The “clean energy transition” and the cost of job displacement in energy-related sectors*

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Abstract

To mitigate the impacts of climate change and boost sustainable growth, many developed countries are transitioning towards cleaner energy systems. Despite this global process is expected to impact job reallocation in important ways, little is known on the economic consequences of job loss for workers in declining energy-related industries. This paper provides the first comprehensive analysis of the consequences of job displacement in energy-related sectors across 9 OECD countries. Based on harmonised linked employer-employee register data and a mass-layoff design, we estimate the effect of job displacement on labour market outcomes in energy-related sectors (energy supply, industrial demand, and transport) compared to non-energy-related sectors. We find that workers displaced from energy supply and industrial demand sectors experience larger earnings losses compared to workers in non-energy-related and transport sectors. Across countries and sectors, there is considerable variation in earnings losses, re-employment probabilities and wages, and days worked. On average, the higher displacement losses in energy-related sectors can be mainly attributed to differences in days worked and re-employment wages, the latter of which is driven by a loss of firm-related wage premia. Workers in industrial demand and energy supply sectors are also more likely to undergo costly sectoral and occupational switches.

Keywords: mass layoffs, firm closure, green transition, structural change, energy sector

JEL codes: J31, J63, Q43

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1. Introduction

1. Across the OECD, economies are transitioning towards greater carbon- and resource-efficiency to mitigate the impacts of climate change and promote sustainable growth. At the heart of these processes is the energy sector, which has been seeing profound restructuring of energy systems to realize the "*clean energy transition*" or "*green transition*". This ongoing transformation is expected to continue at increased speed and intensity in the years to come via the phasing-out of fossil fuels and the adoption of cleaner technologies in energy production (energy supply), the use of more energy-efficient technologies in energy-intensive processes in transport and production (energy distribution and demand), and the reduction of greenhouse gas (GHG) emissions not related to the production and use of energy, notably in agriculture.

2. The transition towards more sustainable energy systems, as part of the broader effort to combat climate change, has already initiated significant changes in the energy sector. While this shift opens new opportunities in green renewable and nuclear energy sectors (see e.g., Borgonovi et al. (Borgonovi, et al., 2023)), it also increases the risk of the destruction of jobs in fossil-fuel-based industries, potentially undermining public support for climate policies. This restructuring in labour markets is expected to result in persistent and significant earnings losses for displaced workers in declining industries due to lower wages in re-employment and challenges in transferring skills to new industries and occupations. While in the period considered (2000-2019) energy-related sectors account for a large share of the labour force (10% in our sample), little is known about the economic consequences of job loss in energy-related declining industries.

3. This paper provides a comprehensive analysis of the causal effect of job loss on labour market outcomes in energy-related sectors by using rich administrative registers and a harmonized design for nine OECD countries (Austria, Estonia, Finland, France, Germany, Hungary, Portugal, Spain, and Sweden). Although this study relates to a growing literature that studies technological change in a broad sense, to date no study has analysed the consequences of the green transition for different types of workers across countries. Having a unified cross-country approach is important in this context because to be effective globally, the green transition requires policy efforts coordinated across countries. Since countries are at different stages of this ongoing societal transformation, it is key to compare the consequences of job loss in different labour markets, so that Member States and the general population are well informed on costs and benefits associated with the green transition. Therefore, in the spirit of Bertheau et al. (Bertheau, et al., 2023), who have recently shown that a precondition to understand cross-country differences in job loss effects is to use fully harmonized data, definitions and methodology across the different labour markets considered, we use of a unified approach in our analysis.

4. The remainder of the paper is structured as follows. Section 2 outlines the measurement of energy-related sectors, presents the national data sources will be used for the main analysis, and discusses the harmonization process to ensure their comparability across different countries. In Section 3, we detail our framework for estimating the consequences of job displacement across sectors. Section 4 presents our main results for various energy-related sectors and the broader economy. Section 5 concludes.

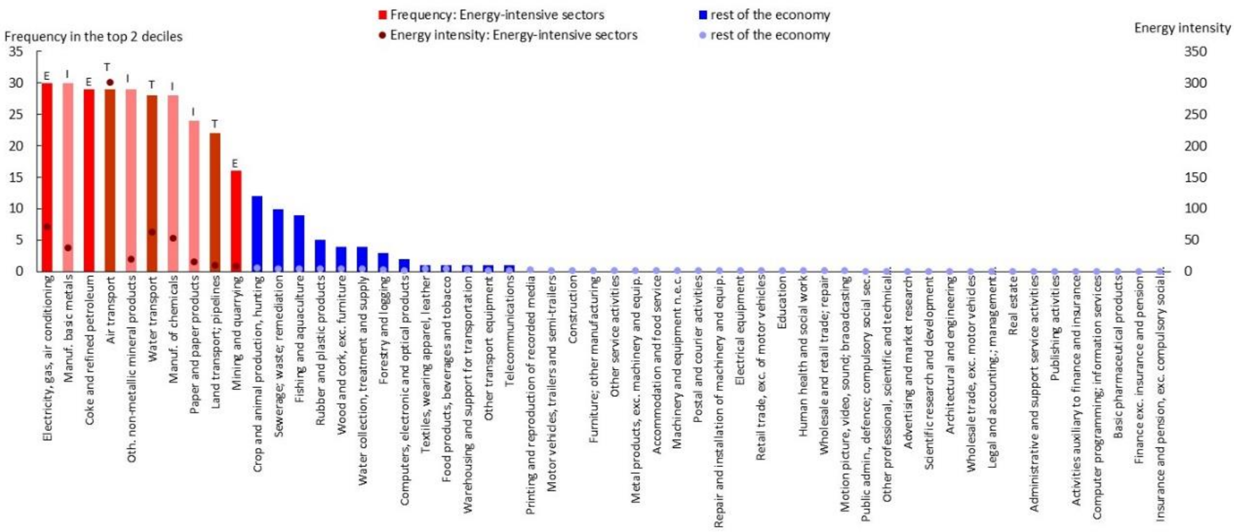
2. Data sources and sampling restrictions

Defining energy-related sectors

5. For the harmonized definition of energy-related sectors across countries, we follow previous work by Barreto, Kril and Grundke (Barreto, Kril, & Grundke, 2023) for Germany. We rely on the NACE 2-digit level and define energy-related sectors as those that appear in the top two deciles energy-intensity distribution in at least 10 countries (Figure 1). Energy-intensity is defined as the total gross energy use in terajoule (TJ) per unit of value added, based on information from the World Input-Output Database Environmental Accounts over the period 2000-2014, including information on gross energy use by source (such as coal, coke, petroleum, diesel, renewables and nuclear, etc.) (European Commission JRC, 2019).

Figure 1. Classification of energy-related sectors

Energy intensity within 2-digit NACE sectors and frequency in top 2 deciles across 30 OECD countries



Note: The figure shows on the left axis the frequency with which a particular industry is ranked among the top 20% of most energy-intensive industries across European countries as well as on the right axis the average energy use across countries expressed in TJ per unit of value added. E refers to energy supply sectors, I refers to industrial demand sectors and T refers to transport sectors.
Source: World Input-Output Database Environmental Accounts

6. We also provide a more disaggregated version of energy-related sector by splitting it into three industry groups: energy supply sectors (E) ii) industrial sectors that are intensive in energy demand (I); iii) transport sectors that are intensive in energy demand (T).

Data sources and harmonisation

7. Our analysis makes use of harmonised linked employer-employee data for 9 OECD countries: Austria, Estonia, Finland, France, Germany, Hungary, Portugal, Spain, and Sweden (see Table 1). For each country, the data is derived from administrative records designed for tax or social security purposes or, in a few cases, mandatory employer surveys. Each of these datasets are panels that contain either the full population or a large random sample of workers. Every year, each worker is linked via unique firm and

worker identifier to their employer, industry, and occupation. The data contains rich information on demographics and labour market outcomes described below. The resulting dataset generally covers the years 2000 to 2019. We stop in 2019 to avoid confounding effects of the COVID-19 pandemic. Table 1 shows the data sources, data structure, and time coverage for each country.

Table 1. Data sources

Country	Name	Earnings data source	Data structure	Time coverage
Austria	AMS-BMASK Arbeitsmarktdatenbank	Social security administration	Universe	2000-2019
Estonia	Data from the Tax and Customs Board Register	Tax administration	Universe	2003-2019
Finland	FOLK employment data from Statistics Finland, Employer Payroll Report from Tax Admin.	Tax administration	Universe	2000-2019
France	Panel DADS	Social security administration	1/12 % random sample of workers	2002-2019
Germany	Integrierte Erwerbsbiographien (IEB)	Social security administration	Universe	2000-2019
Hungary	ADMIN –I - Panel of administrative data (OEP, ONYF, NAV, NMH, OH)	Social security administration	50% random sample of workers	2003-2017
Portugal	Quadros de Pessoal	Mandatory employer survey	Universe	2002-2019
Spain	Muestra Continua de Vidas Laborales con Datos Fiscales (MCVL-CDF)	Social security and tax administration	4% random sample of workers	2006-2019
Sweden	Longitudinell integrationsdatabas för sjukförsäkrings- och arbetsmarknadsstudier (LISA), Företagens ekonomi (FEK), Jobbregistret (JOBB)	Social security administration	Universe	2002-2018

8. To ensure that the results are meaningfully comparable across countries, each of these linked employer-employee panel dataset is harmonized according to common definitions and sampling restrictions. Each year the primary employment spell is defined based on the highest earnings of a worker from a single employer.[1] An employer refers to the establishment whenever possible, or firm otherwise. Worker tenure at these employers is measured as the duration of continuous employment with the current employer.

[1] If a worker has several jobs with identical total earnings, the spell that occupies most of the worker's time is selected. If total time also identical or no information on working time is not available, the primary job is based on a random draw among those with the highest total earnings (or time worked).

9. We sample workers aged 18-60 years, excluding apprentices and self-employed individuals as well as employment spells with implausibly low and high daily wages.[2] In addition, in countries with information on hours worked, we exclude spells with unusually long working hours (more than 60 weekly hours). We focus on mass-layoff events in the private sector.

10. Earnings are defined broadly, encompassing gross (before-tax and social security contributions) labour income, which includes regular pay, overtime, and bonuses. In countries where earnings are censored above a certain ceiling (e.g., Germany and Spain), earnings are imputed following the procedure proposed by Card et al. (2013). All monetary values are expressed in real terms using the Consumer Price Index with 2015 as the base year.

11. Based on the earnings information, we compute a set of harmonized outcomes. Yearly earnings refer to the sum of labour payments each year (potentially, from different employers). Daily wages are calculated as the ratio of annual earnings and days worked at the main employer each year. As is standard in the job displacement literature, we assign zero earnings and missing daily wages in non-employment spells i.e., in the years where no earnings from any employer are recorded in the data.

Descriptive statistics

12. The resulting dataset covers between 8.9 million observations in Spain (random sample of 4% of workers) and 64 million observations in Austria (universe of workers) (Table 2). The energy-related sector covers up to 10% of employment. Workers in energy-related sectors are more likely to be male, are slightly older, have longer tenure, are more likely to work in high paying firms (have higher AKM fixed effects). Employment in energy supply and industrial demand has been on a declining trend, whereas employment in the rest of the economy and, in some countries also transport, has tended to expand.

13. The number of displaced workers in the estimation sample varies considerably across sectors and countries due to, amongst others, differences in sample size (see Table 1), employment shares, and employment trends. While the number of displaced workers tends to be smallest in energy supply. The small number of displaced workers means that the estimates of job displacement for these sectors should be interpreted with caution, notably for France and Spain. In practice, we exclude country-sector combinations with fewer than 100 layoffs over the analysis period.

[2] This is, we remove any employment spells that fall below 80% of the minimum wage or 20% of the median earnings, as well as those that are in the top 0.1% of the daily wage distribution. We also drop employment spells with missing earnings information. Firm FE obtained from AKM regressions with log daily wage as outcome (see Section 3).

Table 2. Summary statistics of estimation samples by country

Country	Number of workers	Age	Share of women	Tenure (years)	Firm size	Log daily wage	Firm FE	Total number of displaced workers	Share in total employment	Employment change (first year - last year)
Panel A. Energy supply										
AUT	667078	41.0	17.4	10.1	566.6	4.8	0.1	330	1.0	-8.3
DEU	657769	43.5	20.1	10.0	794.0	5.0	0.3	769	1.2	-26.5
ESP	39148	44.1	15.0	7.0	328.9	4.5	0.6	49	0.4	-21.2
EST	230561	46.1	24.0	3.8	1209.9	3.5	0.3	72	2.2	-35.9
FIN	211676	43.1	19.7	7.3	1390.1	4.7	0.1	579	1.0	-18.0
FRA	296082	42.4	23.4	8.7	351.1	4.8	0.1	27	1.0	-40.8
HUN	298148	43.6	25.0	5.4	1454.5	9.3	0.4	280	2.5	-46.1
PRT	376325	44.1	13.5	14.8	1223.1	3.9	0.4	181	0.8	-19.2
SWE	616677	44.9	22.8	7.2	948.7	7.0	0.1	349	1.0	22.2
Panel B. Industrial demand										
AUT	2187947	39.1	19.2	7.2	533.7	4.7	0.2	2257	3.2	-1.1
DEU	1889689	43.0	19.5	11.0	2070.1	4.7	0.2	1471	3.4	-16.9
ESP	178322	43.0	18.0	7.2	354.8	4.2	0.4	368	1.9	-25.8
EST	152457	41.8	29.8	3.6	229.0	3.3	0.2	347	1.5	10.0
FIN	583211	42.3	29.5	7.5	473.3	4.7	0.1	1298	2.7	-28.2
FRA	615454	42.5	24.8	7.6	424.6	4.5	0.1	535	2.1	-84.2
HUN	495914	40.8	30.7	4.8	955.1	9.0	0.2	1821	4.2	-14.4
PRT	1330858	41.4	27.4	11.2	207.4	3.4	0.1	2359	2.8	-18.7
SWE	1743199	43.9	20.8	8.8	1069.4	6.9	0.1	1966	2.8	-18.3
Panel C. Transport										
AUT	2274279	39.8	18.8	4.5	282.0	4.3	-0.1	2280	3.3	36.0
DEU	1192494	43.4	19.1	7.0	1234.5	4.3	-0.1	806	2.2	21.0
ESP	260186	44.6	13.0	7.0	722.2	4.0	0.1	218	2.8	-0.6
EST	395484	45.2	18.2	2.8	250.1	3.0	-0.1	413	3.9	19.2
FIN	1755341	40.8	28.6	6.8	317.2	4.7	0.1	1789	8.0	-18.6
FRA	1067456	41.5	19.2	6.5	1033.5	4.4	0.1	542	3.7	-45.7
HUN	806394	43.0	20.2	4.9	10622.4	8.8	0.1	596	6.9	-19.9
PRT	1604742	41.9	13.7	8.2	925.1	3.4	0.1	1909	3.4	36.5
SWE	2089693	44.5	15.6	5.5	1052.0	6.8	0.0	1664	3.4	18.5
Panel D. Rest of economy										
AUT	6.29E+07	37.7	48.4	5.2	375.2	4.3	0.0	63805	91.5	34.1
DEU	5.09E+07	41.4	46.5	7.7	834.1	4.4	0.0	43382	92.4	5.8
ESP	8069335	41.9	46.4	5.5	556.5	3.9	0.0	5999	88.0	6.2
EST	9271452	41.4	53.3	2.8	644.3	3.2	0.0	9159	90.3	7.8
FIN	1.92E+07	39.8	44.9	5.7	1777.2	4.5	0.0	31257	87.9	42.9
FRA	2.65E+07	39.6	49.3	4.9	621.6	4.3	0.0	14416	92.2	-27.5
HUN	9754983	38.9	45.7	4.1	2335.9	8.8	0.1	27379	83.0	-0.6
PRT	4.30E+07	38.6	48.2	6.9	1019.6	3.2	0.0	54723	91.2	30.1
SWE	5.70E+07	43.3	46.8	7.1	4297.6	6.8	0.0	41342	92.1	23.2

Note: Sample means and totals over the time coverage of each dataset.
Source: National linked employer employee data, see Table 1 for details.

3. Methodology

Job loss definition

14. We define job loss due to mass layoff events, and we follow the standard approach in the job loss literature by comparing the labour market histories of workers who lose their job in different sectors in correspondence of plant closures or mass layoffs to the outcome trajectories of observationally similar workers in the same sectors who do not experience such an event. The analysis is therefore performed in two steps. As it is customary in the literature (Jacobson, Lalonde, & Sullivan, 1993; Lachowska, Mas, & Woodbury, 2020; Schmieder, von Wachter, & Heining, 2023), we first match observationally identical displaced and non-displaced workers. Afterwards, we use the sample of displaced workers and matched comparison workers to estimate displacement effects in an event study framework. Our specific job loss design follows closely the one recently adopted by Schmieder, von Wachter and Heining (2023[9]) and Bertheau et al. (2023).

15. The analysis focuses on job displacement as a result of *mass-layoff* events, which ensures that separations are plausibly exogenous and involuntary, therefore unrelated to the performance of workers or their career plans. To identify mass layoff events in the data, we follow Schmieder, von Wachter and Heining (2023[9]) and Bertheau et al. (2023) and define a mass layoff as an event in which employment declines between one year to the next by at least 30% in establishments with at least 30 employees and including entire closures. Moreover, to avoid contaminating our measures of mass layoffs with restructuring events (e.g. mergers and acquisitions), we impose the restriction that no more than 30% of displaced employees move to the same establishment following the event (Hethey-Maier & Schmieder, 2013).

16. Having defined mass layoff events, we define treated workers as those who separate from their employer in the year a mass layoff takes place and are not recalled in the subsequent five years. In practice, we focus on workers aged 50 or less with at least 2 years of tenure in the baseline year (the year of mass layoff). The tenure restriction aims at identifying separations among workers who arguably had stable employment trajectories in their origin employer. Each treated worker is treated only once (only the first event is taken into account), consistent with the idea that displacement represents a permanent shock to its labor market trajectory.

Balancing treatment and controls

17. The outcomes of workers who are displaced between one year and the next as a result of mass layoff (treated) are compared with those of non-displaced workers (control) who satisfy the same restrictions in the year immediately before displacement. Non-displaced control workers are allowed to be co-workers of displaced workers and may separate from their employer in subsequent years for any reason except a mass layoff event.[3]

[3] The latter prevents "forbidden comparisons" of treated units with units that were already treated (de Chaisemartin & D'Haultfœuille, 2020; Callaway & Sant'Anna, 2021); the former avoids overestimating displacement effects when restricting the control group to workers who remain continuously employed (Krolikowski, 2017).

18. As displaced and non-displaced workers may differ in their observable characteristics, each displaced worker is matched to an observationally identical non-displaced worker through a 2-step matching procedure. First, we use exact matching by baseline year, 1-digit industry (ISIC rev4) and energy-related sector and sex. In the second step, we estimate a propensity score separately for each cell using a probit model of job displacement on observable characteristics, including log daily wages in the three years prior to displacement, log employer size, age, and tenure (all included contemporaneously). After the implementing this matching procedure, matched treatment and control workers have similar observable characteristics as shown by standardized differences below a value of 0.1 (Austin, 2011) (see Table 3).

Table 3. Balance table

Standardized differences between displaced and matched non-displaced workers

Variable	Country								
	AUT	DEU	ESP	EST	FIN	FRA	HUN	PRT	SWE
Panel A. Energy supply									
Log daily wage (c-1)	0.05	-0.02	-0.02	-0.04	-0.01	0.02	-0.06	0	0.03
Log daily wage (c-2)	0.06	0	-0.01	-0.08	0	0	-0.06	-0.01	0.06
Log daily wage (c-3)	0.03	0	0.05	-0.08	-0.01	0	-0.05	0.01	0.01
Age	0.05	0.01	-0.02	0.02	0	-0.02	-0.05	0.02	0.01
Job tenure	0.02	0.02	-0.05	0.06	0.02	0.04	0.03	0.07	0
Log employer size	0.08	-0.02	0.09	0.16	0.03	0.02	-0.03	0.1	0.03
Observations	493	920	72	133	879	32	365	234	510
Panel B. Industrial demand									
Log daily wage (c-1)	-0.03	0	0.01	0.03	0.01	-0.04	-0.01	0	0.01
Log daily wage (c-2)	-0.02	0	0.01	0.02	0.02	-0.03	-0.01	0.01	0
Log daily wage (c-3)	-0.01	0	0.01	0.02	0.02	-0.04	-0.01	0.01	0
Age	-0.01	0	0.02	-0.02	0	0	0.01	0	0
Job tenure	0.01	0	0.01	-0.01	-0.01	0	0.01	0	-0.01
Log employer size	0.03	0.01	0.07	0.03	0.03	-0.01	0.05	0.03	0
Observations	3,170	2,025	498	488	2,069	799	2,605	3,270	2,857
Panel C. Transport									
Log daily wage (c-1)	0	-0.02	0.02	0.05	-0.01	0.02	-0.01	-0.03	-0.01
Log daily wage (c-2)	0	-0.01	0.03	0.05	-0.02	0.02	-0.01	0.01	0.02
Log daily wage (c-3)	0	0	0.02	0.04	-0.01	0.02	0	-0.01	-0.02
Age	0.01	0	0.01	-0.02	0.01	0.01	-0.01	0.01	-0.03
Job tenure	-0.02	-0.03	0.01	0.03	0	-0.04	-0.04	0.01	0
Log employer size	0.02	0	-0.01	0.03	-0.01	0.03	0.1	0.07	0.04
Observations	2,867	1,054	378	518	2,340	723	810	2,453	2,282
Panel D. Rest of economy									
Log daily wage (c-1)	-0.01	0	0	-0.01	0	0	0.02	-0.02	-0.01
Log daily wage (c-2)	-0.01	0	0	-0.01	0	0	0.02	-0.02	-0.01
Log daily wage (c-3)	-0.01	0	0	-0.01	0	0	0.03	-0.02	-0.01
Age	0	0	0.01	0	0	0	0.01	0	0
Job tenure	-0.01	-0.01	0.01	0.02	0	-0.01	0.01	0	-0.01
Log employer size	0.01	0.01	0.03	0.07	0.02	0	0.07	0.02	0.02
Observations	79,020	58,488	7,962	12,458	42,304	17,704	35,867	65,930	56,354

Note: Exactly matched characteristics (e.g. gender, sector) are omitted as balanced by construction. See Table 1 for details.

Event study design

19. We rely on an event study design to compare the outcomes of displaced and non-displaced workers before and after displacement separately for each energy-related sector and the rest of the economy, using the equation below:

$$y_{itc} = \alpha_i + \lambda_t + \sum_{k=-4}^{5} \gamma_k 1\{t = c + 1 + k\} + \sum_{k=-4}^{5} \theta_k 1\{t = c + 1 + k\} \times Displaced_i + X'_{it}\beta + r_{itc}$$

where y_{itc} is the outcome of worker *i* belonging to cohort *c* of displaced workers and matched controls at time *t*. The coefficients of interest θ_k capture the change in outcome of displaced workers relative to the evolution of outcome of non-displaced workers in the same sector, where *k* indexes event time such that *k=0* is the first post-displacement year and -1 the baseline year. The coefficients are normalized to *k=-3*, such that the effects are measured relative to that time. The worker fixed effect α_i controls for time-invariant unobserved worker heterogeneity, λ_t is a calendar year fixed effect and X'_{it} contains age squared. The worker fixed effect α_i controls for time-invariant unobserved worker heterogeneity, λ_t is a calendar year fixed effect, γ_k a time since event fixed effects and X'_{it} contains a cubic of age. Finally, r_{itc} is the idiosyncratic error term. Standard errors are clustered at the worker level.

20. The main outcomes of interest that will be considered include yearly earnings relative to pre-displacement average, the probability of being employed, log daily wages and employer-specific wage premia. In addition, the probability of changing industry (2-digit NACE), occupation (3-digit ISCO) or region (NUTS-2) will also be considered.

Estimating employer-specific wage premia

21. Employer-specific wage premia are estimated on the largest connected set of employers following the two-way fixed effect model of Abowd, Kramarz and Margolis (1999). In practice, we estimate the following model:

$$w_{it} = \alpha_i + \psi_{J(i,t)} + \gamma_t + \theta X_{it} + \epsilon_{it}$$

where w_{it} is the log wage of worker *i* in year *t*. Worker fixed effects for each worker *i* are captured by α_i, while $\psi_{J(i,t)}$ captures the firm fixed effects which reflect employer-specific wage premia in each of establishment (firm) *J* of worker *i* in year *t*. Year fixed effects are captured through γ_t, while X_{it} includes a cubic in age interacted with gender dummies. In the estimation of this model, we exclude post-displacement observations of treated and matched control units to avoid these transitions from impacting the estimation of firm effects.

Decomposing earnings losses into wage and employment losses

22. To provide an indication of the different components behind annal earnings, we a decompose annual earnings y for a given worker into the components that can be attributed to the probability of being employed in the year p, the number of days worked N_D, and the daily wage w. Taking expectations over

the samples of displaced and non- displaced workers, we can express the earnings losses of a displaced worker (D) related to the control group (S) in each time period after the event as:

$$E[\Delta] = E[p^s N_D^S w^s] - E[p^D N_D^D w^D]$$

Rearranging terms gives:

$$E[\Delta] = E[p^D]E[N_d^D]\Delta E[w] + E[p^S]E[w^S]\Delta E[N_d] + E[w^S]E[N_d^D]\Delta E[p] + \mu$$

where the first term gives the contribution of daily wage changes to annual earnings changes relative to the control group, and the second and third term that of days worked and employment probability, respectively. Finally, the term μ is a residual which captures the change in the covariances between days worked, employment probability and daily wages and can be broadly interpreted as the selection into employment.

4. Results

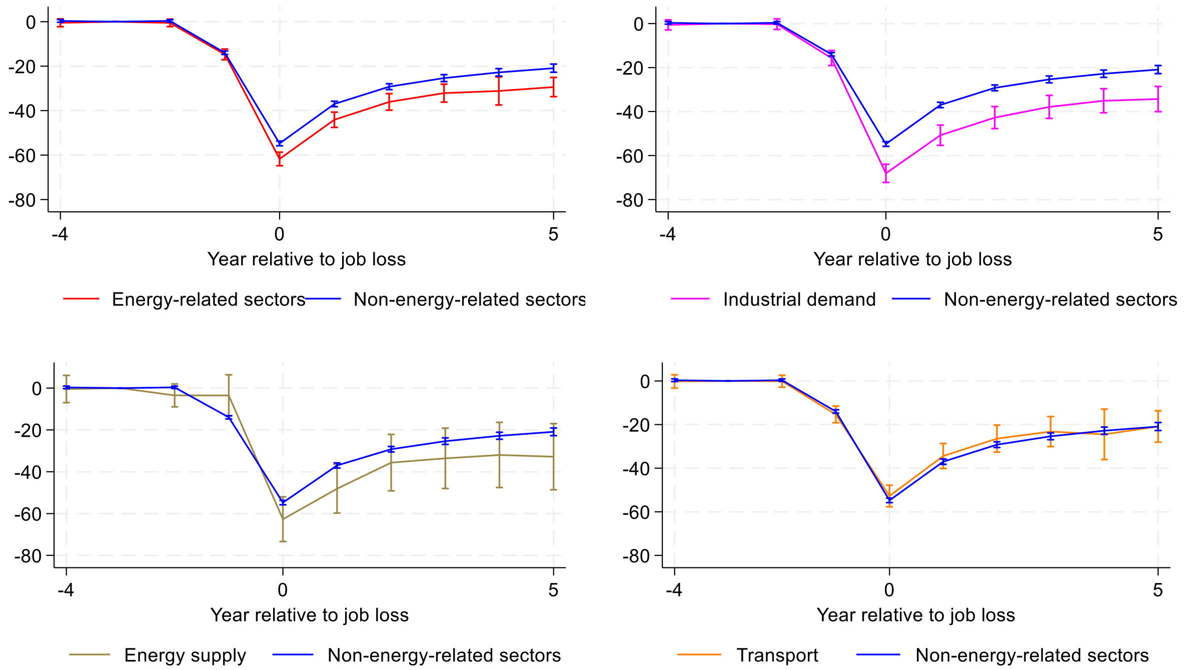
Consequences of job displacement in energy-related sectors across countries

23. Across countries, workers displaced from energy-related sectors have, on average, higher earnings losses than those displaced in non-energy-related sectors (Figure 2). Job displacement in non-energy-related sectors leads to a loss of about 55% of earnings compared to non-displaced workers in the year following the mass layoff while in energy-related sectors, this is on average 62%. However, this reflects important differences between energy-related sectors, with significantly larger losses in industrial demand sectors (68%) and smaller ones in transport where they are similar to non-energy-related sectors. Losses in energy supply are modestly larger, but not statistically different from non-energy related sectors. This responds both to an average effect which is estimated less precisely due to small sample sizes and important variation in the size and direction of earnings losses for energy supply workers across countries.

24. Across all sectors, earnings gradually converge with those of non-displaced workers in subsequent years (Figure 2). However, even five years post-displacement, a notable disparity to non-displaced workers persists. Workers in industrial demand and energy supply sectors still earn approximately 34-32% less than their non-displaced counterparts, whereas those in the transport sector and other non-energy-related industries earn about 21% less. For workers in industrial demand sectors, this difference to workers in non-energy-related sectors also remains statistically significant. Overall, these findings suggest that displacement in energy supply and industrial demand sectors is associated with substantially higher costs than those in other sectors, including transport.

Figure 2. Most energy-related sectors face greater job displacement losees than other sectors

Difference in annual earnings between displaced workers and their matched counterparts relative to the time of displacement, average across country, %



Note: Average across countries of earnings losses of displaced workers relative to observationally comparable non-displaced workers. The point estimates show the impact of job loss on earnings in event time, where workers are displaced between time -1 and time 0, such that time 0 is the first post-displacement year. The reference period for earnings losses is k=-3. Point estimates and 95% confidence intervals from country-level regressions are averaged assigning each country an equal weight. The countries included are: Austria, Estonia, Finland, Germany, Hungary, Portugal, Spain, France, Sweden.
Source: National linked employer employee data, see Table 1 for details.

25. Overall, the results echo findings from Barreto, Grundke, & Krill (2023), who also show that displaced workers in carbon-intensive industries in Germany, which fully overlap with the energy-related sectors of this paper, face elevated costs of job displacement compared to other sector. For energy-supply workers, the results are in line with previous findings for displaced workers in the coal sector. For example, Haywood, Janser, & Koch (2023), Andrews, Dwyer and Vass (2023) and Rud et al. (2022) find elevated earnings losses for displaced coal workers in respectively Germany, Australia and the United Kingdom.

The cost of job displacement in energy-related sectors by country

26. Earnings losses of displaced workers can vary across countries and sectors, and any differences between workers, sectors and countries can also stem from different mechanisms. For example, a reduced likelihood of being in employment and a decreased number of days worked - which can stem from working fewer days in a given year and/or general employment instability - as well as from a reduction in wages once re-employed can all result in lower earnings following displacement. To consider not only sectoral and country variation in the difference in post-displacement earnings losses between workers in energy-

related and non-energy-related sectors, as well as to identify which components drive such differences, **Error! Reference source not found.** presents a decomposition of average earnings losses in energy-intensive sectors over 5 years relative to non-energy intensive sectors. A negative bar indicates that earnings losses are on average higher to those in the non-energy intensive sectors on average over a 5-year period. In addition, the difference in earnings losses relative to non-energy intensive sectors is decomposed into components capturing differences in daily wage losses, employment probability losses and losses in days worked.

27. There is considerable variation across countries in the differences in earnings losses between workers in energy-related sectors and those in non-energy-related sectors over the five years following job displacement. For example, **Error! Reference source not found.** shows that workers in the energy-related sectors of Spain have on average about 14 percentage points higher earnings losses than workers from non-energy-related sectors, closely followed by France with a difference of 12 percentage points. With less than 5 percentage points, differences in the earnings losses over 5 years following displacement are particularly small in Germany, Portugal and Sweden. In Austria, Estonia and Hungary, these differences fall somewhere between 5 and 10 percentage points.

28. When considering the sources of the differences in earnings losses between workers displaced in energy-related sectors compared to workers displaced in non-energy-related sectors across countries, employment probabilities, days worked and the re-employment wages all play an important role. On average across the countries considered, differences in the likelihood of being in employment contribute to about 1.5 percentage points to the differences in earnings losses between both types of workers. The differences in the number of days worked and re-employment wages respectively contribute about 3 and 2.5 percentage points (**Error! Reference source not found.**). However, these margins differ considerably across countries. In Spain, the country with the largest difference in earnings losses between workers displaced in energy-related sectors and non-energy-related sectors, employment is just as important as the number of days worked and more important than differences in re-employment wages. In Hungary and Portugal, employment negatively contributes to earnings differentials as workers displaced from energy-related sectors are more likely to be in employment over the 5 years following displacement compared to those from non-energy-related sectors. Only in Austria, Germany and Sweden are the contributions of differences in days worked smaller than those of employment and re-employment wages fall around or below 2 percentage points.

Figure 3. Differences in earnings losses between energy- and non-energy-related sectors reflect differences in days worked and wages rather than employment

Average annual difference in earnings losses over the 5 years following displacement between energy-related sectors and rest of the economy decompose into different contribution of wage and employment losses by energy-related sector and country, p.p.

Note: Bars represent the average earnings loss five years after displacement, decomposed into the contribution of changes in daily wages, employment probability and days worked. The residual component is negligible and thus omitted for presentational purposes. For Estonia, France and Spain, the number of laid off workers energy supply sectors falls below the 100 person threshold and results for this sector are therefore not presented. Average across the countries shown.
Source: National linked employer employee data, see Table 1 for details.

29. In energy-supply sectors, there is even larger variation in the differences in earnings losses compared to workers displaced in non-energy-related sectors across the included countries, but also in the relative contributions of employment, days worked and re-employment wages to these differences. For example, the differences in earnings losses within countries can be as large as 23 percentage points in Spain, or as low as 6 percentage points in Hungary (**Error! Reference source not found.**). At the same time, the differences in earnings losses following displacement in energy-supply sectors compared to those in non-energy-related sectors are on average across countries mainly driven by differences in days worked and, to a slightly lesser degree, by differences in re-employment wages. Differences in employment between displaced workers in energy-related sectors compared to displaced workers in non-energy-related sectors only play a marginal role on average, but this masks large variation across countries. In fact, the negative differences in earnings losses for Estonia and Sweden, and the particularly large differences for Hungary are all largely driven by differences in the probabilities of being employed probabilities compared to non-energy-related sectors (**Error! Reference source not found.**). Indeed, displaced workers in the Swedish energy supply sector have a higher probability of being employed than workers in non-energy-

related sectors, while those in the energy-supply sector of Hungary have a much lower likelihood of being employed (**Error! Reference source not found.**). This may in part reflect the particularities of the national energy mix, as Sweden pre-dominantly produces energy through renewables, whereas Hungary relies predominantly on energy generation through fossil fuels (IEA, 2024).[4]

30. In the industrial demand sector, the differences in earnings losses to workers displaced in non-energy-related sectors are considerable for all countries and equally reflect differences in re-employment wages and days worked (both about 5 percentage points) (**Error! Reference source not found.**). While the contribution of employment is of roughly equal magnitude to that in energy-related sectors as a while, workers displaced in the industrial demand sectors of France, Hungary and Portugal are somewhat more likely to be in employment over the five years following a mass layoff than workers in non-energy-related sectors in these countries. In contrast, differences in employment between workers in industrial demand and non-energy-related sectors in Spain and Estonia strongly contribute to the differences in earnings losses, with about 7 and 5 percentage points, respectively. Alongside almost equally large contributions of the number of days worked and re-employment wages, both countries therefore have the largest differences in displacement costs compared to workers in non-energy-related sectors. Re-employment wages play a relatively small role in the differences in earnings losses within Hungary, Portugal, and Sweden.

31. As the previous findings have shown, the transport sector in an exception when it comes to the differences in earnings losses to workers in non-energy-related sectors. However, within specific countries, there are considerable differences. For example, transport workers in France experience earnings losses that are almost 12 percentage points larger than those of workers displaced from non-energy-related sectors, of which about 7 percentage points come from differences in employment (**Error! Reference source not found.**). In contrast, workers displaced from the transport sector in Hungary have about 10 percentage points lower displacement costs than workers in non-energy-related sectors, about 7 percentage points of which comes from being more likely in employment over the five years following displacement. At the same time, and like in all other countries except for Sweden, re-employment wages are also higher for workers displaced from transport sectors. Days worked play a marginal role for the differences in earnings losses within most countries, but reduce the earnings losses somewhat in Germany, while increasing them noticeably in France.

Firm- and worker-related wage losses in energy-related sectors by country

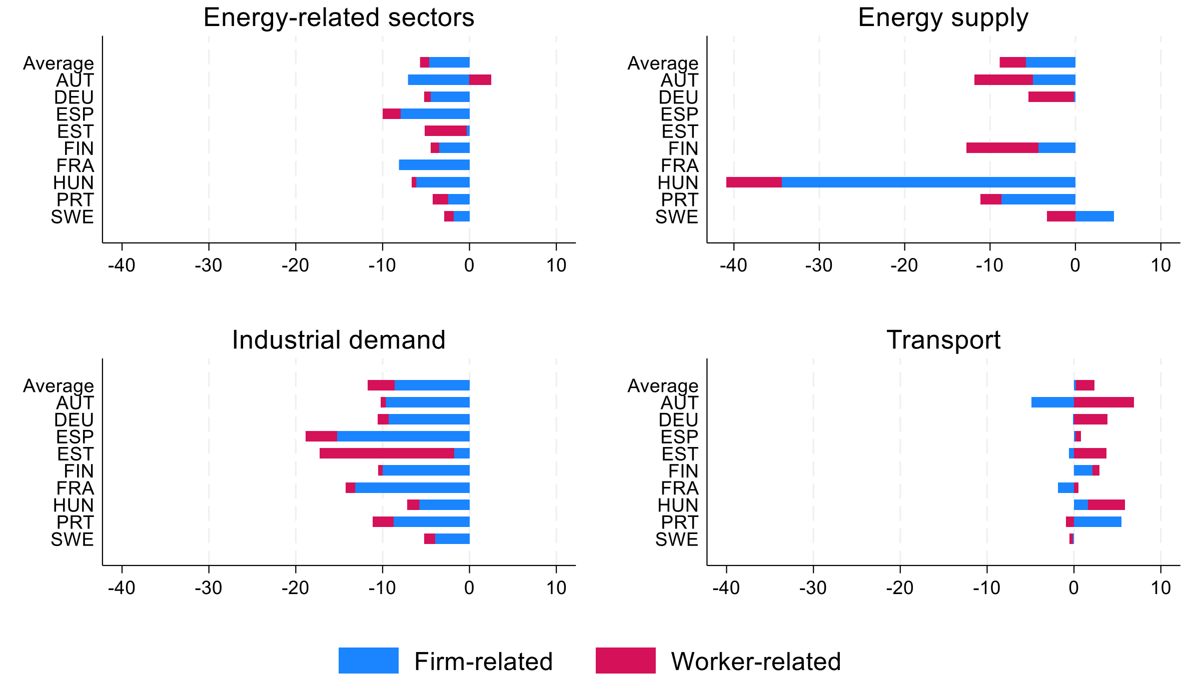
32. Wage losses in re-employment are an important part of the differences in earnings losses across sectors and can reflect both firm-related losses due to foregone firm wage premia and worker-related losses due to human capital depreciation and lower match quality (Lachowska, Mas, & Woodbury, 2020).

[4] A higher share of renewables in the energy mix may mean that there is less of a reason for mass layoffs in the clean energy transition. In contrast, a larger share of fossil fuels in the energy mix would require a stronger degree of restructuring of energy systems to realize the clean energy transition, leading to more job displacement and potentially adverse labour market outcomes compared to workers in non-energy-related sectors.

To understand the role of wage losses across energy-related sectors, **Error! Reference source not found.** shows the difference in log wage losses between the energy-intensive sector and non-energy related sectors on average over 5 years since displacement, which can be decomposed into to the difference in firm-related and worker-related losses between energy-intensive and non-energy related sectors.

Figure 4. Larger wage losses reflect higher firm-related losses in energy-supply and industrial demand

Average annual difference in the five years following displacement in log wage losses between displaced workers from energy-related sectors and non-energy related sectors, decomposed into differences in firm- and worker-related losses, percentage points.



Note: Bars represent the average wage loss five years after displacement, decomposed into the contribution of firm wage premia changes, and worker-related (i.e. match quality and human capital changes) following Lachowska et al. (2020). For France and Spain, the number of laid off workers energy supply sectors falls below the 100 person threshold and results for this sector are therefore not presented. Average across the countries shown.
Source: National linked employer employee data, see Table 1 for details

33. As shown in the previous sub-section, within countries, workers from energy-intensive sectors as a whole have generally higher wage losses than those in non-energy intensive sectors (**Error! Reference source not found.**). In all countries except for Estonia and Finland, these differences in wage losses are driven by the firm-related component, which indicates that they can be mainly attributed to higher losses in firm wage premia relative to non-energy intensive sectors. This may reflect an elevated loss of compensating differentials for physically demanding working conditions or a departure from firms that capture high rents. Overall, the persistent nature of the differences in wage losses are striking as there is

a substantial difference with respect to the wage losses of the rest of the economy over the entire 5-year window post-displacement.

34. Wage losses vary across energy-related sectors, with workers from energy supply and industrial demand generally experiencing higher wage cuts with respect to non-energy intensive sectors, with the exception of Estonia and Sweden (**Error! Reference source not found.**). The contribution of firm wage premia losses is particularly pronounced for workers in industrial demand and energy supply. The contribution of worker-related losses to the within-country differences is much smaller relative to that of firms, but still negative, implying that workers from industrial demand and energy supply also experience higher worker-related losses than the rest of the economy. However, in Estonia, worker-related factors make up are much bigger part, about 15 percentage points, in the differences in wage losses compared to workers in non-energy-related sectors.

35. In contrast, workers from the transport sector have in most countries lower wage losses with respect to non-energy intensive sectors, which is in line with their earnings losses being much closer to the rest of the economy (**Error! Reference source not found.**). In the transport sector, differences in firm-related wage premia losses play generally a smaller role, even being positive in some countries, indicating that the firm-related wage premia losses are even smaller compared to those in the rest of the economy. In addition, the worker component in the differences in wage losses between transport workers and other non-energy-related workers is mostly positive across countries, suggesting that they face smaller worker-related wage losses, which may reflect a higher portability of human capital into the next occupation as well as lower match-related losses.

The effects of job displacement on job mobility in energy-related sectors

36. The clean energy-transition and the associated decline of energy-supply and industrial demand may mean that displaced workers find it harder to find re-employment in the same sector, occupation or region. Occupational and sectoral switches are associated with losses of occupation- and sector-specific human capital, which in turn accentuate earnings losses relative to workers that do not switch along these dimensions (Huckfeldt, 2022; Barreto, Grundke, & Krill, 2023). In contrast, regional mobility may allow workers to move to regions with better employment opportunities and more similar jobs to the one lost, reducing the extent of earnings losses after displacement (Arntz, Ivanov, & Pohlan, 2022). Importantly for energy-intensive sectors, the positive effect of regional mobility on earnings is mostly significant for rural to urban movers (Huttunen, Moen, & Salvanes, 2018)

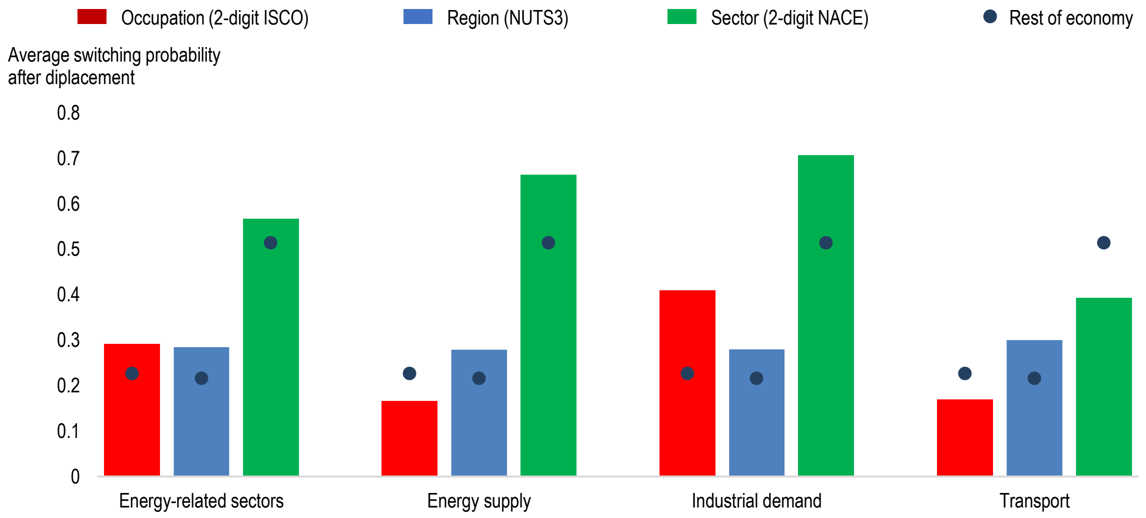
37. To understand how mobility patterns interact with the cost of job loss in energy-intensive sectors, Figure 5 presents the effect of job loss on the likelihood of switching sectors, occupations and regions for energy-intensive and non-energy intensive sector on average over 5 years. Workers in energy-supply and industrial-demand sectors are more likely to change their sector of employment after displacement than workers in non-energy-related sectors, which is suggestive of losses in sector-specific human capital and potential reallocation after displacement into lower-paying sectors. This is in line with the pattern shown before by which wage losses in these two sectors can be mostly explained by higher losses in firm wage premia. In addition, workers from industrial demand are also significantly more likely to switch occupations,

which coupled with the higher sectoral switching may explain that they experience the highest earnings losses among energy-related workers.

38. In contrast, workers displaced in transport sectors are less likely to change occupations and sectors than workers displaced in non-energy-related sectors as well as industrial demand and energy supply. This indicates that workers from the transport sector indeed manage to find re-employment in more similar jobs from the ones they got displaced from and in turn experience lower earnings losses. Strikingly, regional mobility is similar among energy-related sectors and the rest of the economy, which suggests there is scope for facilitating moves towards regions with better employment prospects.

Figure 5. Transitions across sectors, occupations and regions differ across industries

Average difference in transition probabilities between displaced workers and their matched counterparts over five years after displacement, average across country, %



Note: Average across Austria, Portugal, Germany, Spain, Estonia, Hungary, Finland, France, Sweden. For occupational and regional changes, the figure excludes Austria and Estonia.
Source: National linked employer employee data, see Table 1 for details.

5. Policy implications

39. While the clean energy transition is crucial for a sustainable future, it poses significant employment challenges, in part through significant and persistent job displacement costs in energy-supply and industrial-demand sectors. Strategic long-term planning can help to address the labour market challenges posed by the clean energy transition, yet some level of displacement is unavoidable. Consequently, developing and implementing comprehensive labour market policies that reduce the consequences of job displacement and ensure transitions to new and emerging sectors and occupations, for example occupations in sectors relying on clean energy, is not just essential for assisting displaced workers, but also critical for securing public support for the clean energy transition.

40. Income support during periods of non-employment after displacement plays a central role in cushioning earnings losses after job loss. Unemployment insurance (UI) in particular serves as a crucial

safety net, supporting consumption and allowing time for displaced workers to find suitable employment (OECD, 2023). However, the effectiveness of UI depends on careful design to balance income security with the incentives for job search. In some countries, , severance pay plays an important role in offsetting earnings losses following displacement, especially for workers with longer tenures that previously earned relatively high wages (OECD, 2018). Early retirement schemes, which offer a swift transition to pension systems for workers declining and physically demanding occupations, can mitigate adverse labour market outcomes but negatively impact aggregate labour supply and public finances (OECD, 2018), and are therefore not a strategically sound approach for the clean energy transition.

41. As a significant part of earnings losses following displacement in energy-related sectors stems from a decline in re-employment wages, an additional avenue in supporting displaced workers is through in-work income supports, such as in-work benefits (see e.g. Immervoll and Pearson (2009) and wage insurance schemes. The latter, which replaces a significant part of the differences to previous wages, has already shown to be a particularly effective tool to mitigate the consequences of job displacement. In the United States, for example, it has led to faster re-employment and increased cumulative long-run earnings of trade-displaced workers, while paying for itself through reduced public expenditure on UI and increased tax receipts (Hyman, Kovak, & Leive, 2023). Whether such policies should be targeted to support workers specifically affected by the clean energy transition depends on the country context.

42. To support transition from declining sectors to new and emerging industries, which may require re- or upskilling, active labour market policies (ALMPs) and lifelong learning initiatives play a significant role. Public employment services are instrumental in this context, providing job search assistance and identifying relevant training opportunities based on systematic skills assessment and anticipation, ensuring workers can adapt to new job requirements in an evolving labour market (OECD, 2023). Such approaches may be most effective when implemented as early intervention that offer training and job search advice already during notice periods and before effective job loss (OECD, 2018).

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