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The 'Clean Energy Transition' and the Cost of Job Displacement in Energy-intensive Industries

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Abstract

This paper provides a comprehensive analysis of the costs of job displacement in energy-intensive industries in selected OECD countries. Based on harmonised linked employer-employee data from 14 OECD countries, we estimate the effect of job displacement in three energy-intensive industries, namely energy supply, heavy manufacturing and transport, compared to other industries. We find that workers displaced from energy supply and heavy manufacturing, experience larger earnings losses compared with workers in non-energy-intensive and transport sectors. Larger earnings losses mainly result from weaker re-employment outcomes in terms of wages and job instability but also challenges with finding another job. They reflect significant differences in the composition of workers and firms in energy supply and heavy manufacturing and the rest of the economy. Displaced workers in these sectors tend to be older, are less skilled and more likely to be previously employed in high-wage firms.

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The paper provides additional background to a chapter in OECD (2024^[1]) on job displacement in high emission industries with respect to the methodology and the effects of job-displacement across energy-intensive sub-sectors (energy supply, heavy manufacturing and transport). It is part a broader OECD project that mobilises linked employer-employee data for cross-country research and policy analysis (LinkEED 2.0). For more details, please visit: <https://www.oecd.org/en/about/projects/linkeed-200.html>.

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1 Introduction

Across the OECD, economies are transitioning towards greater carbon- and resource-efficiency to mitigate the impacts of climate change, promote sustainable growth, and ensure long-term economic resilience. At the heart of these processes are energy-intensive industries (whether in terms of supply or demand), which will see profound restructuring to realize the “*clean energy transition*”. This includes a reduction in the use of fossil fuels for energy production and consumption, while incentivizing the development of cleaner sources of energy (energy supply), as well as the adoption of technologies that enhance energy-efficiency in energy-intensive processes in transport and production (energy distribution and demand).¹

The transition towards cleaner energy systems, as part of the broader effort to combat climate change, e.g. the EU’s “Fit for 55”, has put in motion significant changes in energy-intensive sectors. While this shift opens up new employment opportunities in renewable and nuclear energy activities (see e.g. Borgonovi et al. (2023_[2])) as well as jobs associated with improved energy efficiency, it increases the risk of job displacement in energy-intensive and predominantly fossil-fuel-based industries, potentially affecting public support for climate policies. Some sectors and firms may be able to change their fuel mix and/or reduce the energy intensity of their production processes by changing the way they operate.² In other cases, such as fossil-fuel extraction, the impacts are likely to arise across firms and sectors, raising the risk of job displacement.

The main objective of this paper is to provide a comprehensive analysis of job displacement in energy-intensive industries (and other industries) using detailed linked employer-employee data for 14 OECD countries.³ Displaced workers in energy-intensive industries may face particularly challenges because of the specific characteristics of firms and workers in these sectors and the limited availability of opportunities for moving to a similar jobs due to the decline in energy-intensive employment (Borgonovi et al., 2023_[2]). A secondary objective is to provide additional background to OECD (2024_[1]) on the methodology and the effects of job-displacement across subsectors (energy supply, heavy manufacturing, transport). Energy-intensive industries, as defined in this paper based on energy-intensity, correspond exactly to the set of high-emission sectors as defined in OECD (2024_[1]) based on greenhouse gas intensity.

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

¹ Recent OECD work on the labour market effects of the transition towards greater carbon- and resource-efficiency and related labour and social policy responses include OECD (2024_[1]; 2023_[1]), Keese and Marcolin (2023_[1]), Borgonovi et al. (2023_[2]), Causa et al. (2024_[1]) and Causa, Nguyen and Soldani (2024_[1]; 2024_[1]).

² Some of this restructuring will take place within a given sector (and even firm), with changes in power generation technologies being an obvious example.

³ As discussed in more detail below, job displacement in the present paper refers to workers separations from firms engaged in mass layoff events.

approaches that can reduce the costs of job displacement in energy-intensive industries and help to build support for the clean energy transition.

2 Data

In this paper, as well as in OECD (2024_[1]), we utilise matched employer-employee data for a total of 14 OECD countries (Australia, Austria, Canada, Denmark, Estonia, Finland, Germany, Hungary, the Netherlands, Norway, Portugal, Spain, France, Sweden). This section defines energy-intensive industries, explains the harmonisation of matched employer-employee data across countries and introduces the empirical strategy for measuring and explaining the costs of displacement between sectors and countries. As such, it provides additional background to the less detailed exposition of the methodology in OECD (2024_[1]).

Defining energy-intensive industries

For comparability purposes, we use a uniform definition of energy-intensive industries across countries.⁴ We rely on Environmental Accounts data from the World Input-Output Database, covering 27 EU countries, the United Kingdom, Norway, Iceland and Switzerland, for the period 2000-2014. The Environmental Accounts include information on gross energy use in terajoules (TJ) and value added across NACE 2-digit industries (European Commission JRC, 2019_[3]). This allows us to define the energy intensity of a sector in terms of energy use over value added and to differentiate between sectors with high-energy intensity and lower energy intensity.

In practice, we define energy-intensive industries as industries appearing in the top two deciles of the energy-intensity distribution across 2-digit NACE industries in at least 15 countries (Figure 1).⁵ The definition of energy-intensive sectors comprises sectors with particularly high energy intensity, averaging about 181 terajoule (TJ) per million EUR of gross value added (in constant 2015 prices of the national currency), from sectors with lower energy intensity. The manufacturing of coke and refined petroleum products stands out in terms energy-intensity, with more than 1200 TJ per million EUR of gross value added, significantly driving up the average energy-intensity of energy-intensive industries. Without this sector, energy-intensive industries would average 64 TJ per million EUR of gross value added. Importantly, the definition of energy-intensive industries coincides with that of carbon-intensive sectors, as used in Barreto, Krill and Grundke (2023_[4]) and with that of GHG-intensive sectors used in OECD (2024_[1]).⁶

⁴ For a discussion of the measurement of polluting and energy-intensive occupations, see OECD (2024_[1]) and Causa, Nguyen and Soldani (2024_[1]).

⁵ This approach is comparable to those using GHG-intensity in OECD (2024_[1]) and carbon-intensity in Barreto, Krill and Grundke (2023_[4]) with the exception that we use a threshold of appearing in the top two deciles of the energy-intensity distribution in at least 15 countries as compared to 10 in the other two classifications. This ensures that the sewerage and waste-collection sector as well as the agricultural sector are omitted from the list of energy-related industries, as these are expected to grow and/or are essential for the clean-energy transition (see also OECD (2024_[1])).

⁶ Using the same approach for GHG-intensive sectors instead yields two differences. The sewerage and waste collection sector and the agriculture sector are both characterised by relatively high emissions but low energy-intensity. However, in the final classification of high emission sectors in OECD (2024_[1]) they are omitted as they are not expected

To provide more insight on the cost of job displacement across energy-intensive industries, we divide them into three separate sectors:

- *Energy supply (“E”)*. This includes three sectors: i) electricity, gas and air conditioning; ii) coke and refined petroleum; iii) mining and quarrying. The NACE-2 digit level classification is not sufficiently granular to single out renewable energy generation which is expected to expand from fossil fuel energy generation (see e.g. Borgonovi et al. (2023_[2])).
- *Energy-intensive manufacturing sectors (“heavy manufacturing” or “M”)*. This includes many sectors commonly defined as “heavy manufacturing” (or sometimes “hard-to-abate”) such as manufacturing of basic metals, chemicals, pulp and paper, and non-metallic mineral products. We refer to this as “heavy manufacturing” (I).
- *Energy-intensive service sectors (“transport” or “T”)*. This includes the part of services related to transport whether by air, sea or land transport. We will therefore refer to energy-intensive services as transport (T). Note that NACE classification does not allow excluding transport based on renewable energy sources such as electrified land transport.

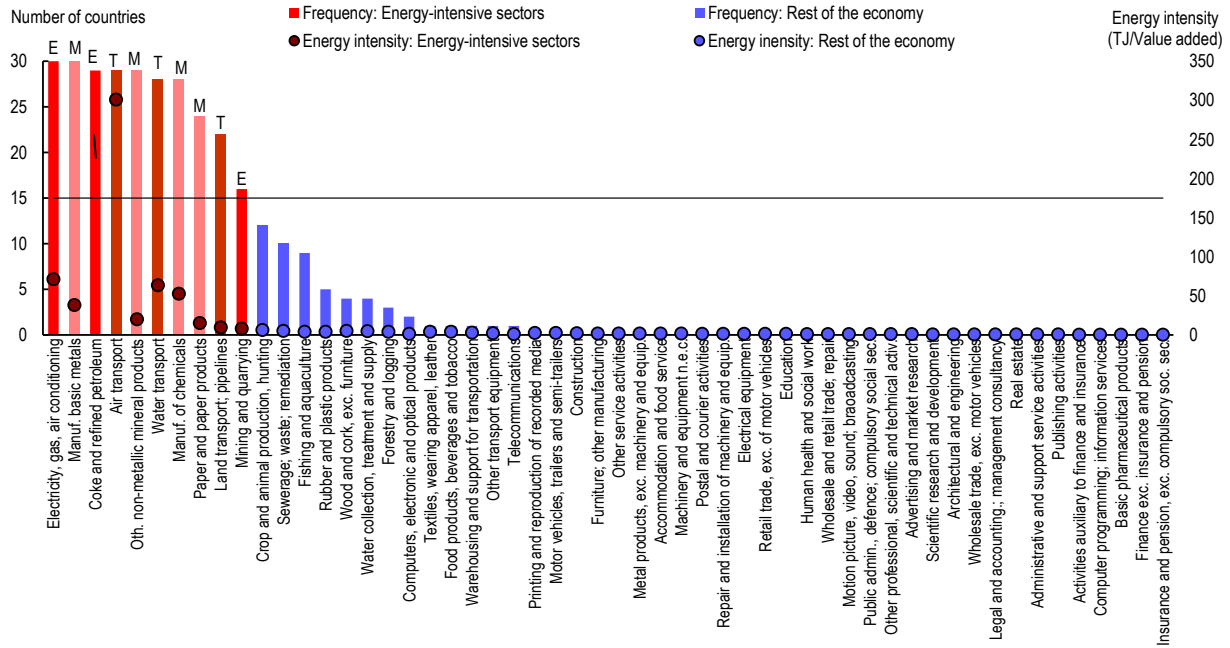
Given the very different nature of these sectors, they are likely to be impacted differently by the clean-energy-transition. For example, energy supply is directly impacted by structural changes in the energy mix of many OECD countries, with a shift from fossil-fuel-based energy-generation to renewables. Heavy manufacturing is indirectly affected by the clean-energy-transition, as it faces changes in energy costs as well as regulatory requirements. The transport sector is affected through technological and infrastructure changes, but also faces increased energy costs as well as regulatory requirements. As such, a sectoral differentiation of the analysis in OECD (2024_[1]) may shed additional light on the labour market effects of the clean-energy transition.⁷

to decline. This partly reflects the role of policies since sewerage and waste collection is very needed for the net-zero transition (D’Arcangelo, Kruse and Pisu, 2023_[1]).

⁷ It is important to note that the present classification is based exclusively on energy demand but – partly by coincidence - also captures key aspects of energy supply. This is most obvious in the case of energy supply. Coke and refined petroleum is energy-intensive because it uses high levels of energy per unit of valued and not because its main activity is energy generation. To a certain extent the same applies to also to energy-intensive manufacturing and services. For example, non-metallic mineral products are energy-intensive in production, but are also potentially relevant for energy supply, e.g. through manufacturing of relevant products derived from critical minerals. Similarly, the definition of energy-intensive service sectors also incorporates parts of the economy directly related to energy supply in the form of distribution (e.g. pipelines in land transport, oil freight in sea transport).

Figure 1. Classification of energy-intensive industries

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, M refers to heavy manufacturing sectors and T refers to transport sectors.

Source: World Input-Output Database Environmental Accounts

Data sources and harmonisation

For the analysis of job displacement in energy-intensive industries, we make use of harmonised linked employer-employee data for 14 OECD countries: Australia, Austria, Canada, Denmark, Estonia, Finland, France, Germany, Hungary, the Netherlands, Norway, Portugal, Spain and Sweden (see Table 1). These data are 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, cover the universe of workers or a large random sample of workers, and contain identifiers for their employers and industries. Each of these features is indispensable to the analysis of job displacement within detailed industries. The resulting dataset typically covers the years 2000 to 2019, and thus avoids potential confounding effects resulting from the COVID-19 pandemic and subsequent energy-cost inflation. For some of the countries, the observation period begins later than 2000 or ends before 2019.

Table 1. Data sources

Country	Name	Earnings data source	Sample structure	Time coverage
Australia	Person Level Integrated Data Asset (PLIDA)	Tax administration	10 % random sample of workers	2002-2019
Austria	AMS-BMASK Arbeitsmarktdatenbank	Social security administration	Universe	2000-2019
Canada	Canadian Employer-Employee Dynamics Database	Tax administration	Universe	2001-2019
Denmark	Integreerede Database for Arbejdsmarkedsforskning (IDA) and other data from Statistics Denmark	Tax 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	10% random sample of workers	2000-2019
Hungary	ADMIN –2 - Panel of linked administrative data (OEP, ONYF, NAV, NMH, OH)	Social security administration	50% random sample of workers	2003-2017
Netherlands	CBS Microdata from Statistics Netherlands	Tax administration	Universe	2006-2019
Norway	Arbeidsgiver- og arbeidstakerregister (Aa-registeret), Lønns- og trekkoppgaverregisteret (LTO)	Tax administration	Universe	2002-2019
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 (JOBBS)	Social security administration	Universe	2002-2018

To ensure comparability across the 14 linked employer-employee panels, we standardize the data using a common data preparation procedure for each country. For each of the datasets, we select the primary employer, which is defined as the employer from which an employee receives the highest earnings in a given year.⁸ Whenever possible, employers are identified based on establishment identifiers rather than those of the firm which may comprise several establishments, potentially operating in different industries

⁸ In the event 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).

and regions. In countries where there are no establishment identifiers available, firm identifiers are used instead.⁹ Worker tenure at these employers is measured as the duration of employment with the current employer in years.

Earnings are defined broadly, encompassing regular wages, overtime, and bonuses, all before taxes and social security deductions.¹⁰ In countries where earnings are censored above a certain ceiling (e.g. Germany), earnings are imputed following the procedure proposed by Card, Heining and Kline (2013^[5]). Based on the earnings information, we compute a set of harmonized outcomes. Annual earnings are calculated as the total labour income for the respective year, potentially from multiple employers beyond the primary employment spell. Daily wages are derived by dividing annual earnings from the main employer by the number of days worked for the main employer that year, excluding marginal jobs with very low earnings.¹¹ Following the standard practice in the job displacement literature, we assign zero earnings and missing daily wages during periods of non-employment spells, that is, years without recorded earnings from any employer.

Finally, we apply common sample restrictions across all datasets. Our baseline analysis focuses on workers aged 18-50 years in the private sector, excluding apprentices and self-employed individuals. While we do not consider mass-layoff events in the public administration and defence sectors, we retain employment spells in the final datasets to avoid overstating earnings losses when workers transition to the public sector after displacement (see the methodology section for a detailed definition of the mass layoff events).

Descriptive statistics

The average number of workers included in the final datasets is large in all countries and sectors, and its absolute number depends on the data structure (i.e. whether the source dataset is the universe or a random sample) (Table 2). The energy-intensive sector accounts about 9% of total employment in the included countries. Workers in this sector tend to predominantly be male, slightly older on average, and often boast longer tenures compared to workers in other sectors. Average length of tenure is especially high in energy supply and heavy manufacturing, while in transport it is not too different from the rest of the economy. Workers in energy supply and heavy manufacturing are also more frequently employed by high-paying firms. While employment in energy supply and heavy manufacturing has been on a declining trend, employment in the rest of the economy¹² and, in some countries also in the transport sector, has been growing.

As evident in Table 2, the number of workers displaced in mass layoff events – which we define further below - varies considerably across sectors. Among other factors, this is the result of differences in sample size and employment shares as well as country- and sector-level employment trends. Notably, the number of displaced workers tends to be smallest in energy supply. For this reason, estimates of job displacement in energy supply sectors should be interpreted with caution, especially for France and Spain. In practice,

⁹ Countries where firm identifiers are used are Australia, Canada, Estonia, the Netherlands and Portugal.

¹⁰ All monetary values are expressed in real terms using the Consumer Price Index with 2015 as the base year.

¹¹ We account for implausibly low and high earnings by removing employment spells with earnings falling below 20% of median earnings and winsorising earnings at the top 0.1% of the distribution. This adjustment is done based on daily wages, whenever available, annual earnings otherwise. Daily wages are used instead of hourly wages to maximize country coverage.

¹² Note that when we refer to “rest of the economy” we refer to non-energy-related sectors throughout this paper.

we exclude country-sector combinations with fewer than 100 individual layoffs and 10 firms experiencing mass layoffs over the analysis period.

Table 2. Summary statistics of matched displaced-non-displaced worker samples by country

Country	Average number of workers	Age	Share of women	Tenure (years)	Firm size	Log daily wage	AKM Firm FE	Number of displaced workers	Number of mass-layoff firms	Average share of sector in total employment	Employment change (first year - last year)
Panel A. Energy supply											
AUS	15,405	38.69	19.83	3.42	441	5.58	0.40	776	367	2.43	35.62
AUT	31,713	41.67	16.96	10.44	566	4.79	0.12	530	17	0.98	1.44
CAN	321,768	41.17	22.15	7.68	4,449	11.23	0.41	10,345	40	3.22	20.87
DEU	32,941	43.53	20.15	9.98	794	4.95	0.32	107	181	1.17	-25.62
DNK	12,556	45.00	22.78	5.92	115	7.08	0.15	33	18	0.60	2.07
ESP	2,797	44.07	15.01	6.98	329	4.47	0.61	72	85	0.43	-21.26
EST	12,848	45.86	24.04	3.83	1,225	9.23	0.32	40	6	2.28	-35.75
FIN	10,530	43.11	19.55	7.33	1,395	4.72	0.09	396	44	0.98	-17.81
FRA	16,893	42.43	23.35	8.65	350	4.80	0.17	41	61	0.97	-22.73
HUN	17,239	43.32	24.40	5.43	1,666	9.35	0.55	339	18	1.05	-27.19
NLD	38,604	43.98	20.45	3.30	1,674	4.96	0.31	10	11	0.55	26.24
NOR	65,377	43.25	19.76	5.51	5,128	7.54	0.43	1,043	14	2.68	57.53
PRT	19,726	44.13	13.59	14.97	1,239	3.89	0.36	169	1	0.83	-15.78
SWE	36,275	44.91	22.80	7.17	949	7.05	0.10	225	20	1.00	22.20
Average	45,334	43.22	20.35	7.19	1,451	6.40	0.31	1,009	63	1.37	-0.01
Panel B. Heavy manufacturing											
AUS	9,927	39.6	22.2	4.0	393	5.2	0.15	335	1,128	1.57	-36.94
AUT	106,058	39.5	18.9	7.3	536	4.7	0.20	3,047	194	3.27	2.95
CAN	263,721	43.5	19.3	8.6	2,252	10.9	0.20	15,500	480	2.64	-35.77
DEU	94,626	43.0	19.6	11.0	2,067	4.7	0.23	955	2,327	3.37	-15.55
DNK	34,408	44.2	24.5	7.1	140	6.9	0.11	2,012	138	1.64	-33.99
ESP	12,751	43.0	18.0	7.2	355	4.2	0.36	501	932	1.94	-25.81
EST	8,372	41.8	30.0	3.7	230	9.1	0.20	363	25	1.48	14.26
FIN	28,909	42.3	29.4	7.5	474	4.7	0.08	1,153	89	2.69	-27.92
FRA	37,400	42.5	24.7	7.6	434	4.6	0.17	836	715	2.14	-38.20
HUN	39,246	40.9	31.1	4.7	837	8.9	0.25	2,515	107	2.40	-5.44
NLD	106,617	45.3	15.2	4.3	1,172	4.7	0.19	2,461	123	1.52	-12.16
NOR	38,487	43.2	19.0	7.6	1,802	7.1	0.23	4,209	142	1.58	-38.13
PRT	66,232	41.6	26.6	11.6	208	3.5	0.11	2,613	139	2.78	-14.98
SWE	102,541	43.9	20.8	8.8	1,069	6.9	0.09	2,431	143	2.82	-18.33
Average	67,807	42.47	22.81	7.21	855	6.15	0.18	2,781	477	2.27	-20.43
Panel C. Transport											
AUS	17,833	40.46	24.36	3.31	372	5.06	0.09	282	2,454	2.82	-9.23
AUT	109,124	39.95	18.61	4.64	284	4.30	-0.07	2,940	473	3.36	38.15
CAN	359,332	43.80	24.19	7.40	4,509	10.61	0.01	6,275	650	3.59	29.44
DEU	60,875	43.43	19.28	6.97	1,219	4.31	-0.09	418	1,331	2.17	35.13
DNK	74,950	43.81	18.87	4.03	59	6.82	0.05	1,910	278	3.58	-12.45
ESP	18,637	44.54	13.04	6.99	721	3.96	0.11	378	803	2.83	-0.51
EST	22,273	44.88	18.36	2.87	243	8.73	-0.11	312	37	3.95	19.64
FIN	86,761	40.88	28.47	6.81	318	4.72	0.04	1,229	149	8.09	-18.10
FRA	61,343	41.45	18.98	5.91	933	4.43	0.06	729	1,320	3.52	37.39

Country	Average number of workers	Age	Share of women	Tenure (years)	Firm size	Log daily wage	AKM Firm FE	Number of displaced workers	Number of mass-layoff firms	Average share of sector in total employment	Employment change (first year - last year)
HUN	33,437	41.19	16.25	3.35	802	8.45	-0.12	502	81	2.04	142.14
NLD	214,825	44.50	19.62	3.29	3,361	4.49	0.07	2,360	320	3.06	-2.96
NOR	91,982	43.30	15.85	4.45	4,892	6.88	0.04	1,943	217	3.77	-8.96
PRT	85,156	41.72	13.42	8.16	937	3.45	0.07	2,241	171	3.58	37.11
SWE	122,923	44.53	15.57	5.53	1,052	6.78	-0.01	1,956	241	3.38	18.49
Average	97,104	42.75	18.92	5.27	1,407	5.93	0.01	1,677	609	3.55	21.81
Panel D. Rest of economy											
AUS	579,944	36.83	49.86	3.15	372	4.86	-0.01	14,108	82,527	91.58	20.54
AUT	2,973,153	38.18	48.14	5.41	379	4.34	0.00	79,992	10,104	91.65	38.51
CAN	8,915,632	40.55	50.35	7.63	3,844	10.49	-0.03	244,620	21,830	89.13	31.59
DEU	2,600,800	41.39	47.05	7.59	819	4.41	-0.01	26,034	78,629	92.52	19.47
DNK	1,945,936	42.10	50.09	4.66	56	6.73	0.00	51,187	5,704	92.95	15.40
ESP	579,140	41.88	46.45	5.45	555	3.86	0.02	7,907	31,695	88.02	6.25
EST	508,767	41.44	54.03	2.98	641	8.84	-0.01	8,419	1,059	90.16	8.40
FIN	942,091	39.96	44.54	5.74	1,781	4.57	-0.01	22,653	3,275	87.79	42.59
FRA	1,611,195	39.51	48.76	4.91	596	4.34	-0.01	17,930	33,628	92.39	40.82
HUN	1,506,675	40.02	51.53	3.68	7,768	8.64	0.01	30,349	3,648	92.04	15.63
NLD	6,598,902	40.95	47.52	3.18	7,496	4.32	-0.01	79,300	9,595	93.86	10.76
NOR	2,187,498	40.73	49.85	4.70	9,844	6.76	-0.02	60,289	7,753	89.55	26.75
PRT	2,170,234	38.85	47.52	7.13	1,048	3.29	-0.01	55,924	5,482	91.15	35.83
SWE	3,352,449	43.34	46.83	7.06	4,298	6.81	0.00	42,679	5,855	92.14	23.22
Average	2,605,172	40.41	48.75	5.23	2,821	5.88	-0.01	52,957	21,485	91.07	23.98

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

Determining the cost of job displacement for a given worker poses important methodological challenges. Ideally, we would like to compare outcomes for the same worker in two states of the world: first, a situation where the worker loses employment and second, a counter-factual situation where the same worker continues to be employed in that same job. As this is evidently infeasible, we follow the job displacement literature and match observationally identical displaced and non-displaced workers (Jacobson, Lalonde and Sullivan, 1993^[6]; Lachowska, Mas and Woodbury, 2020^[7]; Schmieder, von Wachter and Heining, 2023^[8]). Following this procedure, we estimate displacement effects in an event study framework using the matched sample of displaced and non-displaced workers. The precise implementation of the event study approach follows Barreto, Grundke and Krill (2023^[9]) and OECD (2024^[11]).

Defining the treatment

The analysis focuses on job displacement as a result of *mass-layoff* events. This approach ensures that firm separations are plausibly exogenous, involuntary and unrelated to the performance of workers or their individual career plans. As such, it prevents unobservable differences in performance between workers remaining employed and those laid off from affecting the estimates of job displacement costs.

To identify mass layoff events in our datasets, we follow the displacement literature by defining mass layoffs as events in which employment in a establishments with at least 30 employees declines by at least 30% between one year to the next (Jacobson, Lalonde and Sullivan, 1993^[6]).¹³ Our definition of mass-layoff events includes complete plant closures. 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 and Schmieder, 2013^[10]). This tends to be particularly important in sectors that have experienced important pro-competitive reforms during the sample period, such as those in the transport sector of several included countries.

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 to the same employer over the six subsequent years. In practice, we focus on workers 18 to 50 years old at the time of displacement to limit the influence of early retirement programs.¹⁴ To identify separations among workers who had stable employment trajectories in their original employer, we also restrict the analysis to workers with at least 2 years of tenure in the year of mass layoff. By considering only the first observed mass layoff event for each worker, treatment can happen only once over the sample period, consistent with the idea that displacement represents a permanent shock to labour market trajectories.

¹³ We use an employment threshold of 30 instead of 50 as done by Jacobson et al. (1993) to allow for a sufficiently large sample in each of the sub-sectors.

¹⁴ OECD (2024^[11]) presents a robustness check including workers aged 50-60. The results are qualitatively similar, with slightly larger earnings losses in both energy-intensive industries and the rest of the economy, while the difference between the sectors remain the same. For this reason, and in order to minimize the impact of differences in early retirement schemes across countries, our baseline sample includes workers up to 50 years of age at separation.

Balancing treatment and controls

In our main analysis, we compare the outcomes of workers who are displaced between one year and the next as a result of mass layoff (treated) with those of non-displaced workers (control) who satisfy the same restrictions in the year immediately before displacement. We allow non-displaced control workers to be co-workers of displaced workers and to separate from their employer in subsequent years for any reason except a mass layoff event.¹⁵

As displaced and non-displaced workers may differ in their observable characteristics, we match each displaced worker to an observationally identical non-displaced worker through a 2-step matching procedure (“statistical twinning”). First, we use exact matching by baseline year, industry (1-digit NACE) and energy-intensive sector and sex. This ensures that displaced workers are matched only with workers in the same (energy-intensive) sector, of the same sex, and from the same year. 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). Based on the estimated propensity scores, we apply nearest neighbor one-to-one matching without replacement to assign each displaced worker to a unique control worker. 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_[11]) (see 3).

Table 3. Balance table

Standardized differences between displaced and matched non-displaced workers by energy-intensive industries

Variable	Country													
	AUS	AUT	CAN	DEU	DNK	ESP	EST	FIN	FRA	HUN	NLD	NOR	PRT	SWE
Panel A. Energy supply														
Log daily* wage (c-1)	0.03	0.07	0.01	-0.03	0.04	-0.02	0.15	-0.05	0.05	-0.06	-0.07	-0.03	0.03	0
Log daily* wage (c-2)	0.02	0.09	-0.02	0	-0.01	-0.01	0.12	-0.03	0.05	-0.06	0.05	-0.03	0.04	0.02
Log daily* wage (c-3)	0	0.08	-0.01	0	-0.01	0.05	0.15	-0.02	0.16	-0.05	-0.2	-0.03	0.04	0.04
Age	0	-0.01	0	0.09	0.02	-0.02	-0.06	0.02	0.05	0.01	-0.06	-0.01	0.05	-0.02
Job tenure	0.01	0.01	-0.02	0.05	0.02	-0.05	0.14	-0.04	-0.03	-0.03	0	0.02	0.03	0.06
Log employer size	0.01	0.13	0.03	0.07	0	0.09	0.07	0.01	0	0	0.59	0.03	0.12	0.03
Observations	776	530	10300	107	33	72	40	396	41	339	10	1,043	169	225
Panel B. Heavy manufacturing														
Log daily* wage (c-1)	-0.02	-0.02	0.03	-0.01	0.03	0.05	0.02	0.02	-0.03	0	0.02	-0.01	0	0.06
Log daily* wage (c-2)	-0.01	-0.01	0.02	-0.02	0.02	0.04	0.01	0.03	-0.03	0.02	0.01	-0.01	0	0.02
Log daily* wage (c-3)	-0.01	0	0.03	-0.01	0.02	0.05	0.05	0.01	-0.03	0.02	0.02	0	0	0.02
Age	0	-0.01	0.02	0.01	0	-0.01	0	0	0.02	0	0	-0.01	0.01	0

¹⁵ The latter prevents “forbidden comparisons” of treated units with units that were treated in earlier periods (de Chaisemartin and D’Haultfœuille, 2020_[1]; Callaway and Sant’Anna, 2021_[1]) while the former avoids overestimating displacement effects when restricting the control group to workers who remain continuously employed with the same employer (Krolikowski, 2017_[1]).

Job tenure	-0.04	0.01	0.04	0.03	0.01	0	0	0.02	-0.01	0.01	-0.01	0.02	0.01	0
Log employer size	0.04	0.03	0.07	0.02	0.01	-0.02	0.05	0.03	-0.03	0.04	0.03	0.03	0.03	0.01
Observations	335	3,047	15500	955	2,012	501	363	1,153	836	2,515	2,461	4,209	2,613	2,431
Panel C. Transport														
Log daily* wage (c-1)	-0.1	-0.03	0.02	0.04	-0.02	0.05	0	0	-0.03	0.07	0.01	-0.01	-0.01	0.03
Log daily* wage (c-2)	-0.02	-0.02	0.01	0.04	-0.01	0.04	0.01	-0.01	-0.03	0.04	0.03	-0.01	0.01	0.01
Log daily* wage (c-3)	-0.02	-0.03	0.01	0.03	0.03	0.05	-0.01	-0.03	0	0.03	0.03	-0.01	0	0.02
Age	0.01	-0.02	0.01	-0.03	0.01	0.01	-0.02	-0.01	0	0	0	-0.01	0	0
Job tenure	-0.06	-0.02	-0.01	0	-0.01	0.05	-0.03	0.01	-0.05	-0.04	-0.03	-0.03	0.03	0.01
Log employer size	0.02	0.03	0.04	-0.01	0.01	0	0.02	0.04	0.01	0.09	0.04	0.02	0.12	0.03
Observations	282	2,940	6300	418	1,910	378	312	1,229	729	502	2,360	1,943	2,241	1,956
Panel D. Rest of the economy														
Log daily* wage (c-1)	-0.01	-0.01	0	0	0	0	-0.01	0	0	0	-0.01	-0.04	-0.01	0
Log daily* wage (c-2)	-0.01	0	-0.01	0	0	-0.01	-0.01	0	0	0	-0.01	-0.02	-0.01	0
Log daily* wage (c-3)	-0.01	0	-0.01	0	0	0	-0.01	0	0	0	-0.01	-0.02	-0.01	0
Age	-0.01	0	0	0	0	0.01	0	0	0	0	0	-0.01	0	-0.01
Job tenure	-0.01	-0.01	0	-0.01	-0.01	0	0.05	-0.01	0.01	-0.02	0	-0.01	-0.01	0
Log employer size	0.02	0.01	0	0.01	0.02	0.03	0.07	0.02	0.01	0.03	0.03	0.05	0.02	0.03
Observations	14,10	79,99	24460	26,03	51,18	7,907	8,419	22,65	17,93	30,34	79,30	60,28	55,92	42,67
	8	2	0	4	7			3	0	9	0	9	4	9

Note: Exactly matched characteristics (e.g. gender, sector) are omitted as balanced by construction.

Source: National linked employer employee data, see Table 1 for details.

Event study design

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-intensive sector and the rest of the economy, using the equation below:

$$y_{itc} = \alpha_i + \lambda_t + \sum_{k=-3}^6 \gamma_k 1\{t = c + 1 + k\} + \sum_{k=-3}^6 \theta_k 1\{t = c + 1 + k\} \times Displaced_i + X'_{it} \beta + r_{itc}$$

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 the respective outcomes for non-displaced workers in the same sector, where k indexes event time such that $k=1$ in the first post-displacement year and $k=0$ in the last year before displacement. The coefficients are normalized to $k=-2$, such that the effects are measured relative to that time. The worker fixed effect α_i controls for time-invariant unobserved worker heterogeneity (see below), λ_t is a calendar year fixed effect, γ_k a time since event fixed effects and X'_{it} contains a cubic in age. Finally, r_{itc} is the idiosyncratic error term. Standard errors are clustered at the worker level.

The outcomes considered are annual earnings relative to the pre-displacement average, a dummy for being employed, the number of days worked, the log daily wage, the firm wage premium, and various mobility outcomes, such as the likelihood of changing the pre-displacement sector, occupation and region. Annual earnings are defined as the sum of labour payments (potentially, from different employers) in a

given year divided by average pre-displacement annual earnings. The employment dummy is equal to one if a worker has at least one day of dependent employment in a given year and zero otherwise. Recall that in the event a worker is not observed in dependent employment in a given year, zero earnings are imputed. This may overstate the actual costs of job loss to the extent that some displaced workers move to the public sector or become self-employed. Days worked are defined as the total number of days in dependent employment in a given year conditional being employed at least one day irrespective of hours worked. Log daily wages are constructed as the natural logarithm of annual earnings divided by days worked at the main employer. Firm wage premia measure the average wage premia paid to all employees in a firm net of worker characteristics and is estimated using an AKM two-way fixed effects model (Abowd, Kramarz and Margolis, 1999_[12]).¹⁶ Finally, the probability of changing sector, occupation or region is measured using a dummy which is equal to one if the observed value after displacement differs from its pre-displacement value and zero otherwise.

Decomposing earnings losses

To provide an indication of the different components behind displacement costs, expressed as differences in annual earnings between displaced and non-displaced workers, we also include a decomposition exercise into several components that make up annual earnings. These are i) being out of work for an entire year, (ii) fewer days worked conditional on being employed at some point during the year and (iii) lower daily wages upon re-employment. Fewer days worked conditional on being employed at least one day during the year may reflect a combination of the return to work during the year (as the first job after displacement starts after 1 January), the instability of employment following displacement (for example if workers are more likely to be re-employed on temporary contracts) or permanent exits during the year from employment (for example workers moving to inactivity or self-employment after 1 January). Lower wages upon re-employment, measured as daily wages, reflect a combination of hourly wages and working time. Daily instead of hourly wages are used to enhance the cross-country comparability of the results.

In practice, we decompose differences in 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 – mostly following Schmieder, von Wachter and Heining (2023_[8]). 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:

$$E[\Delta y] = E[p^{ND}n^{ND}w^{ND}] - E[p^Dn^Dw^D]$$

Rearranging terms gives:

$$E[\Delta y] = E[w^{ND}]E[n^D]\Delta E[p] + E[p^{ND}]E[w^{ND}]\Delta E[n] + E[p^D]E[n^D]\Delta E[w] + \mu$$

¹⁶ In practice, we estimate the following AKM 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 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.

where the first term gives the contribution of changes in daily wages to changes in annual earnings relative to the control group, while the second and third term capture the contribution of days worked and employment probability, respectively. The contribution of the probability of being employed captures periods out of dependent employment lasting a full calendar year, in which annual earnings are imputed to be zero. The contribution of days worked captures periods of non-employment shorter than a full calendar year, which reflects a combination of non-employment and job instability. The contribution of daily wages captures changes in daily wages following displacement. 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.

To shed light on the underlying drivers of wage losses, the role of daily wages for earnings losses can be further decomposed into a worker- and a firm-related component (Lachowska, Mas and Woodbury, 2020^[7]). We do this by decomposing the treatment effect on wages $\Delta E[w]$ into the sum of changes in firm wage-premia $\Delta E[\Psi]$ plus changes in worker-related components $\Delta E[\rho]$. While the former captures changes in the generosity of a firms' wage policies, the latter captures differences in human capital and match quality. The term μ is a residual which captures the change in the covariances between employment, days worked and daily wages which arise due to selection into employment. In practice, this component is very small and omitted for presentational purposes.

In a second step, wage losses upon re-employment are decomposed into a worker and a firm-related component. This is done by estimating the change in the firm-related component due to job displacement as measured by the firm fixed effect from an AKM two-way fixed effects model. The part of wage losses that is not firm-related may include worker-related wage losses due to the loss of human capital or wage losses due to a reduction in match quality.

Oaxaca-Blinder decomposition

The analysis of job displacement examines the outcomes of displaced workers compared to those who are not displaced but have similar characteristics within the same energy-intensive sector. Nevertheless, the characteristics of displaced workers in energy-intensive industries may still differ from those in other parts of the economy and from displaced workers in similar sectors in other analysed countries. Consequently, differences in the cost of job displacement across industries and countries might reflect variation in the composition of displaced workers or differences in the cost of job displacement for similar workers. Using Oaxaca-Blinder decompositions, we aim to measure the impact of worker composition on the differences in job displacement costs between industries and countries.

For this, we start by denoting the *individual-level* difference-in-differences estimate (Δy_i) as:

$$\Delta y_i = \left(\bar{y}_{i,after}^D - \bar{y}_{i,before}^D \right) - \left(\bar{y}_{i,after}^{ND} - \bar{y}_{i,before}^{ND} \right) \quad (1)$$

where $\bar{y}_{i,after}^h$ indicates the average outcome for $h \in \{Displaced, Non - displaced\}$ after job displacement (1 to 4 years) and $\bar{y}_{i,before}^h$ the corresponding average outcome before job displacement (-3 to -1 years). The estimate individual-level difference-in-differences Δy_i can in turn be characterised as a linear model of the observable characteristics of displaced and non-displaced workers in each sector:

$$\Delta y_i^s = X_i^s \beta^s + \vartheta_i^s \quad (2)$$

where X_i^s , $s \in \{ERI, ROE\}$ is a vector of worker and firm characteristics measured before displacement (i.e. in the baseline period at $k=0$) for energy-intensive industries (*ERI*) and the rest of the economy (*ROE*) and

ϑ_i^s is an error term. Naturally, this analysis extends to specific energy-intensive industries, i.e. energy supply, heavy manufacturing and transport, in place of *ERI*.

Using equations (1) and (2), the Oaxaca-Blinder decomposition of the difference in the difference-in-differences estimate between energy-intensive industries and the rest of the economy can be written as:

$$\Delta \bar{y}_i^{ERI} - \Delta \bar{y}_i^{ROE} = (\bar{X}_i^{ERI} - \bar{X}_i^{ROE}) \beta^{ROE} + \bar{X}_i^{ERI} (\beta^{ERI} - \beta^{ROE}) \quad (3)$$

where the first component on the right-hand side captures the role of composition effect, i.e. the part that is explained by differences in observable characteristics between displaced workers in energy-intensive industries and the rest of the economy, and the second component captures the structural effect, i.e. unexplained differences in the cost of job displacement between energy-intensive industries and the rest of the economy holding composition constant. A similar decomposition can be used to shed light on the drivers of differences in the cost of job displacement in energy-intensive industries between countries.

4 Results

The cost of job displacement in energy-intensive industries on average across countries

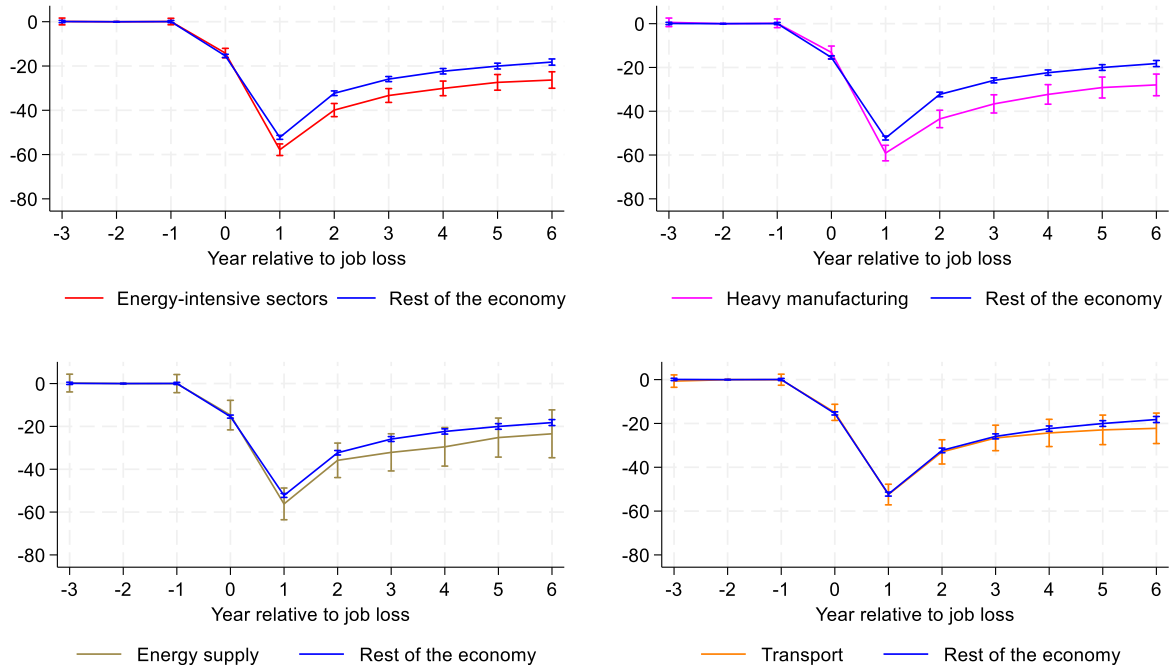
On average across the countries considered in our analysis, workers displaced from energy-intensive industries have significantly higher earnings losses than those displaced in the rest of the economy (Figure 2). In the initial year following mass layoff, displaced workers in the rest of the economy lose about 52% of earnings compared to similar non-displaced workers, while workers displaced in energy-intensive industries lose 58% on average. Earnings losses partly converge with those of non-displaced workers in subsequent years, but differences in earnings losses between workers energy-intensive industries and the rest of the economy remain persistent. Even six years post-displacement, earnings losses are 26% in energy-intensive sectors compared with 18% in low energy-intensive sectors. On average over the six years following displacement, earnings losses are 7 percentage points higher in energy-intensive sectors than in the rest of the economy (which corresponds to a 24% difference in proportional terms).

However, there are important differences within the energy-intensive sector between sub-sectors. For example, the largest losses are observed in heavy manufacturing, where workers lose 38% of their earnings relative to non-displaced workers on average over the six years following job loss. In contrast, in transport the average earnings losses over the six years following displacement are similar to those in the rest of the economy. While the average losses following displacement in the energy supply sector are also larger than in the rest of the economy, they are not statistically. This partly reflects larger confidence intervals due to small sample sizes (see Figure 2) and partly heterogeneity in the direction and size of earnings losses across countries (see the next sub-section).

Overall, our aggregate results across countries suggest that displacement in energy supply and heavy manufacturing is associated with substantially higher costs than those in other sectors, including transport. These results are mirror those in OECD (2024^[1]) and echo findings from Barreto, Grundke, & Krill (2023^[9]), which also demonstrate that workers displaced from carbon-intensive industries in Germany, overlapping entirely with energy-intensive industries used here, experience higher costs of job displacement compared to other sectors. 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^[13]), Andrews, Dwyer and Vass (2023^[14]) and Rud et al. (2022^[15]) find elevated earnings losses for displaced coal workers in respectively Germany, Australia and the United Kingdom.

Figure 2. Most energy-intensive industries face greater job displacement costs than other sectors

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



Note: Average across countries of earnings losses of displaced workers relative to observationally comparable non-displaced workers. "Rest of the economy" refers to non-energy-intensive sectors. The point estimates show the impact of job loss on earnings in event time, where workers are displaced between time 0 and time 1, such that time 1 is the first post-displacement year. The reference period for earnings losses is $k=-2$. Point estimates and 90% confidence intervals (clustered at the worker level) from country-level regressions are averaged assigning each country an equal weight. *The countries included are: Australia, Austria, Canada, Denmark, Estonia, Finland, Germany, Hungary, the Netherlands, Norway, Portugal, Spain, France, Sweden. For the energy supply sector, the number of laid off workers in Denmark, Estonia, France, the Netherlands and Spain falls below the 100-person threshold, in Portugal below the 10-firm threshold and these countries are therefore excluded from the energy supply average.

Source: National linked employer employee data, see Table 1 for details.

The cost of job displacement in energy-intensive industries by country

Differences in the size of earnings losses between workers in energy-intensive industries and those in the rest of the economy can differ across countries and specific energy-intensive industries. For ease of exposition, the size of the effects is compared across countries and industries by focusing on the average effects of job displacement during the six years following job displacement. The results are summarised in Figure 3.

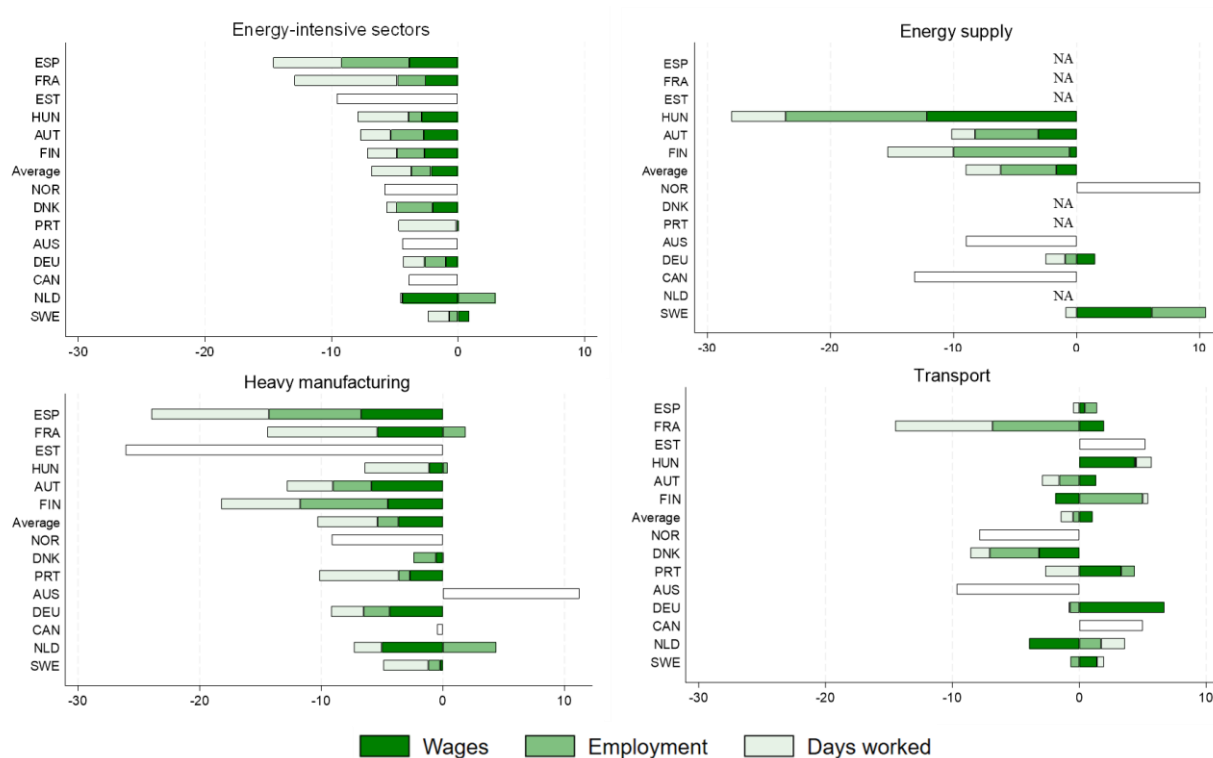
There is wide variation across countries in the difference in average earnings losses between energy-intensive sectors and the rest of the economy.¹⁷ For example, workers in the energy-intensive industries of Spain have on average about 15 percentage points higher earnings losses than workers from the rest of the economy, closely followed by France with a difference of 13 p.p.. With less than 5 p.p., differences

¹⁷ A negative bar indicates that earnings losses are on average higher for those in energy-related industries over a 6-year period.

in the earnings losses over six years following displacement are particularly small in Australia, Canada, Germany, the Netherlands, Portugal and Sweden.

Figure 3. The sources of earnings losses between energy-intensive industries and the rest of the economy industries vary widely across sector and country

Average annual difference in earnings losses over the six years following displacement between energy-intensive industries and rest of the economy decomposed into different contributions of employment, days worked and wages by energy-intensive sector and country, p.p.



Note: Bars represent the average earnings loss six 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. Finland is missing from this figure due to missing information at the time of this draft. For Denmark, Estonia, France, the Netherlands and Spain, the number of laid off workers energy supply sectors falls below the 100-person threshold, in Portugal below the 10-firm 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.

There are also important differences in the pattern of earnings losses across energy-intensive industries between countries. For instance, in energy supply, earnings losses are 28 p.p. larger in Hungary than the rest of the economy, but about 10 p.p. smaller in Norway and Sweden. This may in part reflect particularities in the national energy mix, as Sweden pre-dominantly produces energy through renewables, whereas Hungary relies predominantly on energy generation through fossil fuels (IEA, 2024_[16]).¹⁸ In heavy

¹⁸ 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 industries.

manufacturing, earnings losses for displaced workers are 26 p.p. higher than the rest of the economy in Estonia, while in Australia they are 11 p.p. lower. Even though our previous aggregate findings suggest that there are no elevated earnings losses in the transport sector, there are notable differences within specific countries. For example, transport workers in France face earnings losses nearly 13 p.p. higher than those in the rest of the economy, whereas in Germany, displaced transport workers face about 6 p.p. lower losses than those in the rest of the economy.

The sources of earnings losses in energy-intensive industries by country

Earnings losses following displacement stem from different underlying causes, that can vary in importance by country and sector. Decomposing the earnings losses after job displacement into their contributing factors – namely (i) being out of work for an entire year, (ii) fewer days worked, conditional on being employed at some point during the year,¹⁹ and (iii) lower daily wages upon re-employment - can thus shed light on the underlying drivers of job displacement costs for workers in energy-intensive industries and the rest of the economy. Figure 3 provides a decomposition of average earnings losses in energy-intensive sectors over a six-year period compared to the rest of the economy.

Larger earnings losses due to job displacement in energy-intensive sectors mainly reflect weaker re-employment outcomes, notably differences in the number of days worked and re-employment wages rather than differences in the likelihood of being in employment. However, these margins differ considerably across countries. In France, significant differences in earnings losses are primarily driven by differences in days worked, whereas in Austria and Spain, all three components contribute more or less equally to the elevated earnings losses in energy-intensive industries. The Netherlands stands out as differences in employment probabilities reduce rather than increase the gap in earnings losses between displaced workers in energy-intensive and the rest of the economy.

The sources of differences in earnings losses differ to some degree across energy-intensive sectors. In energy-supply, earnings losses are on average driven in equal parts by differences in employment, days worked, and re-employment wages, though there is considerable variation across countries. For example, days worked explain virtually nothing of the differences in earnings losses in Sweden. In heavy manufacturing, the contribution of employment, days worked and re-employment wages is of roughly equal to that in energy-intensive industries as a whole, while re-employment wages play a relatively small role in the differences in earnings losses in Denmark, Hungary, and Sweden. In transport, there is strong variation in the contributing factors to differences earnings losses across countries. For example, transport workers in France experience earnings losses that are for the most part driven by differences in employment and days worked, while German transport workers see higher re-employment wages after displacement.

Firm- and worker-related wage losses in energy-intensive industries by country

Wage losses in re-employment are an important part of the differences in earnings losses between energy-intensive sectors and the rest of the economy, contributing on average to about a quarter of the overall difference in earnings losses. The origin of these wage losses can stem from firm-related losses due to foregone firm wage premia and worker-related losses due to human capital depreciation and lower match quality (Lachowska, Mas and Woodbury, 2020^[7]). The results are summarised in Figure 4.

¹⁹ Differences in days worked in the first year after displacement are mainly related to the return to employment later in the year (i.e. after 1 January), whereas differences in subsequent years mainly reflect lower job stability upon re-employment.

Higher wage losses in energy-intensive sectors tend to be firm-related. This may indicate that workers in energy-intensive sectors may undergo larger earnings losses in part because they were displaced from higher paying firms. These may be either firms that are more productive, capture more rents, or compensate workers for physically demanding working conditions by paying higher wages (Card et al., 2018^[17]; Sorkin, 2018^[18]; Hirsch and Mueller, 2020^[19]). Differences in worker-related wage losses either tend to be small or negative (i.e. lower in energy-intensive industries). Only in Finland and Portugal, are larger wage losses in energy-intensive industries mainly worker-related.

The importance of firm-related wage losses to differences in re-employment wages in energy-intensive industries tends to be driven by heavy manufacturing, while in energy supply, wage losses tend to reflect worker-related rather than firm-related factors. In transport, wage losses due to job displacement tend to be smaller than in the rest of the economy due to smaller worker-related wage losses. While the pattern for heavy manufacturing is strikingly consistent across countries, the patterns for energy supply and transport are more mixed.

Figure 4. Larger wage losses mostly reflect higher firm-related losses, but vary across country and sector

Average annual difference in the six years following displacement in log wage losses between displaced workers from energy-intensive industries and the rest of the economy, decomposed into differences in firm- and worker-related losses, p.p..



Note: Bars represent the average wage loss six 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). The chart excludes countries for which daily wages cannot be calculated. For Denmark, Estonia, France, the Netherlands and Spain, the number of laid off workers energy supply sectors falls below the 100-person threshold, in Portugal below the 10-firm 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

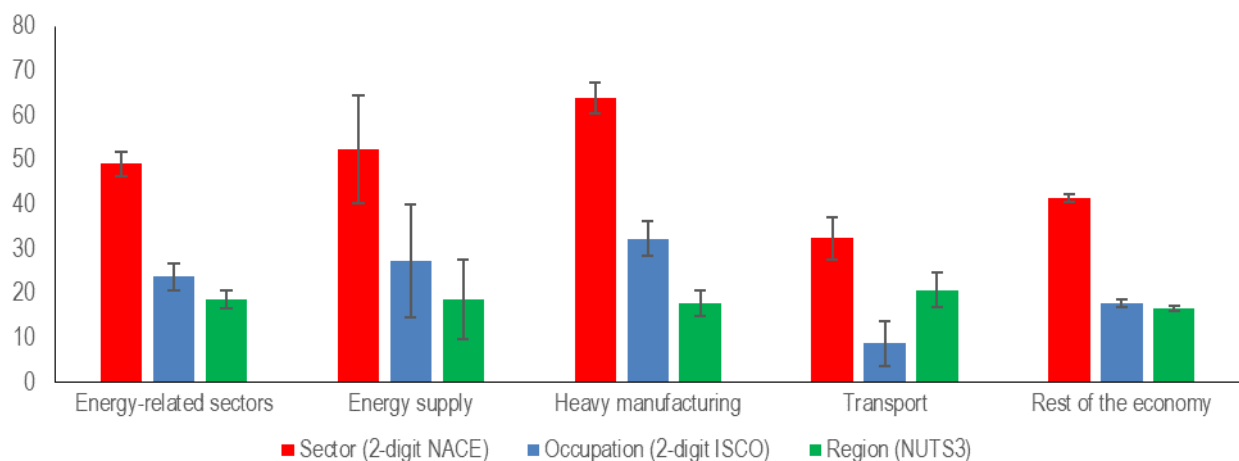
The effects of job displacement on job mobility in energy-intensive industries

The clean energy-transition and its potential impact on employment in energy-intensive industries may mean that displaced workers find it harder to find another job in the same sector, occupation or region. However, switching sector or occupation may entail significant additional costs due to the loss of occupation- and sector-specific human capital (Huckfeldt, 2022^[20]; Barreto, Grundke and Krill, 2023^[9]). Changing region, by contrast, may enhance employment opportunities, potentially mitigating earnings losses after displacement (Arntz, Ivanov and Pohlen, 2022^[21]). Regional mobility from rural to urban areas in particular may also help mitigate the earnings losses of job displacement (Huttunen, Moen and Salvanes, 2018^[22]; Meekes and Hassink, 2019^[23]). 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 in energy-intensive and non-energy-intensive industries on average over six years following job loss.

Workers in energy supply and heavy manufacturing are more likely to change sector and occupation after displacement than workers in non-energy-intensive industries (Figure 5). This may reflect the structural decline in employment in those sectors. The higher incidence of switching sectors and occupations and the associated loss of sector-specific human capital may help explain why displaced workers in those sectors tend to suffer larger earnings losses and weaker re-employment outcomes. In contrast, workers displaced in transport are less likely to change occupations and sectors than workers displaced in non-energy-intensive industries as well as the other energy-intensive industries. This indicates that displaced workers in transport find jobs that are similar to those from which they were displaced and in turn may explain why they experience lower earnings losses. Strikingly, regional mobility does not significantly differ across energy-intensive industries and the rest of the economy.

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

Average difference in transition probabilities between displaced workers and their matched counterparts over the six years after displacement, average across country, percentage points



Note: Average across Austria, Portugal, Germany, Spain, Estonia, Hungary, Finland, France, Sweden. For occupational and regional changes, the figure excludes Austria and Estonia. 90% confidence intervals clustered at the worker level.

Source: National linked employer employee data, see [Table 1](#) for details.

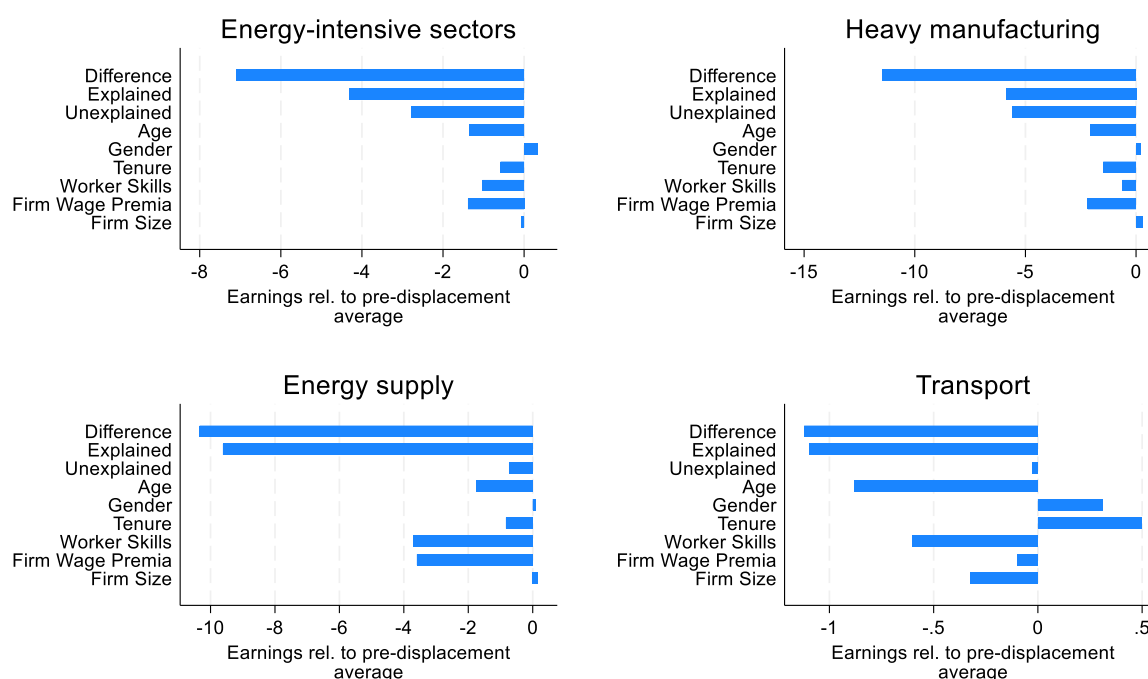
Potential mechanisms behind within-country differences in earnings losses

Although the costs of job displacement are estimated by comparing observationally comparable displaced and non-displaced workers before and after mass-layoff events, there can still be significant differences between displaced workers from energy-intensive industries and those from other sectors in the economy. This raises the question to what extent differences in the composition of firms and workers between industries contribute to the variation in job displacement costs. To determine the extent of these composition effects on the differences in job displacement costs within countries, Figure 6 presents an Oaxaca-Blinder decomposition that takes into account both individual and firm characteristics.

The composition of workers and firms is a key determinant for the differences in the costs of job displacement between each of the energy-intensive sectors and the rest of the economy, explaining at least half of the differences earnings losses. In each of the energy-intensive industries, displaced workers tend to be older, have lower levels of portable skills (as measured by the worker-related component of wages) and tend to be employed in firms that offer high wages, conditional on worker skills, which are lost upon re-employment. The main reason why displaced workers in transport do not experience higher earnings losses than displaced workers in the rest of the economy appears to be related to tenure. Whereas displaced workers in heavy manufacturing and energy supply tend to have somewhat higher tenure than displaced workers in the rest of the economy, contributing to higher earnings losses, in transport displaced workers tend to have shorter tenures relative to other energy-intensive sectors as well as the rest of the economy, reducing earnings losses.

Figure 6. The composition of workers and firms drives differences in the cost of job displacement between energy-intensive sectors and the rest of the economy

Oaxaca-Blinder decompositions of earnings gap (p.p.) after six years, between energy-intensive sectors within countries



Note: The figure refers to within-country differences in job displacement costs between workers in each energy-intensive industry and the rest of the economy (reference group_) and decomposes the difference in mean earnings losses within a country between sectors net of year effects. Worker skills are measured by the worker-related wage component, whereas firm wage premia are measured by the firm-related wage component. Both are estimated using two-way fixed effects wage models (Abowd, Kramarz and Margolis, 1999^[12]). The decomposition excludes Australia and Canada as it is not possible to estimate two-way fixed effects for firms and workers due to data limitations. For Denmark, Estonia, France, the Netherlands and Spain, the number of laid off workers energy supply sectors falls below the 100-person threshold, in Portugal below the 10-firm threshold and results for this sector are therefore not included in the average.

Source: National linked employer employee data, see Table 1 for details

5 Policy implications

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 costs of job displacement is essential for assisting displaced workers in sectors and occupations at risk and ensuring transitions to new and emerging sectors and occupations, for example occupations in sectors relying on clean energy. However, it is also critical for securing public support for the clean energy transition (see OECD (2024_[1]) for a comprehensive overview of policy approaches).

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_[1]). 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_[1]). While early retirement schemes can in principle can mitigate adverse labour market outcomes by offering a swift transition to pensions, they negatively impact aggregate labour supply and public finances (OECD, 2018_[1]), and are therefore not a strategically sound approach for the clean energy transition.

As a significant part of earnings losses following displacement in energy-intensive industries 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_[1])) 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 job displacement costs. 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 and Leive, 2023_[1]; Hyman et al., 2021_[1]). Whether such policies should be targeted to support workers specifically affected by the clean energy transition depends on the country context.

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, e.g. Causa et al (2024_[1]). 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_[1]). 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_[1]).

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