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A new measurement approach for identifying high-polluting jobs across European countries

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ABSTRACT/RÉSUMÉ

This paper develops a novel classification of high-polluting occupations for a large sample of European countries. Unlike previous efforts in the literature, the classification exploits country-level data on air polluting emission intensity by industry. The country-level data allows to capture important cross-country differences, due to differences in technology and in production focus. Applying the new classification to European Labour Force Survey data shows that, on average across the countries covered, about 4% of workers are employed in high-polluting jobs, ranging from 9% in Czechia and the Slovak Republic to around 2% in Austria. These shares do not exhibit any clear decreasing trend over the past decade. High-polluting jobs are unequally distributed, being over-represented among men, workers with lower and medium educational attainment and those living in rural areas.

JEL: J21; Q51; Q53; Q56

Keywords: climate change; green transition; labour markets; high-polluting jobs; air polluting emissions; classification.

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Cette étude développe une nouvelle classification des métiers polluants pour un large éventail de pays européens. À rebours de la littérature existante, la classification exploite des données sur l'intensité des émissions par pays et secteur d'activité. Cela permet de tenir compte d'importantes différences entre pays, tant dues à des facteurs technologiques qu'aux spécialisations sectorielles respectives. L'application de la nouvelle classification aux données de l'enquête de l'Union Européenne sur les forces de travail révèle que, en moyenne dans l'ensemble des pays étudiés, environ 4% des travailleurs occupent des emplois très polluants, allant de 9 % en Tchéquie et en République Slovaque à environ 2% en Autriche. La part des métiers polluants n'affiche pas de tendance claire à la baisse sur la dernière décennie. Dans la grande majorité des pays couverts par l'étude, les métiers polluants sont inégalement répartis, étant surreprésentés chez les travailleurs faiblement et moyennement éduqués et dans les zones rurales.

JEL: J21; Q51; Q53; Q56

Mots clés: changement climatique; transition verte; marché du travail; emplois polluants; émissions atmosphériques polluantes; classification

A new measurement approach for identifying high-polluting jobs across European countries

Orsetta Causa, Maxime Nguyen, Emilia Soldani [1]

Introduction

The rising awareness about the urgency to tackle environmental and climate-related pressures whilst minimizing distributional costs has motivated a rich and recent literature on the labour market effects of the green transition, involving academics, national authorities and international organizations, as discussed in Causa et al. (2024[1]).[2] In this literature, high-polluting jobs are broadly defined as jobs prevalent in high-emitting industries. The focus on such industries is due to the assumption that, in the context of the green transition and associated environmental policy actions, these industries will likely be more prone to transform their ways of producing and operating, to innovate or to shrink, with local and sectoral effects on labour markets (Bibas, Chateau and Lanzi, 2021[2]).

Due to data limitations, high-polluting jobs have been generally identified based on US emissions, hence implicitly assuming the same ranking of emission intensity by industry across countries, despite differences in production technologies and environmental policies. Recent cross-country analyses at the OECD and elsewhere have used this approach, starting from the list of high-polluting occupations defined under the US classification in (Vona et al., 2018[3]) and cross-walking to other national and international occupation classifications.[3] Alternatively, others have adopted definitions of high-polluting jobs based on the industry (instead of occupation) an individual is working in (see for instance (Vandeplas et al., 2022[4]) for a discussion). Table 1 delivers a non-exhaustive overview of the recent literature.

The main contribution of this paper is the identification of country-specific high-polluting industries and occupations for a large sample of European countries. [4] This is achieved by elaborating an harmonized framework to maximize cross-country comparability. The framework relies on air polluting emissions data

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[2] See for instance Vandeplas at al. (2022[12]), IMF (2022[13]) or Keese and Marcolin (2023[11]).

[3] See OECD (2023[6]), Tyros et al. (2023[7]), Scholl et al. (2023[10]).

[4] In this paper, high-polluting jobs are defined at the occupation level. As a result, the text refers to high-polluting jobs and high-polluting occupations interchangeably.

by country and industry to develop an identification methodology based on a careful adaptation of Vona et al. (2018[3])'s original methodology.

The rest of this paper details the framework, starting with the data and methodology, then the results and a discussion of how they compare to the previous literature, followed by a robustness analysis to alternative methodological choices. The conclusion wraps-up and raises preliminary policy implications.

Table 1. Overview of recent definitions of high-polluting jobs

Reference	Data	Measure	Region	Result
Vona et al. (2018[3])	Facility-level information on air emissions from the National Emission Inventory database (year 2011) and the Greenhouse Gas Emissions from Large Facilities (year 2011) Employment data from BLS	High-polluting measure at the SOC 6-digit occupation level, based on emissions by industry and on distribution of workers in each occupation across industries. High-polluting industries are defined as those four-digit NAICS21 industries in the top 95th percentile of emissions of at least 3 (out of 8) contaminants: CO2, CO, VOC, NOx, SO2, PM10, PM2.5, and lead)	US	62 high-polluting NAICS 4-digit industries 87 high-polluting SOC 6-digit occupations
Vandeplas et al. (2022[4])	Air Emission Accounts, aggregate EU-LFS	High-polluting employment is defined at the sector level. Sectors that are most often top-ranked based on their GHG emission intensity in European countries are considered 'high-polluting'	EU	Average high-polluting employment of 8.2% in 2008 and 5.7% in 2021
European Commission (2021[5])	Air Emissions Accounts Eurostat National Accounts	High-polluting industries are identified as those with a high energy intensity, and which manufacture materials in the economy, at the beginning of the chain of production. Industries C16, C17, C19, C20, C22, C23, C24 are defined as high-polluting	EU	Average high-polluting employment of 3.8% in 2018
OECD (2023[6])	List of high-polluting occupations (Vona et al., 2018[3]) O*NET crosswalk	Building on Vona et al. (2018[3]), cross-walking to national or international occupations classification, with a final binarized measure	USA, CAN, AUS, NZL, Europe	Average high-polluting employment of 11.7% in 2021
Tyros et al. (2023[7])	List of high-polluting occupations (Vona et al., 2018[3]) O*NET crosswalk	Building on Vona et al. (2018[3]), cross-walking to national or international occupations classification, with a final discrete measure representing the share of underlying high-polluting jobs at SOC 6-digit	USA, AUS, Europe	Average high-polluting employment of c.6%
IMF (2022[8])	List of high-polluting occupations (Vona et al., 2018[3]) O*NET crosswalk	Building on Vona et al. (2018[3]), cross-walking to national or international occupations classification, with a final discrete measure representing the employment-weighted share of underlying high-polluting jobs at SOC 6-digit	US, Europe	Average high-polluting employment ranging between 2% and 6%

Source: OECD Secretariat elaborations

Identifying high-polluting jobs: data sources

The methodological approach to identify high-polluting occupations in European countries follows the logic developed by Vona et al. (2018[3]) in the context of the United States, with important adaptations to cope with data availability and structure for the countries under consideration. Given the important differences

in industrial structures, specialization, and technology across the two sides of the Atlantic and among European countries, the aim is to define high-polluting jobs on a country-by-country basis, hence departing from the application of US-based characteristics to European countries. This is not a straightforward exercise, in particular because it requires industry-level data on polluting emissions per worker and the distribution of occupations by industry. This information is obtained and elaborated based on the following sources:

- **Eurostat air emission accounts**:[5] the dataset reports the emissions of greenhouse gases and air pollutants in the atmosphere by NACE 2-digit industry by resident production units.
- **Eurostat national accounts on employment by industry**:[6] the dataset covers employees and self-employed persons working in resident production units by NACE 2-digit industry.
- **Census data from the UK on the distribution of occupations by industry**: the dataset allows the derivation of bivariate distribution of UK SOC 4-digit occupations and UK SIC 2-digit industries, that is, the number of workers by occupation and industry, for 2011.

Estimates of industry-level pollution intensity per worker are obtained by combining data from Eurostat Air Emission Accounts and from National Employment accounts. The distribution of occupations across industries is based on UK Census data from 2011. This is the best available data source given the absence of suitable harmonized data for European countries.

The analysis covers the following countries, selected on the basis of data availability: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom. The harmonized cross-country focus is relevant but not sufficient to properly address country-specific situations and challenges and can be profitably complemented with country-specific approaches to reflect local situations, for instance the importance of specific pollutants associated with industrial specialisation (e.g., methane in the case of the agricultural sector).

Eurostat Air Emissions accounts

Assigning emissions to specific industries by country is challenging due to the interlinkages between industries and to global value chains. For European countries, three main approaches could be taken in defining relevant polluting emissions, which are reflected in the three different datasets available from Eurostat. The choice of the approach is conditional on the question at stake and on the characteristics (for example the granularity) of available data:[7]

- **Residential production perspective** (database ENV_AC_AINAH_R2):[8] follows the so-called residence principle as established in national accounts, reporting only the emissions generated by resident economic actors. This measure is available at the industry level (NACE Rev.2 2-digit), under Eurostat Air Emission accounts. The reliance on national accounts classification principles makes it possible to match national accounts employment data and compute emissions per worker.
- **Territorial production perspective** (database ENV_AIR_EMIS):[9] reports the emissions produced within national borders irrespective of the residence status of the emitting actors, based on national air

[5] Online data code: ENV_AC_AINAH_R2

[6] Online data code: NAMA_10_A64_E

[7] This summary is purely illustrative to introduce the approach developed in this paper to assess high-polluting jobs in a European cross-country comparative perspective. A proper discussion of the different production/consumption/territorial issues surrounding the allocation of polluting emissions to one entity is fundamental in the area of international policy dialogue to achieve net-zero. This is outside the scope of this work.

[8] Link to the database: https://ec.europa.eu/eurostat/databrowser/view/ENV_AC_AINAH_R2/default/table?lang=en

[9] Link to the database: https://ec.europa.eu/eurostat/databrowser/view/ENV_AIR_EMIS/default/table?lang=en

pollution inventories. The resulting figures are used in official international reporting framework for climate policies, e.g., under the UNFCCC. Sectors are classified according to the Common Reporting Format/Nomenclature for Reporting (NFR 14).[10] This classification does not univocally map to NACE, making these data less useful for the identification of high-polluting industries.

- **Consumption perspective** (database ENV_AC_IO10):[11] presents estimates of air emissions 'embodied' in products (goods and services) for final use, sometimes referred to as *footprints*. The estimates are based on input-output modelling and assign to a product the emissions produced along the entire production chain, irrespective of the territory where the pollution occurred. This approach is relevant, e.g., to assess imported pollution. Yet the link with domestic labour market dynamics is not straightforward and would probably be best elaborated through the lenses of large-scale general equilibrium modelling, taking into account international trade linkages.

For the purpose of identifying high-polluting industries in European countries, the production perspective of the Eurostat Air Emission Accounts is preferred, as it reports the polluting emissions produced by the firms in the country, classified by industrial sector. This approach is the most likely to identify where labour markets adjustments may be needed and where the role of domestic policies are felt in a cross-country perspective, despite possible limitations (e.g., pollution emitted by the final product like motor vehicles are not taken into account, nor are global value chains).

The Air Emissions Account dataset provides emissions data for 62 industries (see Table 2), defined mostly at the NACE Rev. 2 2-digit level, and it covers 24 greenhouse gases and air pollutants and 33 European countries from 1995 to 2021. Except for lead, this dataset covers all the 8 pollutants considered by Vona et al. (2018[3]).

Table 2. Coverage of NACE industries

NACE 2-digit industry	Label
A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10-C12	Manufacture of food products; beverages and tobacco products
C13-C15	Manufacture of textiles; of wearing apparel; of leather and related products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment not elsewhere classified (n.e.c.)
C29	Manufacture of motor vehicles, trailers and semi-trailers

[10] More details on NFR at https://unece.org/emissions-reporting.

[11] Link to the database: https://ec.europa.eu/eurostat/databrowser/view/env_ac_io10/default/table?lang=en

C30	Manufacture of other transport equipment
C31-C32	Manufacture of furniture and other manufacturing
C33	Repair and installation of machinery and equipment
D	Electricity, gas; steam and air conditioning supply
E36	Water collection, treatment and supply
E37-E39	Sewerage; Waste collection, treatment and disposal activities; materials recovery; Remediation activities and other waste management services
F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Wholesale trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59-J60	Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities
J61	Telecommunications
J62-J63	Computer programming, consultancy and related activities; Information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L	Real estate activities
M69-M70	Legal and accounting activities; Activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74-M75	Other professional, scientific and technical activities; Veterinary activities
N77	Rental and leasing activities
N78	Employment activities
N79	Travel agency, tour operator reservation service and related activities
N80-N82	Security and investigation activities; Services to buildings and landscape activities; Office administrative, office support and other business support activities
O	Public administration and defense; compulsory social security
P	Education
Q86	Human health activities
Q87-Q88	Residential care activities; Social work activities without accommodation
R90-R92	Creative, arts and entertainment activities; Libraries, archives, museums and other cultural activities; Gambling and betting activities
R93	Sports activities and amusement and recreation activities
S94	Activities of membership organizations
S95	Repair of computers and personal and household goods
S96	Other personal service activities

Source: Eurostat Air Emissions Accounts.

National Accounts on employment by industry

Employment by NACE 2-digit industry is derived from National Accounts Data, recognised as the most accurate data source in this area and, as mentioned before, classified consistently with Air Emission Accounts data.[12]

UK Census data on the distribution of occupations by industry

Identifying high-polluting jobs at the occupation level requires data on the distribution of occupations across industries. Among the countries covered in the study, relevant and granular-enough data (i.e., at least 3-digit ISCO and 2-digit NACE) are only available from the UK 2011 census. While similar information would also be available from US data, UK-based information is better suited to the current exercise, given the European focus. UK data are defined at a very granular level, with occupations at the SOC 4-digit and industries at the SIC 2-digit level.

Identifying high-polluting jobs: methodology

The methodology to identify high-polluting jobs using the above-defined data sources is detailed below.

Identification of high-polluting industries

- High-polluting industries are identified from emissions per worker across seven pollutants. This is based on data at the most disaggregated available level possible. Pollution intensities per worker, for every industry, year, and country, are obtained by dividing emissions by the number of workers employed. The pollutants considered, following Vona et al. (2018[3]) are Carbon monoxide (CO), Non-methane volatile organic compounds (NMVOC), Nitrogen oxides (NOx), Sox in SO2 equivalents (SOX), Particulate Matter < 10µm (PM10), Particulate Matter < 2.5µm (PM2.5), and Carbon Dioxide (CO2T). The World Health Organization (WHO) identifies these pollutants as particularly harmful for human health and local ecosystems.
- Rather than yearly values of emissions per worker, the analysis relies on 2011-2019 averages for each country, industry, and pollutant. This is to smooth the series and limit the sensitivity to measurements errors and outliers, and the analysis yields qualitatively consistent results when using only data from 2019 or 2011.
- Within each country and for each pollutant, industries are then ranked in terms of pollution intensity: a given industry is classified as high-polluting in a given country if it belongs to the top 15% most polluting industries for at least 3 of the 7 pollutants (3-out-of-7 rule). Relying on the ranking instead of a specific threshold is the standard approach in the literature, because this mitigates the influence of outliers and facilitates the selection of the same number of industries in each country (Vona et al., 2018[3]). The use of the 3-out-7 rule is a standard approach in the literature and captures the multidimensionality of polluting emissions, as the seven pollutants differ in their effects in terms of global warming as well as public health. An alternative, based on the warming potential of pollutants, is the use of total GHG emissions: the resulting list of polluting industries is similar when following this approach.
- The analysis does not cover methane emissions, often originating from agricultural activities. Because non-methane emissions are generally low in agriculture, the 3-out-of-7 rule implies that agriculture would not be identified as a high-polluting industry even if methane were added to the list of pollutants.

[12] Employment statistics within national accounts - Statistics Explained (europa.eu). The analysis uses EU-LFS for Norway, due to incomplete employment data in the National Accounts.

Still, this is a very important environmental issue to be addressed on a contextual basis, in particular in countries featuring a large agricultural sector, such as Ireland.

- In order to enhance comparability across countries, the same number of industries is selected for each country. The top 15% would normally correspond to nine industries, except in case of a tie between several industries. Two tie break rules are therefore applied: i) in case of a tie, the industry which is in the top 15% in the highest number of pollutants is selected and ii) in case of further tie the larger industry is selected.

Overall, the current approach presents a number of differences with respect to Vona et al. (2018[3]):

- The choice of using average emissions from 2011 to 2019 (instead of the emissions from a specific year) mitigates the potential impact of yearly shocks, and thus statistical noise in identification of high-polluting industries. This also allows the impact of progressive decarbonization to be captured. For example, Land transport industry displays much higher emissions per worker at the beginning of the period than later, possibly due to technological shifts and the greening of motor vehicles.
- The higher level of aggregation in European relative to US data implies a lower number of industries. Therefore, out of the shorter list of all industries, the top 15% of emitters for at least three pollutants are selected, instead of the top 5% as in Vona et al. (2018[3]).

The country-by-country list of high-polluting industries based on this procedure are listed in Table 3. Some industries are only high-polluting in a few countries, reflecting various factors such as the diversity in industrial structure, in energy efficiency and technology.

Table 3. High-polluting industries, country-by-country list

NACE 2-digit Industry	Label	AUT	BEL	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	NLD	NOR	POL	PRT	SVK	SVN	SWE
D	Electricity, gas; steam and air conditioning supply	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
H50	Water transport	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
C19	Manufacture of coke and refined petroleum products	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
C24	Manufacture of basic metals	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
C23	Manufacture of other non-metallic mineral products	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
H51	Air transport	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓
C20	Manufacture of chemicals and chemical products	✓			✓		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
B	Mining and quarrying	✓	✓	✓		✓		✓	✓	✓	✓			✓	✓		✓		✓		✓	✓
A01	Crop and animal production, hunting and related service activities			✓	✓	✓	✓			✓			✓	✓	✓	✓				✓	✓	✓
A03	Fishing and aquaculture		✓			✓		✓	✓	✓	✓			✓		✓		✓				✓

NACE 2-digit Industry	Label	AUT	BEL	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	NLD	NOR	POL	PRT	SVK	SVN	SWE
C17	Manufacture of paper and paper products	✓					✓	✓	✓								✓	✓	✓	✓	✓	✓
E37-E39	Sewerage; Waste collection, treatment and disposal activities; materials recovery; Remediation activities and other waste management services			✓	✓	✓						✓	✓									
H49	Land transport and transport via pipelines			✓		✓						✓		✓						✓		
A02	Forestry and logging		✓								✓											
N77	Rental and leasing activities												✓									

Source: OECD Secretariat calculations, Eurostat Air Emission Accounts, Eurostat National Employment database.

Employment and emission data are not available for a few pollutants (notably for SOx) in several country-industry combinations (Table 4). Because an industry needs to appear in the top 15% in at least 3 pollutants to be classified as high-polluting, missing data for one pollutant is generally not an issue and thus unlikely to affect the identification process. This is especially the case when the industry is not identified as a major emitter of other pollutants or pollution of SOx is expected to be low on the basis of available information. When employment data are missing, the computation uses the most recently available data or area-wide averages.

Table 4. Countries and industries affected by missing employment or pollution data

Country	Missing data	Assessment and treatment of the issue
Portugal	For pollutant SOx: Missing data in the industries C30, J58, J59-60, K66, M72, M74-75, N78, R90-92, S95 across several years	These industries are not identified in the top 15% for any other pollutant. Irrespective of the value of the missing pollution data, the industry would not have been identified as high-polluting. In addition, for industries C30, K66, M74-75, R90-92, the few available data suggest very few SOx emissions in Portugal ➢ The industries are identified as not high-polluting
Estonia	For pollutant SOx: Missing data in the industries C21, C26, H53, J58, J59_J60, J61, K65, K66, M74_M75, N78, N79, S95 across several years	For J58 and S95: there is no SO_X data across the years, but the industries are not identified in the top 15% in other pollutants. As such, irrespective of the level of pollution in SOx, the industries would not have been identified as high-polluting. For all the other industries, SO_X pollution levels are extremely low in the other years. ➢ The industries are identified as not high-polluting
Finland	For numerous pollutants: missing pollution data in the industries C18 C21 C26 C27 C33 E36 and S95 across several years	For some industries, the missing data can be interpreted as a 0, as the pollution figure for other years is low (<1 ton) Given low pollution in these industries across countries and years, it can be assumed that those would not have been identified as high-polluting. ➢ The industries are identified as not high-polluting
Sweden	Employment data missing for industries C21, H53 M72	These industries are never identified as high-polluting across countries. ➢ The industries are identified as not high-polluting
Norway	Missing pollution and employment data for several industries	EU-LFS data is more complete but employment data is largely missing from 2017. ➢ Use of a 2011-16 EU-LFS average
Greece	No A02 SO_X data for 2017 to 2019	In the years prior to 2017, emissions were extremely low (0.1 tons). ➢ The industries are identified as not high-polluting
Denmark	No employment data for C19 from 2017 to 2019; pollution data available	Data available for previous years. Employment in missing years assumed equal to previously available period. ➢ The industry are identified as high-polluting

Source: OECD Secretariat elaborations

Identification of high-polluting occupations

High-polluting jobs are identified at the occupation level, based on industry emissions and the distribution of occupations by industry. The choice to focus on occupations rather than industries is driven by economic and empirical considerations. From the labour economics perspective, sectoral shifts due to the green transition are likely to have a varying impact depending on the occupation: an accountant in the mining industry may possess more transferable skills across industries than a coal miner (working in the same industry), and thus may face a smoother transition. From the empirical perspective, labour force surveys (including the EU-LFS used in this project) provide more granular data at the occupation than at the industry level. The high-polluting occupations identification process is summarized below.

Following Vona et al. (2018[3]), an occupation is classified as high-polluting if its employment share in high-polluting industries is at least seven times higher than the average across all occupations. The data allows the identification of a country-specific list of high-polluting occupations at the ISCO 4-digit level. Since the distribution of occupations across industries is based on UK census data, this step requires the use of official cross-walks between UK and EU classifications (i.e., between SOC 4-digit and ISCO 4-digit for occupations, and between UK SIC 2-digit and NACE Rev. 2 2-digit for industries).

Because the subsequent analysis is based on EU-LFS data, it requires the aggregation from ISCO 4-digit to ISCO 3-digit. Each ISCO 3-digit occupation is therefore assigned a score based on the (unweighted) share of underlying ISCO 4-digit identified as high-polluting. For instance, if an ISCO 3-digit includes one high-polluting 4-digit occupation and 3 which are not, it receives the score 0.25 (1/4).

This results in a country-specific list of high-polluting occupations at the ISCO 3-digit level (Table 5). While some occupations are classified as high-polluting in all (e.g., Manufacturing, mining, construction and distribution managers) or most countries (e.g., Mobile plant operators and Ships' deck crews and related workers), others are classified as high-polluting in few countries (e.g., Forestry workers). For each occupation, Table 5 also shows the corresponding employment shares on average across countries.[13]

[13] The employment shares in Table 5 are computed based on the score: for example, a score of 1/4 means that only one quarter of the workers in the occupation are accounted for as having a high-polluting job.

Table 5. High-polluting occupations, country-by-country list

ISCO 3-digit	Label	AUT	BEL	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	NLD	NOR	POL	PRT	SVK	SVN	SWE	Average Employment share
132	Manufacturing, mining, construction, and distribution managers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0.223
315	Ship and aircraft controllers and technicians	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0.037
811	Mining and plant operators	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0.031
818	Other stationary plant and machine operators	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0.091
313	Process control technicians	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0.048
511	Travel attendants, conductors and guides	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0.036
835	Ships' deck crews and related workers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	0.009
721	Sheet and structural metal workers and related	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	0.154
812	Metal processing and finishing plant operators	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	0.054
834	Mobile plant operators	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	0.196

ISCO 3-digit	Label	AUT	BEL	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	NLD	NOR	POL	PRT	SVK	SVN	SWE	Average Employment share
731	Handicraft workers	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		0.045
813	Chemical and photographic products plant and machine operators	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		0.029
921	Agricultural, forestry and fishery laborers		✓	✓	✓	✓	✓			✓	✓		✓	✓	✓	✓				✓	✓	✓	0.088
211	Physical and earth science professionals	✓			✓		✓		✓	✓	✓		✓		✓	✓	✓	✓	✓		✓		0.018
215	Electrotechnology engineers	✓	✓				✓	✓	✓		✓				✓	✓	✓	✓	✓		✓	✓	0.052
131	Production managers in agriculture, forestry and fisheries			✓	✓	✓	✓			✓			✓	✓	✓	✓				✓	✓	✓	0.007
612	Animal producers			✓	✓	✓	✓			✓			✓	✓	✓	✓				✓	✓	✓	0.049
722	Blacksmiths, toolmakers and related trades workers			✓	✓	✓	✓			✓			✓	✓	✓	✓				✓	✓	✓	0.153
752	Wood treaters, cabinet makers and related trades workers	✓					✓	✓	✓								✓	✓	✓	✓	✓	✓	0.039
831	Locomotive engine drivers and related workers			✓		✓						✓		✓						✓			0.011
832	Car, van and motorcycle drivers			✓		✓						✓		✓						✓			0.056

ISCO 3-digit	Label	AUT	BEL	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	NLD	NOR	POL	PRT	SVK	SVN	SWE	Average Employment share
833	Heavy truck and bus drivers			✓		✓						✓		✓						✓			0.115
961	Refuse workers			✓	✓	✓						✓	✓										0.025
621	Forestry and related workers		✓							✓	✓					✓						✓	0.005
932	Manufacturing laborers										✓												0.008

Source: OECD Secretariat calculations, Eurostat Air Emission Accounts, Eurostat National Employment database, UK census data.

This new identification exercise inevitably comes with some caveats and limitations:

- Relying on UK Census data for the bivariate distribution of occupations and industries across countries implicitly assumes that this distribution is similar across countries. This assumption is likely to hold in most occupation/industry cases; for example workers in the occupation *bus and truck drivers* will likely be employed in the industry *land transport*. This assumption risks being more questionable for those occupations whose distribution across industries is likely to vary depending on countries' economic specialization, for example *assemblers*.
- Relying on UK Census data also introduces the necessity of applying a crosswalk. Although the availability of an official detailed and weighted crosswalk provided by ONS facilitates the process and allows avoiding typical pitfalls (such as many-to-many correspondences), the ISCO occupations listed in Table 6 are absent from the crosswalk and cannot be assigned a high-polluting score.

Table 6. ISCO 3-digit occupations unmatched in the cross walk from UK SOC

ISCO 3-digit	Label
223	Traditional and complementary medicine professionals
224	Paramedical practitioners
252	Database and Network Professionals
322	Nursing and Midwifery Associate Professionals
412	Secretaries
613	Mixed crop and animal producers
622	Fishery workers hunters and trappers
631	Subsistence crop farmers
632	Subsistence livestock farmers
633	subsistence mixed crop and livestock farmers
634	subsistence fishers, hunters, trappers and gatherers
817	Wood processing and papermaking plant operators
951	Street and related service workers

Note: Unmatched ISCO 3-digit occupations refer to these for which no underlying ISCO 4-digit have a correspondence in the UK SOC 4-digit to ISCO 4-digit crosswalk
Source: ONS

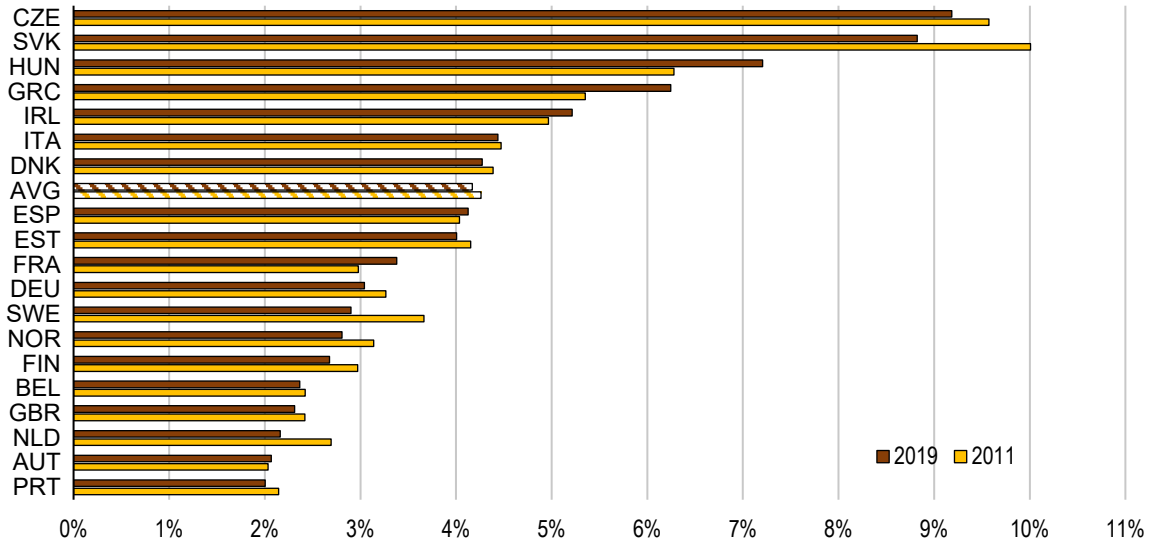
Results and comparisons with previous literature

New estimates of high-polluting jobs across European countries

The methodology developed in this work delivers a list of high-polluting occupations by country, resulting in a tentative quantification of the incidence of high-polluting jobs. As illustrated in Figure 1, the employment share of high-polluting jobs is around 4%, but there is wide variation across countries, from around 9% in Czechia and the Slovak Republic down to around 2% in Portugal and Austria. In line with the previous literature (OECD, 2023[6]), the data do not indicate a marked decline in the share of high-polluting jobs.

The main advantage of relying on country-specific data on emissions is that it allows to capture cross-country heterogeneity in emission intensity by industry. As illustrated in Figure 2, cross-country differences can be very large. For instance, in electricity, gas, steam and air conditioning supply activities, most polluting countries emit 4 times more GHG per worker than least polluting ones.

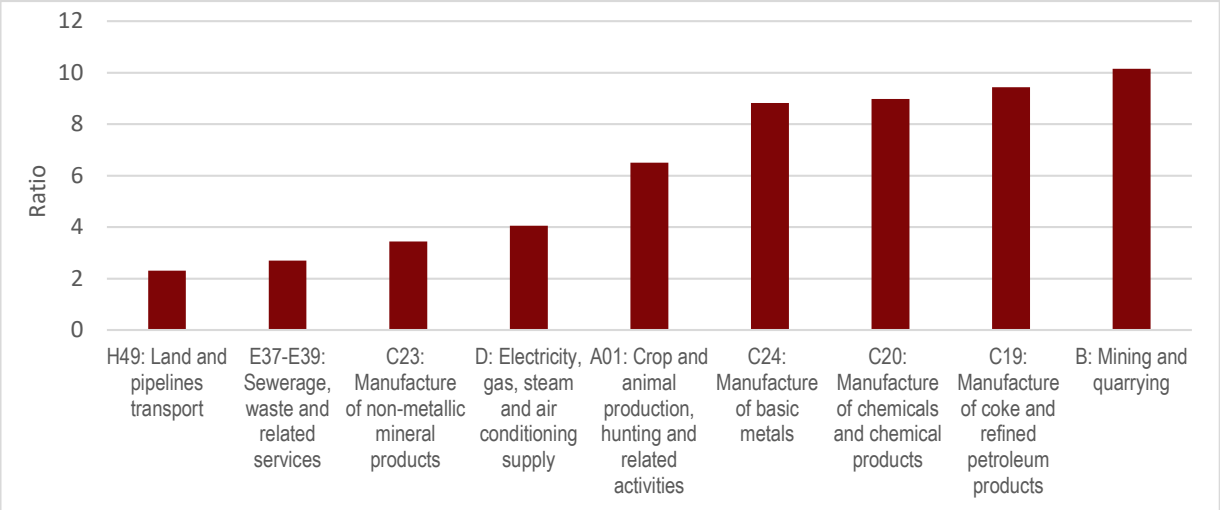
Figure 1. Share of employment in high-polluting jobs across countries, 2011-2019



Note: See text for the definition of high-polluting jobs.
Source: EU-LFS and Secretariat calculations.

Figure 2. Cross-country differences in emission intensity by industry, 2019

GHG emission intensity: ratio between most and least polluting countries for selected industries



Note: How to read: in industry Crop and Animal production, hunting and related service activities, the most pollution intensive country pollutes 6.5x per worker than the least pollution intensive country. Pollution intensity is defined using GHG emitted by the industry (measured in tonnes, following a residential production perspective) and dividing by the number of workers in each industry. Total Green House Gases (GHG) emissions, reported in Figure 4, are obtained by multiplying the emissions in each polluting gas by their 100-year 'global warming potential' value, i.e., the amount of warming one tonne of the gas would create relative to one tonne of CO_2 over a 100-year period. The ratio is between the 3rd most polluting and the 3rd least polluting country to reduce possible noise associated with outliers. Countries covered are: AUT, BEL, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, NLD, NOR, POL, PRT, SVK, SVN, SWE.
Source: OECD Secretariat calculations, Eurostat Air Emissions Accounts, Eurostat National Accounts

One key contribution of the approach developed in this work is that it allows to capture cross-country heterogeneity in terms of high-polluting industries and therefore occupations. Such is the case of forestry

and related workers in Belgium, France, the United Kingdom, Netherlands and Sweden; of Heavy truck and bus drivers in Czechia, Denmark, Greece, Ireland and Slovak Republic (Table 3). At the same time, some jobs are systematically high-polluting in all or most countries (Table 5), in particular those relating to mining. As a result of this approach, the identification of high-polluting occupations at the European country level implies a relatively wide range of high-polluting employment shares. Yet, overall the results are consistent with previous literature, and the ranking of countries roughly similar to the one obtained by cross-walking US-based lists of high-polluting occupations classifications to EU employment data.[14]

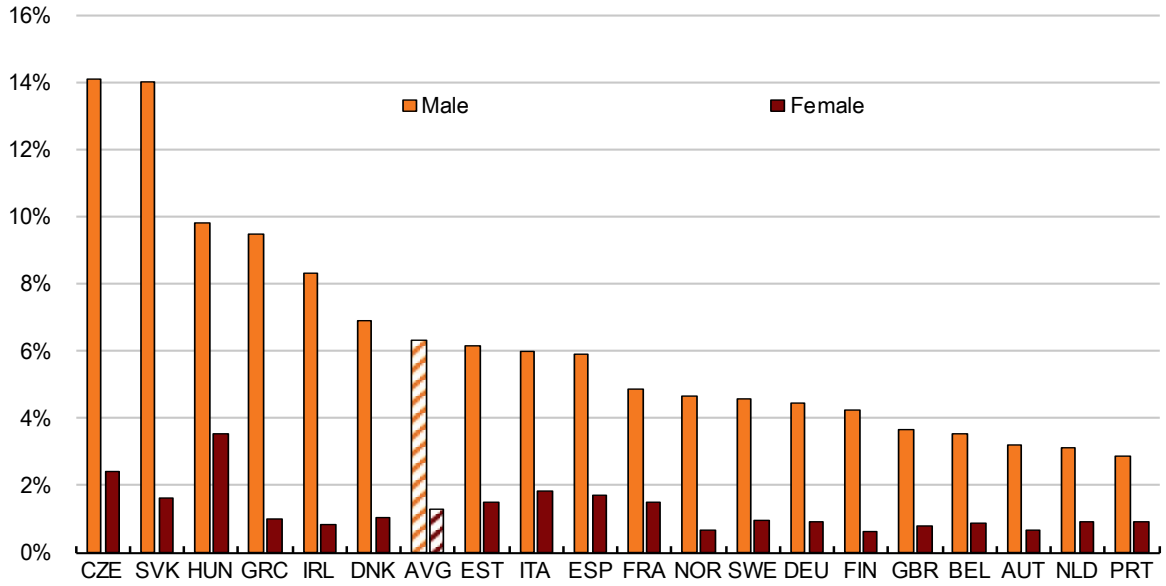
Evidence on the distribution of high-polluting jobs across socioeconomic groups is particularly relevant in identifying the workers most vulnerable to the green transition, and who may require well-designed targeted support. The main highlights from the distributional analysis of high-polluting jobs are the following:

- Men are much more likely than women to have a high-polluting job (Figure 3). On average, 6.3% of male workers have a high-polluting job, almost 5 times more than female workers. The contrast is even starker in countries with higher shares of high-polluting workers. For instance, in the Slovak Republic, 14% of working men have a high-polluting job, and 1.6% of working women. This reflects the fact that men tend to be over-represented in relatively more polluting industries such as utilities and transport while women tend to be over-represented in less polluting industries, typically in services like hospitality and education activities.
- Workers who attained a lower or medium level of education are more likely to have a high-polluting job relative to those with higher educational attainment (Figure 2). On average, 5.3% of middle and low-educated workers have a high-polluting job, contrasting with 1.6% of high-educated workers. Similar to gender, these disparities are particularly strong in countries with high shares of high-polluting workers. For instance, in Czechia, 11.2% of workers of middle and low-educated workers have a high-polluting job by contrast with 1.7% of high-educated workers.
- The distribution of high-polluting jobs does not systematically vary across age groups (Figure 5), consistent with recent evidence (OECD, 2023[6]).

[14] Using a Spearman rank correlation, the ranking of countries is positively correlated with a value of 0.39, and an associated p-value of 0.09. Using data from 2011, like Vona, to compute pollution intensity, the rank correlation is even higher (0.59).

Figure 3. The gender distribution of high-polluting jobs across countries, 2019

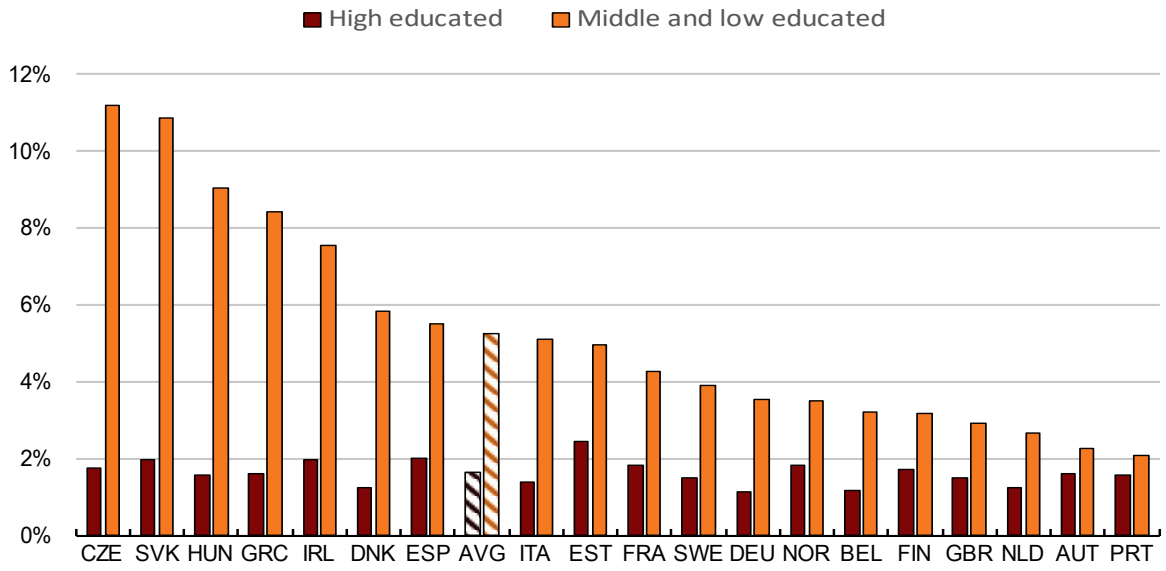
Incidence of high-polluting occupations among employed individuals, by gender



Note: How to read: In Greece, 9.5% of employed men hold high-polluting jobs, by contrast with 1.0% for employed women.
Source: EU-LFS and Secretariat calculations.

Figure 4. The education distribution of high-polluting jobs across countries, 2019

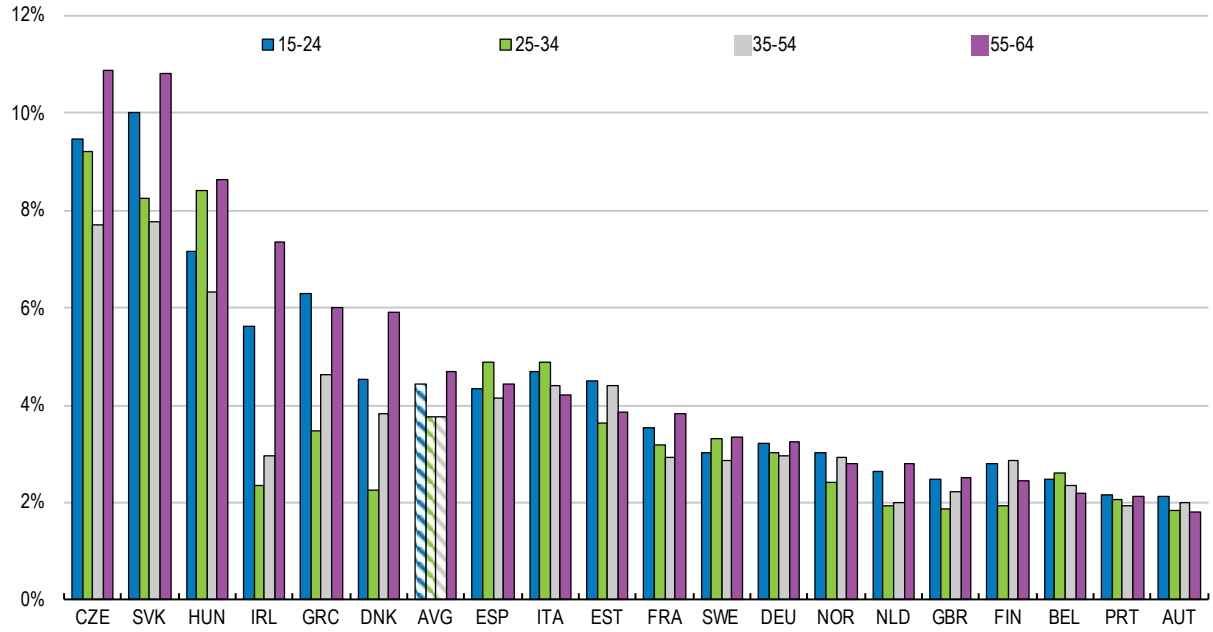
Incidence of high-polluting occupations among employed individuals, by educational attainment



Note: How to read: In Denmark, 1.2% of middle and low-educated workers hold high-polluting jobs, by contrast with 5.8% of high-educated workers
Source: EU-LFS and Secretariat calculations.

Figure 5. The age distribution of high-polluting jobs across countries, 2019

Incidence of high-polluting occupations among employed individuals, by age

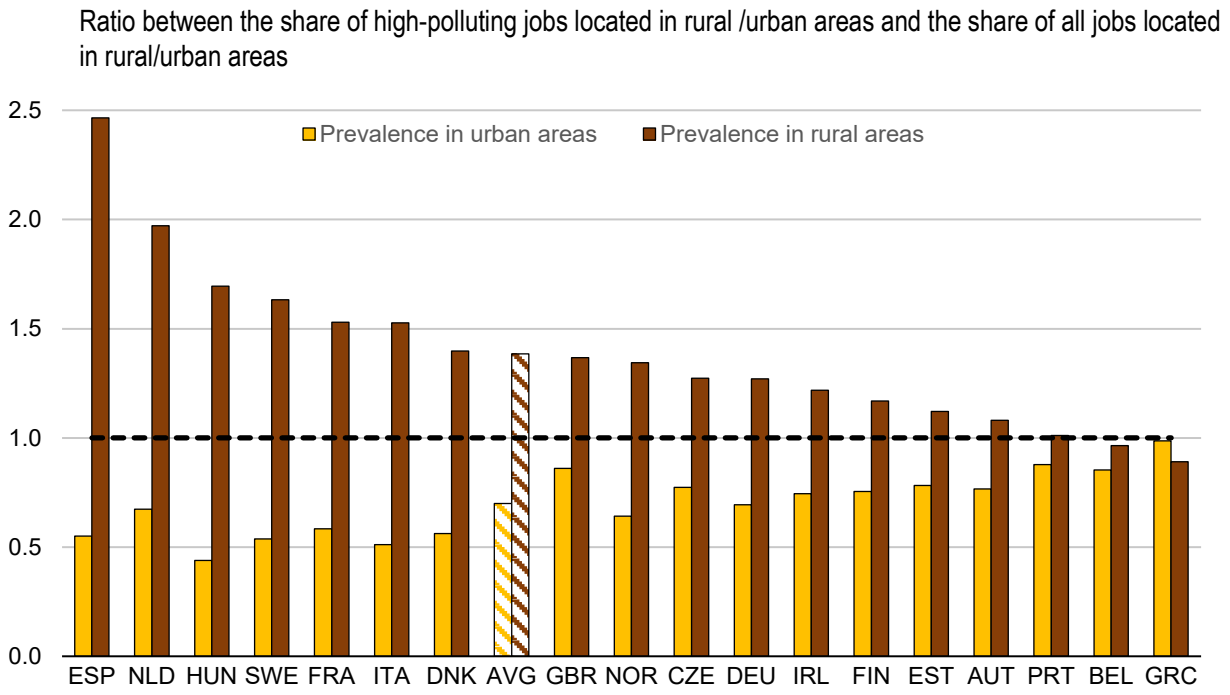


Note: How to read: In Spain, 4.3% of workers aged 15-24 hold a high-polluting job, in contrast with 4.9% for workers aged 25-34, 4.2% for workers aged 35-54 and 4.4% for workers between 55-64 years old.
Source: EU-LFS and Secretariat calculations.

The analysis of the spatial distribution of high-polluting jobs *within countries* reveals that high-polluting jobs are systematically overrepresented in rural areas (Figure 6). This is in line with OECD work on the green transition and local economic development (OECD, 2023[9]).[15]

[15] See OECD (2023[9]) for an analysis of greening labour markets at the local level. That report shows that capital regions stand out with more green-task and fewer polluting jobs. Chapter 2 presents regional divides within countries, with country-specific fiches available online, e.g., https://www.oecd.org/cfe/leed/GBR.pdf

Figure 6. The prevalence of high-polluting and green jobs in rural and urban areas, 2019



Note: How to read: in Spain, high-polluting jobs are more than twice as prevalent in rural areas than they are in the whole country, while they are half less prevalent in urban areas.
Source: EU-LFS and Secretariat calculations.

Robustness analysis

This section delivers several robustness checks to assess the solidity of the analysis, by relaxing some of the assumptions and changing some of the thresholds. The bottom line is that the methodology is robust to changes in the period used to identify high-polluting industries, the choice of pollutants and the selection of thresholds for high-polluting occupations:

- **Using alternative base years to identify high-polluting industries and occupations**: Using 2011 emissions data yields a similar list of high-polluting industries to the one obtained using a 2011-2019 average, with a 95% overlap between the two lists. For half of the countries only, a change of one or two industries is observed. Similar conclusions are reached using 2019 emission data.
- **Accounting for different pollutants**: Although CO_2 accounts for two-thirds of GHG emissions, a few sectors (notably agriculture) have very high emissions of methane, a pollutant which is not considered by the preferred methodology nor by Vona et al. (2018[3]). The list of high-polluting industries is robust to adding methane as a pollutant. Agricultural sectors (A01, A02, A03) are not more often identified (because their non-methane emissions tend to be lower relative to the other sectors, see above).
- **Varying the thresholds for high-polluting industries and occupations:** Several tests were carried out, with alternative thresholds to identify high-polluting occupations. Although the final list of high-polluting occupations slightly differs, the ranking of countries and the time trends remain very similar.

Concluding remarks

Greening the economy may cause jobs to contract in the "high-polluting" sector and grow in the "green" sector.[16] A "just" transition in the labour market should reduce costs for individuals and communities. This requires policies to manage and minimise scarring effects associated with job losses in polluting industries. In this context, the present paper contributes to the literature by developing a new approach to identify high-polluting jobs, based on European emission data by country and industry. This approach takes into account cross-country differences in emission intensity by industry and, as highlighted above, the empirical analysis suggests that these differences can indeed be very large.

The descriptive evidence in this paper points to the policy challenges associated with greening the economy from a labour market perspective, reflecting in particular: i) the low progress achieved in terms of reducing the incidence of jobs in high-polluting activities, ii) the inequalities in terms of the socioeconomic composition of high-polluting jobs, especially the pervasive over-representation of low-educated workers, iii) the spatial divide associated with the geography of high-polluting jobs, particularly the concentration of high-polluting jobs in rural areas. In this context, achieving progress in reaching environmental objectives will require identifying workers and communities at risk of displacement and taking policy action to accompany individuals and territories. This includes well-designed and targeted active labour market policies, for instance to support job search, training and requalification, as well as to remove obstacles to geographical relocation. At the same time, place-based policies will also be needed to support economic redeployment and therefore social stability in the areas affected by the contraction of high-polluting production processes.

[16] The companion paper (Causa, Soldani and Nguyen, 2024[1]) provides a broad assessment and discussion about high-polluting and green jobs, across countries and across socioeconomic groups.

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