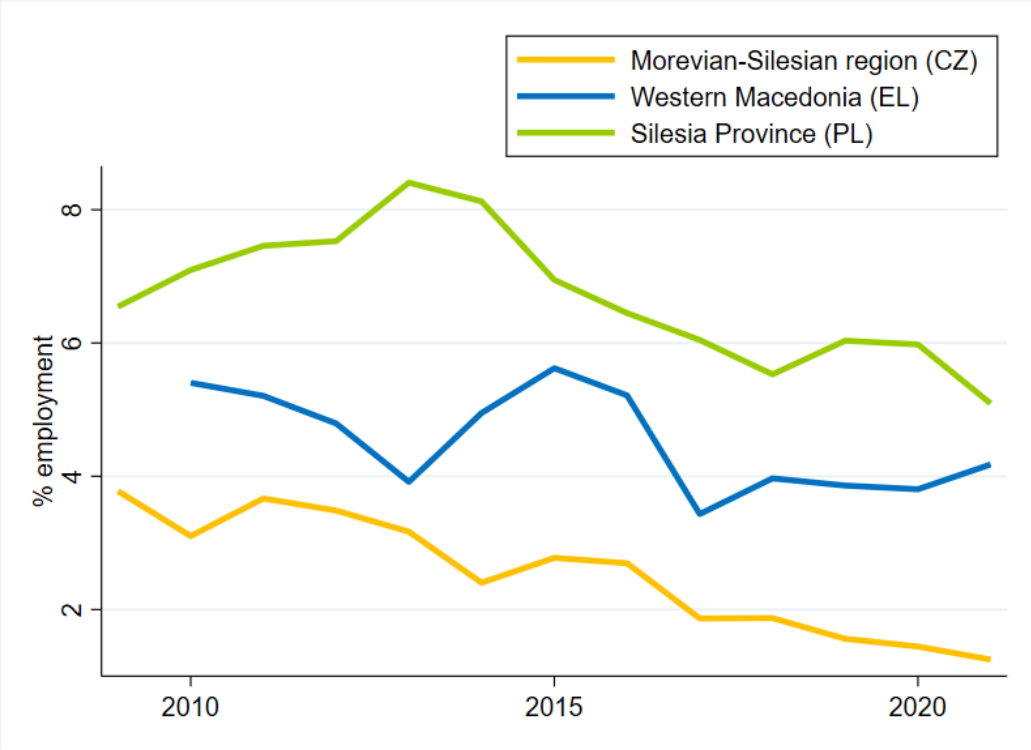
Figure A.5: **Scatter plot and linear fit of change in unemployment rate versus change over 2009-19 in proportion of brown employment out of total employment**




Note: The dots in the scatter plot represent regional observations of changes between 2009 and 2019, after controlling for country fixed effects.

Source: Commission calculations based on EU-LFS and AEA data.

Figure A.6: **Trends in coal mining employment in the EU NUTS2 regions with the highest remaining employment share in coal mining**




Note : EU-LFS (special extraction).

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