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Abstract

This paper examines the potential labour market implications of the green transition in Ireland by analysing the incidence and nature of green and brown jobs. We find that the share of green employment in Ireland has been trending slightly upwards over time, increasing from 8 per cent of total employment in 2011 to 10 per cent in 2023. The share of brown jobs has remained relatively stable, with an estimated share of total employment in 2023 ranging from 3 to 5.5 per cent depending on the definition employed. At a sectoral level, green jobs are relatively broad-based while Agriculture and Transport account for the majority of brown jobs in Ireland. Regarding worker characteristics, we find that men are more likely than women to work in both green and brown jobs. The pay and education levels for workers in green jobs is higher compared to brown jobs. Overall, the analysis suggests that the aggregate impacts of the green transition on the labour market may be relatively limited. However, these impacts will not be evenly distributed across the population, with differences by gender, region, sector and educational attainment. These findings underscore the important role for policy in supporting the up-/re-skilling of workers to ensure a just transition.

JEL Codes: J3, J4, Q0

Keywords: decarbonisation, green transition, green jobs, brown jobs, Ireland

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Non-technical summary

Climate change poses a significant risk to the global economy, with implications for economic growth, fiscal policy and financial market stability. Decarbonising economic activity and shifting to clean and renewable energy sources – often referred to as 'the green transition' - is a central element of the global policy response to addressing the risks and challenges posed by climate change. As part of the European Green Deal, the EU has committed to making Europe the first climate-neutral continent by 2050. Meeting these targets will require major structural shifts in the economy, with potentially significant labour market implications.

Employment in carbon-intensive occupations is likely to decline, for instance, due to structural shifts in certain industries (e.g. coal-reliant jobs), as well as through the adoption of new technologies that change the nature of tasks. The green transition also presents potential opportunities. New jobs will be created, particularly in sectors associated with the transition to a zero-carbon economy (e.g. renewable energy, sustainable building and retrofit etc.). Given that green jobs are typically higher paid than brown jobs, this also offers the possibility for some workers to access higher-paid employment. Realising these opportunities will require a 'just transition'– a concept at the heart of EU climate action policy. In practice, this means that climate action policies are guided by the principle of fairness and, from a labour market perspective, ensuring that people are equipped with the right skills to be able to participate in and benefit from the future net zero economy.

The purpose of this paper is to assess the incidence and nature of green and brown jobs in Ireland and gain an understanding of the potential labour market adjustments arising from the ongoing decarbonisation process. Both green and brown jobs are identified using a definitional approach developed in recent work carried at the OECD by Causa et al. (2024). We find that the share of green jobs in Ireland has gradually increased over time, from 8 per cent of total employment in 2011, to 10 per cent in 2023. In contrast, the share of brown jobs has remained relatively stable, accounting for approximately 3 per cent of total employment in 2023.

At a sectoral level, transport accounts for the majority (56 per cent) of brown jobs, although many of these jobs are likely to become green over time, as the sector continues to adopt low-carbon modes of transport. The approach of Causa et al. (2024) to measuring brown jobs does not account for methane pollution, thereby excluding many agricultural occupations from being classified as brown. Expanding the definition to also account for high methane emitting occupations increases the estimated incidence of brown jobs in Ireland in 2023 to approximately 5.5 per cent. Under this broader definition, just under half of all brown employment is in the agricultural sector, predominantly among mixed crop and animal producers. These findings highlight the importance of targeted reskilling and upskilling initiatives to support more sustainable practices and technologies in this sector.

When comparing the share of green and brown jobs in Ireland to other European countries, we find that in 2022 Ireland had the third highest incidence of green jobs after Sweden and Estonia and recorded the second largest increase in green jobs since 2011. In terms of brown jobs, in 2022 Ireland had the fifth highest incidence in Europe, after Czechia, Slovakia, Hungary and Greece. Expanding the brown-job definition to include high methane-emitting occupations raises the measured incidence across all countries but leaves Ireland's relative position unchanged.

Our analysis on the characteristics of workers indicates that men make up a disproportionate number of workers in both green and brown jobs in Ireland. Workers in green jobs have higher

levels of educational attainment than those in brown jobs suggesting that green jobs are typically higher skilled and generate greater value added relative to brown jobs. This is supported by our finding that green jobs are associated with a wage premium for employees, while brown jobs are associated with lower wages. Moreover, green jobs in Ireland are found to be of somewhat higher quality compared to the EU green job average, particularly when measured in terms of training intensity.

An important finding from our analysis is that the labour market impacts of the green transition will not be evenly distributed across sectors or regions. Brown jobs are disproportionately located in sectors such as transport and agriculture, as well as in rural areas. Furthermore, we find that the distribution of brown jobs, based on the broader definition that includes agriculture, is concentrated in the Border region and in the West and Southeast regions. This highlights the importance of targeting policies to where they are most needed to ensure that, as much as possible, the green transition corresponds to a 'just transition' in which workers are equipped with the skills needed to take advantage of the future net zero economy.

1. Introduction

One of the primary policy goals of the EU is to achieve climate neutrality by 2050. Central to this agenda is the so-called 'green transition', which refers to the process of decarbonising the economy and shifting to clean and renewable energy sources. This process will involve major structural shifts in the economy with potentially important implications for employment and the way people work. Indeed, it is likely that the demand for so-called 'green jobs' will increase, while the demand for carbon-intensive brown jobs will decline (ILO, 2018; IMF, 2022; OECD, 2024). According to the ILO's (2016) definition, 'green jobs are decent jobs that contribute to preserve or restore the environment, be they in traditional sectors such as manufacturing and construction, or in new, emerging green sectors such as renewable energy and energy efficiency'. Brown jobs, on the other hand, are usually related to highly polluting activities which will need to be adapted, or phased out, to meet emissions targets. Therefore, to ensure a 'just' green transition, policies involving upskilling and reskilling of workers will be needed to improve the re-allocation of workers from brown to green jobs and minimise any potential scarring effects associated with labour market adjustments in brown industries.

Identifying and quantifying green and brown employment is challenging due to the lack of a consistent international classification system. However, in recent years researchers have been developing cross-national methodological frameworks (Vona et al., 2018; Vandeplas et al., 2022). Most notably, in recent work carried at the OECD, Causa et al. (2024) have developed a new empirical framework using European Labour Force Survey data (EU-LFS) which allows for consistent measurement of green and brown employment across EU Member States.

In this paper, we apply the methodology of Causa et al. (2024) to Irish data from 2011 to 2023 to investigate the potential labour market implications of the green transition. We begin by measuring the incidence of green and brown jobs in Ireland and how this compares to trends in other European countries. We also examine the characteristics of workers in green and brown jobs, as well as the skill content of such jobs. Finally, we examine the relationship between job type (green or brown) and outcomes such as wages and job satisfaction. The data sources used in this analysis include Irish and EU Labour Force Surveys, as well as the second wave of the European Skills and Jobs Survey (ESJS2).

We find that the share of green employment in Ireland has been slightly increasing over time, standing at approximately 8 per cent of total employment in 2011, and at 10 per cent in 2023. In contrast, the share of brown jobs has been relatively stable over time, with an estimated share of total employment in 2023 varying from 3 to 5.5 per cent depending on the definition employed. When methane-emissions-related occupations are included in the definition of brown jobs, almost half of brown employment is located among Mixed Crop and Animal Producers, with the remainder largely concentrated in transport-related occupations. Many jobs in the transport sector will likely transition from brown to green over time as the sector continues to decarbonise through the adoption of low- and zero-emission vehicles. For example, Dublin Bus recently introduced 280 plug-in hybrid buses which qualify as 'clean vehicles' under the European Union's revised Clean Vehicles Directive.[1] However, reducing methane emissions in livestock production may require training and upskilling of workers in the agricultural sector to allow them to adopt sustainable practices and use clean technologies, and hence benefit from the opportunities offered by the green transition. An example of this can be seen in the Teagasc Climate Action

[1] See https://busconnects.ie/cities/dublin/cleaner-technology/ for details on Dublin Bus's low emission vehicles.

Strategy, which seeks to engage with 50,000 farmers to assist them in adopting new technologies that can help meet Ireland's target of reducing greenhouse gas emissions in agriculture by 25 per cent by 2030 (Teagasc, 2022).

Our results show that men make up a disproportionate number of workers in both green and brown jobs. Workers in green jobs are found to have higher levels of educational attainment than those in brown jobs; 70 per cent of those in green occupations have a tertiary level of education compared to just 18 per cent of those in brown occupations. Green jobs in Ireland are associated with a wage premium when compared to environmentally neutral (neither green nor brown) jobs. Brown jobs, on the other hand, are associated with a wage penalty when compared to environmentally neutral jobs. Our findings also indicate that workers in green jobs undertake more advanced digital tasks and have a greater ability to plan their own working schedule, compared to workers holding non-green jobs. Generally, the results suggest that green jobs in Ireland are of somewhat higher quality relative to the EU-27 average, particularly when measured in terms of educational requirements, job autonomy and training intensity.

2. Existing Approaches for Measuring Green and Brown Jobs

In recent years researchers have been working to develop methodological frameworks for conceptualising and measuring green and brown employment. A range of approaches have emerged in the literature, broadly categorised as either top-down (industry-based) or bottom-up approaches (occupation/task based) (Valero et al, 2021; Vandeplas et al., 2022).

2.1 Green Jobs

According to top-down approaches, green jobs can be defined as jobs in sectors that directly relate to green technologies and processes. For instance, according to Eurostat, green jobs are those involved in the production of environmental goods and services (EGS) in a subset of established industries, based on national accounts data (Vona, 2021; Vandeplas et al., 2022). The so-called EGS sector includes goods and services aiming at the protection of the environment, waste management, the management of natural resources and energy preservation.[2] The issue with this approach, however, is that it is very narrow and only includes employment in industries that directly relate to green technologies and processes. As such, it would not capture all workers employed in roles with a sustainability focus. Similarly, the ILO provides an industry-based approach, as green jobs are defined as those that *'contribute to preserve or restore the environment, be they in traditional sectors such as manufacturing and construction, or in new, emerging green sectors such as renewable energy and energy efficiency'*.[3]

An alternative top-down approach is to define jobs according to their pollution intensity. Under this approach, jobs in sectors with low emissions per worker would be considered as 'green'. As many service occupations have low carbon emissions, this would translate into a wider share of 'green' jobs compared to the EGS approach. An alternative way of defining green jobs, which does not appear to be as widely used, is to consider the pollution content of the final product, or the potential of a product or service to harm the environment (Vandeplas et al., 2022).

[2] For further information, see: https://ec.europa.eu/eurostat/cache/metadata/de/env_egs_esms.htm
[3] For further information, see: https://www.ilo.org/resource/article/what-green-job.

In contrast, bottom-up approaches identify green jobs based on the tasks or duties performed, regardless of the industry in which the job is located. A well-established bottom-up approach for identifying green jobs is the American O*NET classification system, the Occupational Information Network, which is an online database that provides occupational definitions, supported by the US Department of Labour. In 2009, the National Centre for O*NET Development published research about the implications of the green transition for the O*NET classifications of occupations (Dierdorff et al., 2009). A green occupational labelling for the US Standard Occupational Classification has been developed by Dierdorff et al. (2009; 2011). The O*NET database identifies the tasks required within occupations and classifies the tasks that occupations use as 'green' or 'non-green' (Bowen and Haken, 2019). The O*NET Green Task Development Project identified three categories of occupations within the US Standard Occupational Classification: (i) *New and Emerging Green*, which includes new occupations with unique task requirements as a result of the green transition; (ii) *Green Enhanced Skills,* which captures those existing occupations that will require a shift in skills and tasks; (iii) *Green Increased Demand,* which covers occupations likely to experience increased demand due to the green transition but without significant changes in tasks (Dierdorff et al., 2011; Bowen and Hancké, 2019). On this basis, 138 *Green Enhanced Skills* and *New and Emerging Green* (N&E) occupations were included in the green task development process. As a result, a total of 1,369 green tasks were identified/developed.[4] In Appendix Table A1, we show some examples of occupations that fall into the green transition-related categories and also some examples of 'green' tasks, defined as such by O*NET.

Vona et al. (2018) assessed the green task intensity of jobs by examining the proportion of 'green' tasks within an occupation, using the green task labelling provided by Dierdorff et al. (2011) in O*NET. This approach calculates the share of green tasks within each occupation and then uses the distribution of employment by occupation to determine the share of green employment across countries. As the O*NET is based on the US SOC 8- digit occupational classification, translating this to EU data is challenging (Bowen and Hancké, 2019; Vandeplas, 2022). The new methodology developed in recent work carried at the OECD by Causa et al. (2024) that we use in this paper builds on Vona et al. (2018)'s methodology and expands it to Europe with the use of the crosswalk between the O*NET US SOC occupational classification and the International Standard Classification of Occupations- ISCO used in European countries. This methodology is explained in detail in Section 3.

Another bottom-up approach was developed in the UK by Rocks (2022) for the Greater London Authority. This uses a crosswalk from the O*NET occupational classification to the UK Standard Occupational Classification (SOC2010) to identify green jobs in London and in the UK context. Using this approach, 100 out of 369 UK SOC 4-digit level unit groups were found to be occupations that are potentially subject to, or affected by, the green transition. Yet another approach for measuring green jobs was developed by the UK's Office of National Statistics (ONS) and employs a task and occupation-based methodology to quantify the time spent on performing green tasks within occupations (Martin and Monahan, 2022). By using the 'green' task content framework from the O*NET occupational classification, the authors estimated the green time

[4] For further information, see: https://www.onetcenter.org/reports/GreenTask.html.

share for each of the nearly 1,000 occupations in the O*NET database and then translated it into the UK SOC occupational classification.[5]

A relatively recent development for analysing green jobs is based on using online job vacancy data to monitor in real-time the labour demand for green vacancies. The European Centre for the Development of Vocational Training (Cedefop) determines whether an occupation is green by analysing the presence of green skills in online job advertisements (OJA), using their Skills-OVATE dataset (Cedefop, 2024).[6] Cedefop developed their green taxonomy, which includes green technologies, tasks, roles, tools and skills, by employing several existing frameworks and taxonomies along with validation by national experts.[7] Cedefop arrived at two main indicators: (i) *Green Pervasiveness,* which is the ratio of all OJAs with at least one green skill to the total number of OJAs in specific occupations, sectors, countries, etc.; (ii) *Greenness*, which is the ratio of the number of green skills to the total number of skills found in OJAs in specific occupations, sectors, countries, etc.

Lightcast, a private labour-market analytics company that scrapes and collects job postings from many online job portals, has also developed a methodology for analysing green jobs. As part of a work in collaboration with Working Nation in the US, Lightcast identified several green jobs categories: (i) *Core Green*, which are jobs where the primary responsibility is associated with the green economy; (ii) *Green Enabling* are jobs within green firms and green industries, but not directly involved in green technology; (iii) *Green Enabled* are jobs requiring green skills.[8] Lightcast's taxonomy categorises skills as 'green' based on several 'green' clusters derived from the European Green deal.[9]

2.2 Brown Jobs

A top-down (industry-based) approach is commonly used in the literature to identify 'brown' jobs. These jobs are related to highly polluting activities (e.g., in mining and manufacturing) some of which are likely to be phased out as economies decarbonise. Existing approaches employ industry-level emissions data along with data on the distribution of occupations per industry. The intensity of greenhouse gas (GHG) emissions per worker (kg/per worker) is computed and those jobs that are identified as highly polluting according to their GHG emission intensity are considered to be 'brown'. This approach was pioneered by Vona et al. (2018), who identified pollution-intensive industries in the US using emissions data. The methodology from Causa et al.

[5] For further information, see: https://www.ons.gov.uk/economy/environmentalaccounts/articles/developingamethodformeasuringtimespentongreentasks/march2022.

[6] Skills-OVATE offers detailed information on the jobs and skills employers demand based on online job advertisements (OJAs) in 32 European countries. It is powered by Cedefop's and Eurostat's joint work in the context of the Web Intelligence Hub. For more information, see: https://www.cedefop.europa.eu/en/tools/skills-online-vacancies.

[7] The frameworks used are: classification of environmental protection activities (CEPA 2000), classification of resource management activities (CReMA), IRENA Global Renewables Outlook 2020, Linkedin 'green' skills; SGG Singapore green economy skills, Joint Research Centre's GreenComp framework and O*NET and ESCO green classifications.

[8] For more information, see: https://kb.lightcast.io/en/articles/9006635-researching-green-jobs.

[9] The skills clusters include: Air quality and emissions, Clean Energy, Climate Change, Conservation, Energy Efficiency, Energy Management, Environmental Engineering and Restoration, Environmental Regulations, Solar Energy, Waste Management, Water Energy and Wind Energy (Magrini et al., 2023).

(2024) used in this paper builds on Vona et al. (2018)'s methodology and expands it for EU countries (see Section 3 for full methodological explanation).[10]

2.3 Green and Brown Jobs in Ireland

Recent research from De Vita et al. (2024) analysed green and brown jobs in Ireland. To identify brown jobs, the authors used Environmental Goods and Services Sector data and emissions accounts data from Eurostat. To measure green jobs, the authors employed the O*NET green occupations classification (New and Emerging Green, Green Enhanced Skills and Green Increased Demand occupations) and combined it with the green job classification of the Greater London Authority (Rocks, 2022) and the UK's Office for National Statistics measure of time spent on green tasks within occupations. Census data from 2011, 2016 and 2022 was used to analyse the Irish labour market.[11]

Brown jobs were located among highly polluting sectors. The authors identified the following sectors as having the highest emissions per job in 2021: electricity, gas, steam and air conditioning supply; agriculture, forestry and fishing; water supply; sewerage, waste management and remediation activities; transportation and storage; and manufacturing. In contrast, financial and insurance activities, information and communication, professional, scientific and technical activities, human health and social work activities and education had the lowest emissions in 2021.

According to the authors' estimates, 'green' jobs in Ireland among the *New and Emerging Green* occupations increased from 3.4 per cent in 2011 to 4.4 per cent of total employment in 2022. Green jobs among the *Enhanced Skills* occupations declined from 14.2 in 2011 to 13.3 per cent in 2022. Based on this approach, estimated green employment increased from 17.6 per cent in 2011 to 17.7 per cent in 2022. Note that these estimates exceed both those in this analysis as well as those of Causa et al. (2024). In addition to this, the authors estimated that green jobs in *Green Increased Demand* occupations increased from 8.6 per cent in 2011 to 9.7 per cent of total employment in 2022. The analysis suggests that all green jobs in Ireland increased from 26.1 per cent of total employment to 27.4 per cent between 2011 and 2022. 'Green' workers appear to be most prevalent in the agricultural sector. This is because, in the approach used by De Vita et al. (2024), farmers are classified as a 'green' occupation as they are assumed to have the ability to manage their land sustainably in order to reduce emissions and pollution. Furthermore, certain roles in the mining and quarrying sector are classified as 'green' as they are considered to be important in obtaining the minerals required to transition to a low-carbon economy. The methodology also identifies green jobs in construction, water supply, sewerage, waste management and remediation activities, electricity, gas, steam and air conditioning supply. Some concerns related to this approach are the classification of agricultural jobs as green, particularly given the high emissions associated with certain agricultural activities.

[10] An alternative method of estimating brown employment shares is to simply calculate emissions per worker by NACE sectors. The issue with this approach however is that not all high-polluting sectors would be fully 'brown', so this method tends to overestimate the incidence of brown employment. For this reason, there has been more emphasis on identifying brown occupations using industry-level emissions data along with data on the distribution of occupations per industry.

[11] The authors highlight several data issues: specifically, an inconsistency between official Irish Census data from the CSO and the data from Eurostat, with discrepancies in the estimates between the same sets of data, specifically the industry employment data.

3. Methodology and Data

3.1 Identifying Green Jobs

As mentioned in Section 2, in recent work carried at the OECD, Causa et al. (2024) developed a methodology for identifying green jobs that is based on the O*NET database for the US (see, ONET, 2010; Vona et al., 2018; Causa et al., 2024). As a starting point for this process, each 8-digit O*NET occupation is a assigned a green score. This is based on the estimated share of tasks within the 8-digit O*NET occupation that can be considered green, and hence takes a value from zero to one. A cutoff of 10 per cent is then used to determine whether an occupation is green, or not. That is, 8-digit O*NET occupations with a green task share of at least 0.10 are considered green occupations, while those with a task share below 0.10 are not considered green.

As noted by Causa et al. (2024), mapping the 8-digit O*NET occupations to the ISCO framework used in EU Labour Force Survey data is challenging. The 8-digit O*NET occupation classification is more granular than the ISCO 3-digit framework used in EU Labour Force Survey data. As such, Causa et al. (2024) had to develop a method that addresses mapping, weighting and aggregation issues. The first step is to aggregate the 8-digit O*NET occupations into O*NET 6-digit occupations. The authors then crosswalk from O*NET 6-digit to ISCO 4-digit categories. Multiple O*NET 6-digit occupations may fall under the same ISCO 4-digit occupation. To illustrate this, Causa et al. (2024) give the example of the ISCO 4-digit occupation "Senior government officials". The authors note that three O*NET 6-digit occupations correspond to the ISCO occupation "Senior government officials". Therefore, to assess the green score of "Senior government officials", an employment weighted average of the three O*NET 6-digit occupations is used when mapping to the ISCO 4-digit occupations. Specifically, each SOC 6-digit occupation is weighted by its share of employed workers over the total number of workers in all occupations mapped into the same ISCO 4-digit, based on US employment data, as in Scholl et al. (2023). This process, therefore, estimates the share of workers within one ISCO occupation that work in green jobs.

While ISCO 4-digit occupation data may be available in national Labour Force Survey microdata files, including, Ireland, the EU-LFS reports the slightly more aggregated ISCO 3-digit occupations. To identify the share of workers within a given ISCO 3-digit occupation that work in green jobs, the Causa et al. (2024) take a simple average of the green score of the 4-digit occupations underlying each 3-digit occupation.[12] In Appendix Table B1, we list all of the ISCO 3-digit jobs in which there is some positive share of green employment.[13]

3.2 Identifying Brown Jobs

To identify brown jobs, we apply the methodology of Causa et al. (2024), which uses country-specific emissions data by sector from Eurostat's Air Emission Accounts.[14] High polluting jobs are defined in two steps. First, within each country, sectors are defined as high-polluting if they are above the 85th percentile in terms of emissions per worker for at least three out of seven polluting

[12] The share of workers within an ISCO category that are in green jobs is constant across EU countries.
[13] We do not report the share of green employment within jobs in Appendix Table B1. These data were shared with us by Causa et al. (2024), and we direct readers to the authors of Causa et al. (2024) to request the data.
[14] Emissions data used by the Causa et al. (2024) covers the period 2011-2019. While our analysis in extends to 2023, Causa et al. (2024) note that the definition of 'high polluting' sectors stays relatively constant across time. However, we cannot rule out the possibility that the COVID-19 pandemic altered industrial production structures across countries.

substances, based on industry-specific average emissions per worker between 2011 and 2019.[15] An occupation is then identified as being 'brown' if a considerable number of workers within that occupation are located in the high-emitting sector. Specifically, an occupation is considered 'brown' if their share of workers in the identified brown industries is at least seven times greater than the share of workers in those same industries across all occupations. Since harmonised data on the distribution of employment across occupations and industries is not available for Europe with an adequate level of granularity (specifically, at an ISCO 4-digit occupational level), Causa et al. (2024) use UK Census data from 2011.[16] Thus, a crosswalk is required to map from UK SIC 2-digit industry and SOC 4-digit occupation classifications to the NACE and ISCO classifications used in the EU-LFS. This yields a binary variable equal to 1 if a given 4-digit ISCO occupation is considered high-polluting (i.e., 'brown') and 0 otherwise.[17] Appendix Tables B2 and B3 list the brown occupations and brown sectors.

It is again worth noting that EU-LFS data does not include an ISCO 4-digit occupation variable, and instead uses the more aggregated ISCO 3-digit occupation structure. As such, the share of workers in brown jobs within an ISCO 3-digit occupation is calculated by the unweighted share of the underlying ISCO 4-digit occupations that can be classified as brown.

Causa et al. (2024) acknowledges challenges and limitations related to their green and brown jobs measurement approach. First, there is no unified and consistent taxonomy of green jobs specific to Europe, which forces reliance on a U.S.-based classification system. This requires making significant assumptions about how job roles translate between the U.S. and European countries, which can lead to potential inaccuracies due to differences in job content and the use of conversion tools. Second, the available cross-country data on industry emissions for EU countries is quite aggregated and more granular data would be required to improve the precision of this approach. Moreover, there is no harmonised cross-country dataset that shows the bivariate distribution of how workers are distributed across both occupation and industry categories; that's why the analysis must depend on data from just one country (the U.K).

For the brown jobs classification, a limitation acknowledged by Causa et al. (2024) is that, among the pollutants, the analysis does not include methane, which is highly polluting in the agricultural sector. Non-methane emissions tend to be low in agriculture, such that if methane were to be included, the three out of seven rule would not identify agriculture as a high-polluting industry. However, for countries with a large agricultural sector such as Ireland, this may result in an underestimate of brown jobs. For this reason, we also include an additional definition of brown jobs which expands on the methodology from Causa et al. (2024) by including methane-emitting occupations related to agriculture. Specifically, we identify those occupations that mostly relate to livestock production (i.e., enteric fermentation, manure management), which are considered to be high methane emitting for Ireland. See Appendix Table B2 for further detail of specific

[15] The pollutants covered include 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. The use of the 3-out-7 rule is a standard approach.

[16] The use of UK data in this instance implicitly assumes the same distribution of occupations and industries applies across EU countries.

[17] See Appendix Tables B2 and B3 for a list of 'brown' occupations and sectors.

occupations.[18] In this case, we do not apply the share greater that seven times rule, but we consider the entire occupation as brown.

3.3 Irish Labour Force Survey Data

The Irish Labour Force Survey (LFS) is a large-scale nationally representative survey of Irish households, administered by the Irish Central Statistics Office. The data include information on a variety of individual and job characteristics, as well as the individual's labour market status. The Irish LFS also has detailed information on a person's occupation. Specifically, it has data at the ISCO 4-digit level, which is the most granular level of data within the ISCO occupation framework, enabling us to apply the methodology of Causa et al. (2024)'s to identify green and brown jobs at the ISCO 4-digit level. For the green jobs analysis, we report occupational data at the more aggregated level (ISCO 3-digit level) for synthesis purposes, since the list of green occupations at 4-digit level is very extensive. In this study, we use annual LFS data from 2011 to 2023 to analyse the incidence of green and brown jobs in Ireland over time. We then explore the average characteristics of workers in green and brown jobs in 2023. We also investigate the potential existence of a wage premium, or a wage penalty, associated with green and brown jobs, relative to non-green and non-brown jobs. To do this, we estimate the following OLS regression,

$$\ln(W_i) = a + \beta_1 Green_i + \beta_2 Brown_i + X_i' \beta_3 + e_i \qquad (1)$$

where the dependent variable, *ln(Wi)* denotes the log hourly earnings of individual *i*. The variables Green and Brown represent dummy variables that capture whether the individual is in a green job or a brown job, respectively. Note that the omitted category is a dummy variable capturing individuals in jobs that are neither brown nor green. Therefore, the coefficients β_1 and β_2 capture the wage premium or penalty relative to workers in non-green or brown (environmentally neutral) jobs. The vector *Xi'* includes addition control variables including education, age, gender, tenure, nationality, temporary contract, part-time and sector.

Note that the methodology described in Sections 3.1 and 3.2 shows that brown jobs are identified as a binary ('brown' or non-brown) at the ISCO 4-digit level. However, green jobs at ISCO 3-digit have an associated score to denote the estimated share of workers that are working in green jobs within the specific ISCO 3-digit category. For the purpose of estimating equation (1), we create a green binary that categorizes an ISCO 3-digit occupation as green if it has an estimated green employment share of 0.5 or above.

Finally, note that we are interested in examining potential wage premia or penalties associated with holding green or brown jobs, while controlling for a range of other characteristics. We do not claim to definitively state causality. There may be features of a job or individual that are not captured by our control variables that are correlated with both the likelihood of being in a green or brown job and with wages. Nonetheless, our analysis will provide important information on the relative wage structures of green and brown employment within the economy. This information is particularly important given that some workers that are currently working in brown jobs will likely transition to green jobs or environmentally neutral jobs over time.

[18] In this case, we do not apply the 'share greater than seven times' rule.

3.4 European Labour Force Survey Data

We compare the share of green and brown jobs in Ireland to the shares in other European countries using European Labour Force Survey (EU-LFS) data. Unlike the Irish Labour Force Survey which has occupation data at the most disaggregated level (ISCO 4-digit), the occupation data in the EU-LFS is slightly more aggregated (ISCO 3-digit). As a result of this lack of granularity, the incidence of green and brown jobs in Ireland using the EU-LFS will be slightly different compared to the incidence of green and brown jobs in Ireland using the Irish-LFS. Moreover, due to some data constraints, we cannot compare Ireland to all EU countries. The methodology developed by Causa et al. (2024) can be applied to 19 of the 27 EU countries.[19] The eight excluded countries are: Malta; Cyprus; Romania; Latvia; Luxembourg; Croatia; Bulgaria; Lithuania. Due to data limitations relating to occupations in the EU-LFS, Slovenia is also excluded. However, one non-EU country is included for the purpose of comparison – Norway. The incidence of green and brown jobs is calculated for each country using the methodology explained above (Causa et al., 2024). The earliest year for which we can calculate the incidence of green and brown jobs is 2011, as this was the first year that the ISCO08 occupational classification was applied. We compare the incidence of green and brown jobs in 2011 to the incidence in 2022 across the 19 countries in our sample.

For each ISCO 3-digit occupation, we have an estimated share of workers that are working in green jobs within that occupation. We also have an estimated share of workers that are working in brown jobs within an ISCO 3-digit occupation. While the methodology above identifies jobs as brown or not (i.e., a binary variable) at the ISCO 4-digit level, when moving to the ISCO 3-digit level we work with a continuous measure that captures the share of workers in brown jobs. This is because ISCO 3-digit occupations typically include several ISCO 4-digit occupations. An unweighted average is taken to estimate the share of brown jobs withing an ISCO 3-digit level. For example, if an ISCO 3-digit occupation is comprised of two ISCO 4-digit occupations, and one is brown and the other is not, then the estimated share of brown workers within the ISCO 3-digit occupation is 0.5.

3.5 European Skills and Jobs Survey Data

We also use data from the 2021 European Skills and Jobs Survey (ESJS). The ESJS is the second wave of the survey administered by Cedefop. It is a comprehensive and representative employee-based survey on adult employees aged 24 to 65 in EU countries, plus Iceland and Norway, with a total sample of over 46,000 observations. The survey collects information on employees' sociodemographic characteristics, as well as detailed job characteristics on skill requirements and task content, working arrangements, wages, and job satisfaction. Similar to the Irish-LFS, it has detailed occupation information allowing us to identify green and brown jobs at the ISCO 4-digit level. While there are 46,000 observations overall, the corresponding sample sizes for an individual country are smaller. For Ireland, there are approximately 1,300 observations in the data with information on occupation. As such, while we analyse green jobs using this data, the sample size for brown jobs is relatively small, making it unsuitable to assess this group separately.

[19] Occupation scores for brown jobs were developed for 19 EU countries.

We employ a probit model to identify the key characteristics that distinguish workers in green occupations in the EU-27 from their non-green counterparts. Specifically, we estimate the following probit model,

$$\Pr(Green_{ic}) = \Phi(\alpha + X'_{ic}\beta_1 + JQ'_{ic}\beta_2 + \beta_3 Digital_{ic} + \delta_c) \quad (2)$$

where the outcome variable, $Green_{ic}$, is a binary variable that equals to one if the employee works in a green job and zero otherwise. Similar to equation (1), green jobs are defined as ISCO 4-digit occupations that have an estimated share of green employment of at least 50 percent. The vector X_{ic} includes control variables for gender, educational attainment, tenure, hours worked, firm size, contractual status and training. In the vector JQ'_{ic}, we include measures of job quality and autonomy including, (a) if the job contained short repetitive tasks (b) if the employee can often choose methods for doing work (c) if the employee can plan their own work activities, and (d) if the job often involves learning new things. $Digital_{ic}$ is a digital intensity index, which has values from zero to nine, that measures the extent to which the job involves up to nine digital related skills ranging from using basic word processing software to advanced programming. Finally, we include country fixed effects, denoted by δ_c.

In addition, we use the ESJS data to examine the relationship between green employment and job satisfaction, as well as the relationship between green employment and wages (similar to the analysis using LFS data). For job satisfaction, we estimate the following probit model,

$$\Pr(Satisfied_{ic}) = \Phi(\alpha + X'_{ic}\beta_1 + JQ'_{ic}\beta_2 + \beta_3 Digital_{ic} + \delta_c) \quad (3)$$

where $Satisfied_{ic}$ is a binary variable equal to one if the respondent indicates that they are satisfied in their current job, and zero otherwise. The right-hand side variables are the same as those defined in equation (2). With regard to wages, we estimate the following OLS regression,

$$\ln(W_{ic}) = \alpha + X'_{ic}\beta_1 + JQ'_{ic}\beta_2 + \beta_3 Digital_{ic} + \delta_c + \varepsilon_{ic} \quad (4)$$

where $ln(W_{ic})$ captures the log hourly wage of employee *i* in country *c*, and the right-hand side variables are the same as previously defined.

4. Results

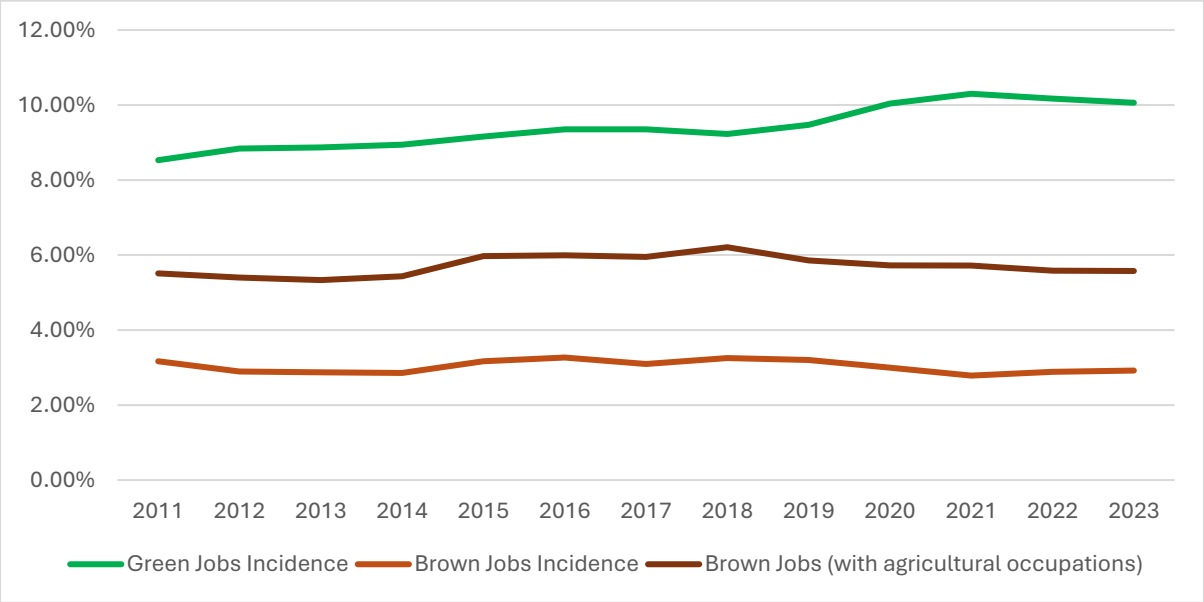
4.1 Incidence of Green and Brown Employment

Figure 1 shows the incidence of green and brown jobs in Ireland from 2011 to 2023 using Irish LFS data.[20] The share of green employment in Ireland has increased over time, from approximately 8 per cent of total employment in 2011 to 10 per cent in 2023. The share of brown jobs according to the classification of Causa et al. (2024), and excluding agriculture, (*in light brown*) has been relatively stable over time, at around 3 per cent of total employment. When we include brown occupations related to agriculture (*in dark brown*), the incidence of brown jobs is higher, at approximately 5.5 per cent of total employment, but still remains relatively stable over time. It is worth noting that the vast majority of jobs in Ireland are categorised as environmentally neutral.

[20] Note that both employees and self-employed are included in this analysis.

Figure 2 compares the incidence of green and brown employment in Ireland over time against 18 other EU countries and Norway using EU-LFS data.[21] The incidence of green jobs is shown for the years 2011 and 2022. All countries apart from Slovakia and Estonia recorded an increase in the percentage of green jobs over time. On average, for all countries, 8.4 percent of jobs were categorised as "green" in 2011, compared to 9.2 percent in 2022. Ireland had the third highest incidence of green jobs in 2022 (at 10.5 percent), after Sweden and Estonia. Ireland also recorded the second largest increase (in percentage points) in green jobs over time, second only to Sweden.

Figure 1: Incidence of Green and Brown jobs in Ireland, 2011-2023



Source: Irish Labour Force Survey (authors' elaboration).

[21] As mentioned, the EU-LFS data has occupations at the ISCO 3-digit level, while the Irish LFS microdata has ISCO 4-digit information. As such, there are slight differences in the incidence of green employment when comparing Figure 1 to Figure 2.

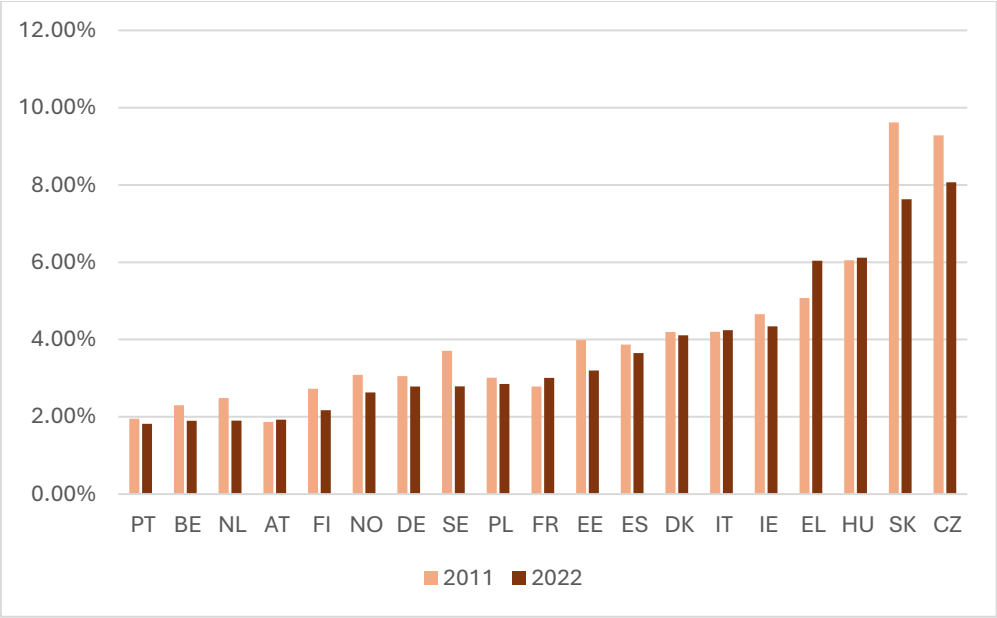
Figure 2: Incidence of Green Jobs Across Europe

Source: European Labour Force Survey (authors' elaboration).

In Figure 3 below we show the incidence of brown jobs (excluding agricultural occupations) across Europe using EU-LFS data. For most countries, brown employment either decreased or remained relatively constant. In Greece, however, the percentage of brown jobs increased from approximately 5 percent in 2011 to 6 percent in 2022. At 4.3 percent, Ireland recorded the fifth highest incidence of brown employment in 2022 after Czechia, Slovakia, Hungary and Greece.[22]

[22] Note that the brown job estimates in Ireland based on the EU-LFS differ from estimates if Figure 1 that are based on Irish LFS microdata. The Irish LFS data has the more detailed ISCO 4-digit classification for occupations. With the ISCO 3-digit classification used in the EU-LFS, a brown share of employment within each ISCO 3-digit occupation has to be calculated based on the percentage of the sub-occupations (at ISCO 4-digit) within the ISCO 3-digit occupation that are brown. This can lead to an overweighting of brown employment within ISCO 3-digit occupations, and hence an overestimate of brown employment compared to Figure 1. Nonetheless, despite the limitation, the method is applied consistently over both time and countries.

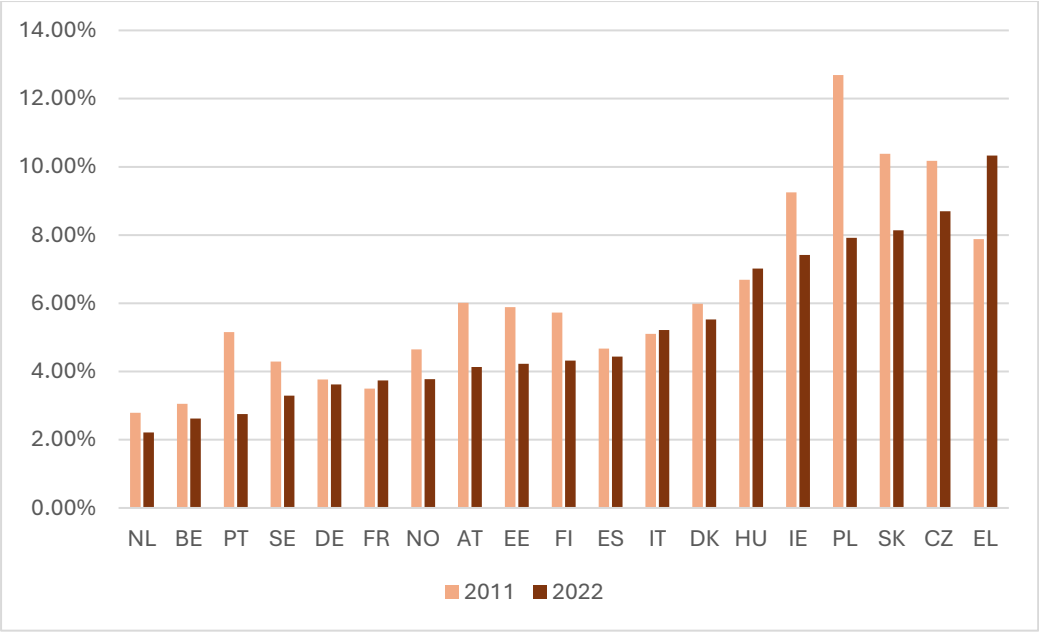
Figure 3: Incidence of Brown Jobs Across Europe (Excluding Agricultural occupations)



Source: European Labour Force Survey (authors' elaboration).

We next apply the expanded definition of brown jobs which includes occupations relating to agriculture. As per Appendix Table B1, these occupations include: agricultural technicians (ISCO 3142); poultry producers (ISCO 6122); mixed crop and animal producers (ISCO 613); subsistence livestock farmers (ISCO 632); subsistence mixed crop and livestock farmers (ISCO 633); livestock farm labourers (ISCO 9212). Three of these six occupations (ISCO 613, ISCO 632 and ISCO 633) are defined at the 3-digit ISCO level, which is directly applicable to the EU-LFS data. For the other three occupations, which are defined at the more detailed 4-digit level, we aggregate them to their corresponding 3-digit classifications in order to apply it to the EU-LFS data. Therefore, life science technicians and associate professional (ISCO 314) is used instead of agricultural technicians (ISCO 3142), animal producers (ISCO 612) instead of poultry producers (ISCO 6122), and agricultural, forestry and fishery labourers (ISCO 921) instead of livestock farm labourers (ISCO 9212). The results are shown in Figure 4 below. First, note that the inclusion of agriculture does not change Ireland's ranking; Ireland has the fifth highest incidence of brown jobs out of the 19 countries studied. However, as expected with the inclusion of additional occupations, the incidence of brown jobs is higher for all countries. For Ireland, the incidence of brown jobs (including agriculture occupations) was 9.3 percent in 2011 and 7.4 percent in 2022. This compares to an incidence of 4.7 percent in 2011 and 4.3 percent in 2022 when agriculture is excluded.

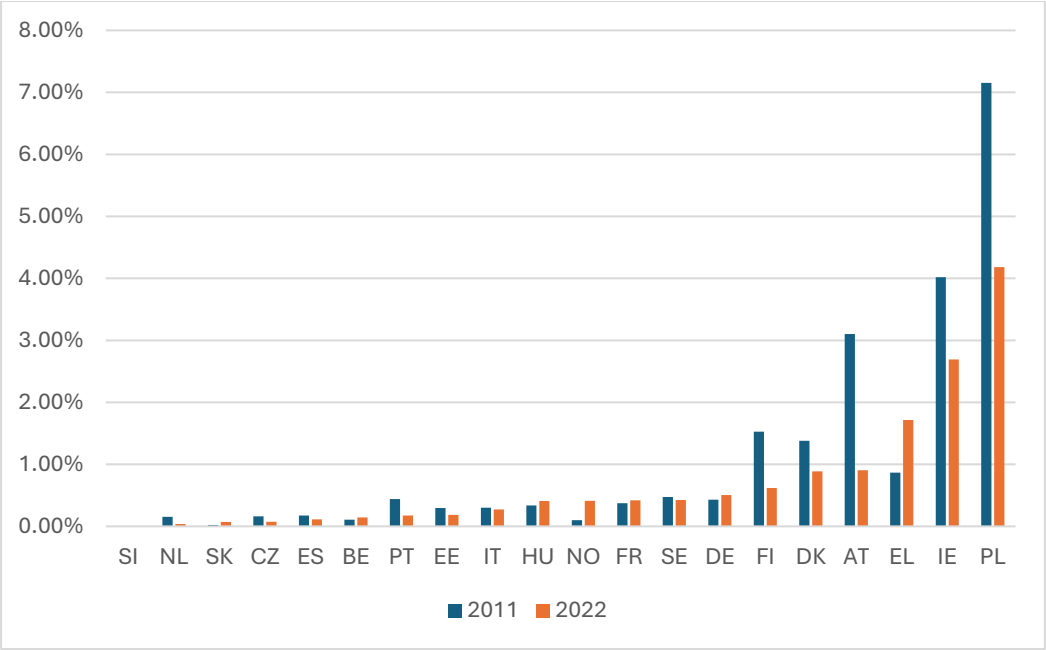
Figure 4: Incidence of Brown Jobs Across Europe (Including Agricultural occupations)



Source: European Labour Force Survey (authors' elaboration).

We examine the agriculture-specific occupations in more detail to see which occupation has the greatest impact on the number of brown jobs. The increase in the incidence of brown jobs in Ireland that occurs when agriculture is included is almost entirely driven by one occupation – Mixed Crop and Animal Producers (ISCO 613). In Figure 5, we show the percentage of workers in this occupation in 2011 and 2022 across Europe. Ireland has the second highest number of individuals working as mixed crop and animal producers (after Poland). In 2011, 4 percent of workers in Ireland were working in this occupation. However, this reduced to 2.7 percent in 2022.

Figure 5: Employment shares for Mixed Crop and Animal Producers (ISCO 613)



Source: European Labour Force Survey (authors' elaboration).

4.2 Distribution of Green and Brown Jobs by Sector and Occupation

While green and brown jobs account for a relatively low share of employment in Ireland, they are not equally distributed across sector and occupation. Using Irish LFS data from 2023, we show the sectoral distribution of green employment in column 1 of Table 1. Approximately one fifth (19 per cent) of all green jobs in Ireland are in the *manufacturing* sector, which is a higher share than any other sector. Just over 16 per cent of green jobs occur in the *professional, technical and scientific activities* sector, and 14 per cent are in *construction*. Other sectors that account for a relatively large share of all green jobs include: *finance, insurance and real estate activities* (9 per cent); *information and communication* (8 per cent); and *wholesale and retail* (6 per cent).

In column 2 of Table 1, we show the sectoral distribution of brown jobs. Most brown jobs are in the Transportation and Storage sector (over 56 per cent). The next highest is Wholesale and Retail (over 13 per cent), followed by Manufacturing (over 11 per cent). In column 3 of Table 1, we show the distribution by sector when methane emitting occupations from agriculture are included. This shows that almost half of brown employment appears to be in Agriculture.

Table 1: Sectoral distribution of green and brown employment in Ireland, 2023

(1)		(2)		(3)	
Green employment by sector		**Brown employment by sector (Causa et al., 2024 methodology)**		**Brown employment by sector (Including agricultural occupations)**	
NACE C Manufacturing	19.00%	NACE H Transportation and Storage	56.30%	NACE A Agriculture	49.29%
NACE M Professional, technical and scientific activities	16.20%	NACE G Wholesale and Retail	13.37%	NACE H Transportation and storage	29.51%
NACE F Construction	14.40%	NACE C Manufacturing	11.47%	NACE G Wholesale and Retail	7.00%
NACE K Finance and insurance activities NACE L Real estate activities	8.80%	NACE B Mining and Quarrying	3.27%	NACE C Manufacturing	6.00%
NACE J Information and Communication	8.40%	NACE A Agriculture	3.27%	NACE B Mining and Quarrying	1.71%
NACE G Wholesale and Retail Trade	6.40%	NACE E Water supply, waste management	1.64%	NACE E water supply, waste management	0.86%
Other sectors	26.80%	NACE D Electricity and gas	1.21%	NACE D Electricity and gas	0.63%
		Other sectors	9.48%	Other sectors	4.99%

Source: Irish Labour Force Survey (authors' elaboration).

In Table 2 we show the occupational distribution of green and brown employment at the ISCO 3-digit and ISCO 4-digit level respectively. The occupation with the largest overall share of green employment is ISCO 132 - manufacturing, mining, construction and distribution managers, accounting for approximately 15 per cent of all green jobs.[23] Other occupations that account for a relatively high number of green jobs include: finance professionals (13 per cent); administration professionals (9 per cent); engineering professionals (9 per cent); sales, marketing and public relations professionals (8 per cent).

Column 2 of Table 2 shows the distribution of brown jobs by occupation when agricultural occupations are excluded. This shows that car, taxi, van, truck, bus and tram drivers account for the majority (84 per cent) of all brown occupations in Ireland. As we move towards a decarbonised economy, and as green technology is adopted more widely, it is likely that the transportation sector will continue to transition to cleaner, low-emission vehicles. An example of this is the recent introduction of 280 plug-in hybrid buses by Dublin Bus, which qualify as 'clean vehicles' under the European Union's revised Clean Vehicles Directive. Such changes may not lead to a drastic change in the skills required by workers in these occupations. That is, driving a zero-emission vehicle will require a similar skillset to driving a diesel vehicle. Column 3 of Table 2 shows the occupational distribution of brown jobs when agricultural occupations are included. In this case, almost half of brown employment is located among one occupation - mixed crop and animal producers. Achieving emission reduction targets in agriculture will require the adoption of greener techniques and eventually training workers to adapt to those techniques (i.e.,

[23] Note that ISCO 132 has four underlying ISCO 4-digit occupations (Manufacturing Managers, Mining Managers, Construction Managers and Supply, Distribution and other Managers). Only around one per cent of the green workers in this category is located among 'Mining Managers'.

sustainable farming techniques). As such, it will be important to invest in training and upskilling of workers to ensure a just transition.

Table 2: Occupational distribution of green and brown employment in Ireland, 2023

Green employment by occupation		Brown employment by occupation (Causa et al., 2024 methodology)		Brown employment by occupation (including agricultural occupations)	
132 - Manufacturing, mining, construction and distribution managers	14.94%	8322 - Car taxi and van drivers	35.79%	6130 - Mixed Crop and Animal Producers	47.65%
241 - Finance professionals	13.28%	8332 - Heavy truck and lorry drivers	32.45%	8322 - Car taxi and van drivers	18.74%
242 - Administration professionals	9.28%	8331 - Bus and tram drivers	16.13%	8332 - Heavy truck and lorry drivers	16.99%
214 - Engineering professionals	9.07%	Other brown occupations (#13)	15.62%	8331 - Bus and tram drivers	8.32%
243 - Sales, marketing and public relations professionals	7.91%			Other brown occupations (#18)	8.20%
143 - Other services managers	4.54%				
311 - Physical and engineering science technicians	4.37%				
711 - Building frame and related trades workers	4.06%				
Other green occupations (#30)	32.55%				

Source: 2023 Irish Labour Force Survey (authors' elaboration).

4.3 Characteristics of workers in Green and Brown Jobs

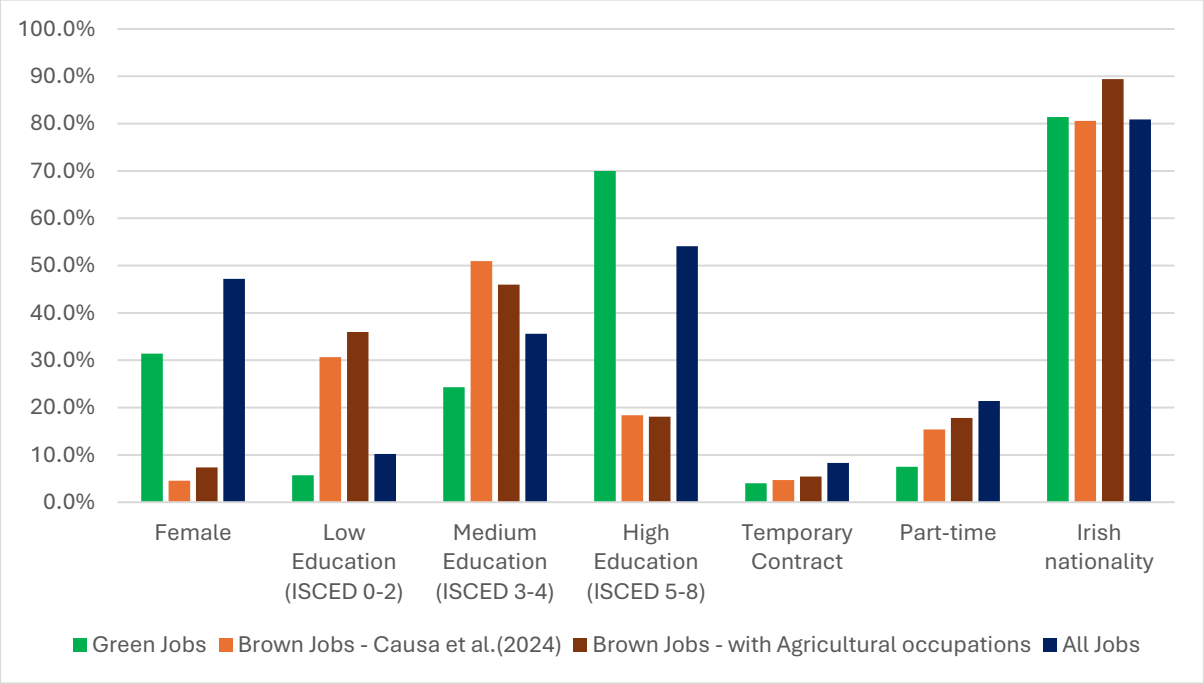
In Figure 6, we show the average characteristics of individuals working in green and brown jobs in Ireland in terms of gender, educational attainment, contract type, part-time status and nationality. We also show the same characteristics for total employment in Ireland, to provide a benchmark. There is an underrepresentation of women in both green and brown jobs. Despite making up approximately 50 per cent of the workforce in Ireland, women account for just 30 per cent of workers in green jobs, and just 4 to 7 per cent (depending on definition used) of workers in brown jobs. This gender difference largely reflects the sectoral and occupational concentration of green and brown employment, which mostly occurs in jobs that are typically made up of a higher percentage of men. Women by contrast are more likely to work in service sectors, such as hospitality, health and education, which are often categorised as environmentally neutral (Causa et al., 2024).

Compared to workers in brown jobs, those in green jobs have higher levels of educational attainment. Approximately 70 per cent of workers in green occupations are educated to tertiary level (ISCED 5 and above), compared to 18 per cent of those in brown employment. This is even

higher than the share for total employment in Ireland (around 55 per cent). This pattern is consistent with the notion that green jobs are, on average, higher-skilled and less routine-intensive than non-green occupations. This is important as individuals with lower levels of educational attainment may face higher displacement risks as a result of the green transition, given their overrepresentation in high-polluting jobs, which again underscores the importance of supporting workers to upskill/reskill as required.

A small share of workers in both green and brown employment holds temporary contracts (4-5 per cent). Between 15 and 17 per cent of people in brown jobs work on a part-time basis, compared to 8 per cent of workers in green jobs. Both green and brown jobs are less likely to experience less stable working conditions/arrangement (i.e., temporary contract and part-time) than general employment in Ireland. Around 80 per cent of workers in green and brown jobs are Irish nationals, similarly to the average for the entire workforce. This share rise to 90 per cent in the latter when including agriculture-related brown jobs.

Figure 6: Characteristics of Workers in Green and Brown Jobs, 2023

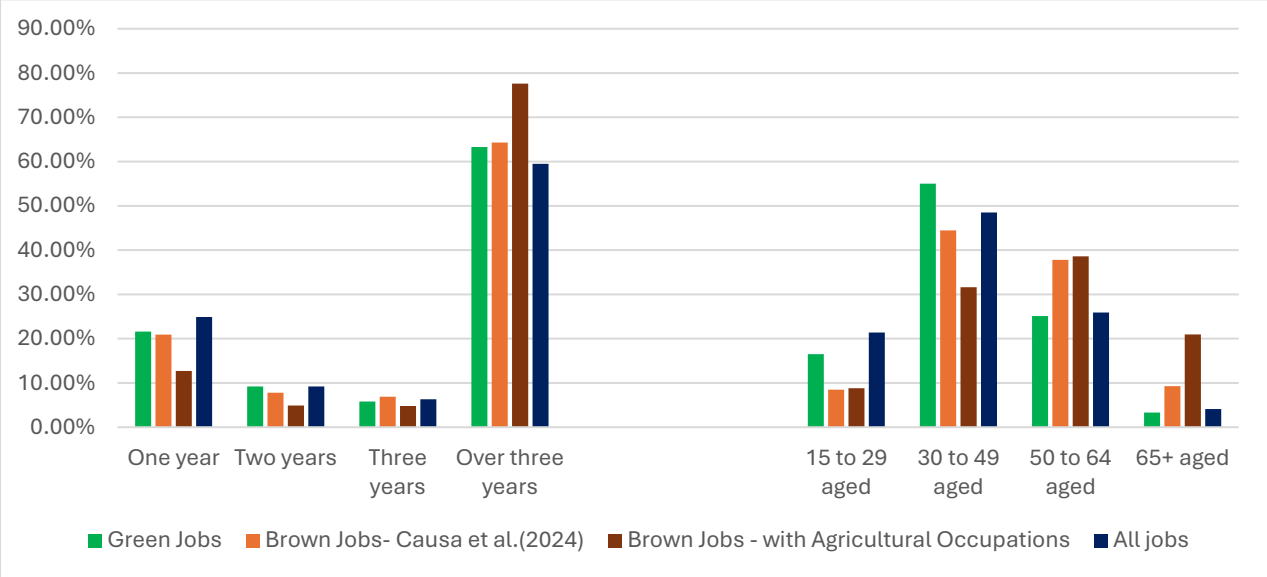


Source: 2023 Irish Labour Force Survey (authors' elaboration).

Figure 7 shows the job tenure and age distribution of workers in green and brown jobs. Again, we also include the same characteristics for total employment in Ireland. Young people appear to be under-represented among both green and brown jobs, compared to total employment. Adult workers are over-represented among green jobs. Older workers are over-represented among brown jobs. Approximately 21 per cent of workers in brown jobs that include agriculture are aged 65 and over. The comparable figure for green jobs is just 3 per cent. In terms of tenure, on average, 60 per cent of workers in both green and brown jobs have over three years of experience in the same job, and this reflects the distribution for total employment. However, when considering brown employment with the inclusion of agricultural occupations, 80 per cent of workers have

over three years of experience. This likely reflects the older age profile of those employed in agriculture.

Figure 7: Tenure and Age Distribution of Green and Brown Employment, 2023



Source: 2023 Irish Labour Force Survey (authors' elaboration).

In Table 3 we compare the regional distribution of green and brown jobs compared to the regional distribution of total employment in Ireland. Dublin accounts for the highest share of total employment in the country, at 36 per cent. Green jobs appear to be overrepresented in the Dublin region, at 42 per cent, while brown jobs (excluding agriculture) are slightly underrepresented, at 33 per cent. When agricultural occupations are included, the share of workers in brown jobs in Dublin falls to just 18 per cent. This is because, when agriculture is included, brown jobs are overrepresented in all areas apart from Dublin and the Mideast. For example, while just 7 per cent of workers in Ireland are in the Border region, 12 per cent of workers in brown jobs (including agriculture) are located here. The findings suggest that some rural areas may be more exposed to the impacts of the green transition. Again, this highlights the importance of upskilling workers in agriculture to encourage the adoption of green technologies.

Table 3: Distribution of green and brown jobs across regions, compared to total employment shares by region, 2023

	Border	West	Mid West	South East	South West	Dublin	Mideast	Midlands	All
Total Employment	7.3%	8.8%	8.9%	7.8%	14.2%	36.0%	10.3%	5.3%	100
Green Jobs	5.4%	8.3%	7.6%	6.7%	13.3%	42.8%	9.4%	4.4%	100
Brown Jobs	8.0%	10.4%	8.3%	9.7%	12.1%	33.4%	9.6%	5.4%	100
Brown Jobs + Agriculture	12.3%	13.2%	10.8%	11.3%	16.6%	17.6%	9.2%	7.2%	100

Source: 2023 Irish Labour Force Survey (authors' elaboration).

4.4 Wages, Job Satisfaction and Job Complexity

In Section 4.3, we showed that workers in green jobs have higher levels of education, on average, than workers in brown jobs. In this section, we examine whether this translates into higher pay and higher job satisfaction. Furthermore, we also examine whether this is reflected in greater task complexity of green jobs.

In Table 4, we use Irish LFS data to show the mean and median hourly wage for all employees in Ireland in 2023, as well as separately for employees in green and brown jobs.[24] The average hourly wage for workers in green jobs (both the mean and median) is substantially higher than the average wage for all employees. However, the average hourly wage for workers in brown jobs falls well below the average wage for those in green jobs, as well as for all employees generally. When we include agriculture in the definition of brown employees, the median and mean hourly wage are slightly lower compared to a situation where agriculture is excluded. However, there is an important caveat here. The wage data in the LFS relates only to employees. Therefore, it does not capture the earnings of the very large share of self-employed individuals that work in agriculture.

[24] The wage data in the Irish LFS comes from administrative sources. Respondents are matched to official tax records for the purpose of collecting wage data. However, not all employees can be matched. Coverage has improved over time, with around 70 per cent of employees matched in 2023.

Table 4: Mean and Median Hourly Wages of Employees in Ireland, 2023

	Mean Hourly Wage (€/h)	Median Hourly Wage (€/h)
All jobs	26.64	21.65
Green Jobs (score>0.5)	33.43	29.34
Brown Jobs (excluding agriculture)	18.67	17.16
Brown Jobs (including agriculture)	18.25	16.71

Source: 2023 Irish Labour Force Survey (authors' elaboration).

Using Irish LFS data for 2023, we estimate equation (1) to investigate the extent to which green and brown jobs are associated with a wage premium / penalty relative to the common reference group of non-green and non-brown (environmentally neutral) jobs. The results are shown in Table 5. Column (1) of Table 5 employs the definition of brown jobs that excludes agriculture. After controlling for other variables, green jobs are associated with a 23 per cent hourly pay premium, while brown jobs are associated with a 9 per cent wage penalty relative to environmentally neutral jobs.[25] When agricultural occupations are included in the definition of brown jobs (column (2) of Table 5), the pay penalty associated with brown jobs increases from 9 to 13 percent. Again, we caveat this result by noting that wages relate to employees only and therefore do not capture the earnings of the high numbers of self-employed farmers.[26]

In Table 6, we show the results from estimating equations (3) and (4) using the European Skills and Jobs Survey data. Column (1) of Table 6 shows that, relative to environmentally neutral jobs, green jobs across the EU-27 are associated with an 8 per cent wage premium. Column (2) of Table 6 shows that employees in green jobs across the EU are four percentage points more likely to be satisfied in their jobs, relative to employees in environmentally neutral occupations.

[25] Converting the regression equation into a percentage change requires the following calculation: $e^{\beta} - 1$.
[26] As we explained in the methodological section, we decided to restrict the wage analysis to the occupations with a green score equal or higher than 0.5. This is because we want to focus on occupations that have a consistent bulk of green employment. These include 6 out of 40 ISCO 3-digit occupations (132 Manufacturing, Mining, Construction and Distribution Managers; 215 Electro-technology Engineers; 216 Architects, Planners, Surveyors and Designers; 241 Finance Professionals; 243 Sales, Marketing and Public Relations Professionals; 961 Refuse Workers). As the green score is a continuous measurement, including a specific occupation in the analysis means that the entire occupation would be considered green, which is not the case for most occupations (for instance, occupations with only 0.1 or 0.2 share of green employment). Therefore, a cut-off value needs to be identified. However, we did try to run our wage models including all occupations with a non-zero green score (this implies considering the entire 40 ISCO 3-digit green occupations). In this case, the wage premium associated with green jobs would be 15 per cent compared to environmentally neutral jobs. As a consequence, also the reference category of environmentally neutral jobs would be different than the one presented in our main analysis.

Table 5: OLS Wage Regressions for Green and Brown Employees, 2023 data

	(1) Excludes Agricultural occupations	(2) Includes Agricultural occupations
VARIABLES	Log Hourly Wage	Log Hourly Wage
Female	-0.12***	-0.12***
	(0.007)	(0.007)
Age	0.03***	0.03***
	(0.002)	(0.002)
Age^2	-0.00***	-0.00***
	(0.000)	(0.000)
Medium Education	0.09***	0.09***
	(0.011)	(0.011)
High education	0.37***	0.37***
	(0.012)	(0.012)
Temporary Contract	0.02	0.02
	(0.015)	(0.015)
Part-time	-0.04***	-0.04***
	(0.009)	(0.009)
Tenure	0.01***	0.01***
	(0.000)	(0.000)
Irish Native	0.08***	0.08***
	(0.010)	(0.010)
(ref: non green/non brown job)		
Green job	**0.21*** **	
	(0.012)	
Brown job (Causa et al., 2024, methodology)	**-0.09*** **	
	(0.016)	
(ref: non green/non brown job)		
Green job		**0.21*** **
		(0.012)
Brown job (Causa et al., 2024/ESRI methodology)		**-0.12*** **
		(0.016)
Controls for Sector	Yes	Yes
Constant	2.12***	2.12***
	(0.120)	(0.120)
Observations	21,974	21,974
R-squared	0.329	0.329
F	351.1	351.7

Source: 2023 Irish Labour Force Survey (authors' elaboration).

*Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.*

Table 6: Wages and Job Satisfaction of Employees in Green Jobs, (EU-27, 2021)

VARIABLES	Wages	Job Sat
green	0.08***	0.04***
	(0.013)	(0.008)
Male	0.18***	0.01
	(0.007)	(0.005)
Upper / post-secondary	0.09***	0.01
	(0.014)	(0.008)
Third level	0.32***	0.05***
	(0.013)	(0.008)
Training	0.11***	0.11***
	(0.007)	(0.005)
Permanent contract	0.13***	0.06***
	(0.010)	(0.007)
Hours worked	-0.02***	0.00*
	(0.000)	(0.000)
Tenure	0.01***	0.00***
	(0.000)	(0.000)
Firm size (11-49)	0.09***	-0.01**
	(0.010)	(0.007)
Firm size (50-249)	0.13***	-0.00
	(0.010)	(0.007)
Firm size ((>=250)	0.18***	-0.01
	(0.011)	(0.007)
Constant	2.58***	
	(0.031)	
Observations	31,833	42,374
R-squared / Pseudo R	0.48	0.04

***Source**: 2021 European Skills and Jobs Survey (second wave)*
***Note**: controls for country level fixed effects included; standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

In Table 8, we show the results from estimating equation (2), which identifies the characteristics of green employees in the EU, including measures of job complexity and job quality. The results indicate that, relative to environmentally neutral jobs, employees in green jobs in the EU are more likely to be male, be educated to third level and have permanent contracts. The results also show that green jobs tend to be associated with higher levels of job autonomy and digital skills use, while being less likely to involve short repetitive tasks.

Table 8: Probit: Characteristics of Green Employees: EU 27 2021

VARIABLES	(1) Spec 1
Male	0.06***
	(0.003)
Age	0.00
	(0.000)
Upper / post-secondary	0.00
	(0.005)
Thid level	0.01***
	(0.005)
Digital Index	0.04***
	(0.005)
Repetitive tasks	-0.01***
	(0.003)
Choose worth meth	0.01*
	(0.003)
Plan work	0.01***
	(0.003)
Learning in work	-0.00
	(0.003)
Training	-0.00
	(0.003)
Permanent	0.01***
	(0.003)
Hours worked	-0.00
	(0.007)
Tenure	-0.00***
	(0.000)
Firm size (11-49)	0.00
	(0.001)
Firm size (50-249)	-0.01**
	(0.004)
Firm size (>=250)	0.01**
	(0.004)
|	
Pseudo R2	0.0468
Observations	42,374

***Source**: 2021 European Skills and Jobs Survey (second wave)*
***Note**: controls for country level fixed effects included; standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Coefficients relate to marginal effects.*

In Tables 9 to 11, we compare the characteristics of green employees in Ireland to the EU-27 in order to assess the extent to which the quality of green jobs in Ireland compares to the EU

average. Employees in green occupations in Ireland are substantially more likely to be educated to third level relative to the EU-27 green job average (see Table 9). This reflects the fact that Ireland, in general, has a very highly educated workforce when compared to other EU countries. With respect to the components of digital complexity (Table 10), green jobs in Ireland closely align with the EU average.

In relation to task content, Irish green jobs are more likely to involve short repetitive tasks, however, Irish workers have somewhat greater capacity to plan their own work activities relative to the EU green average (see Table 11). Finally, Irish employees in green occupations are more likely to have received training in the previous twelve months relative to the EU green job average.

Table 9: Educational Distribution of Green Jobs

	Ireland	Rest of EU
Lower secondary	2.3	6.7
Upper / post-secondary	18.6	30.0
Third level	79.1	63.3
	100	100

***Source**: 2021 European Skills and Jobs Survey (second wave)*

Table 10: Digital Complexity of Green Jobs

	Ireland	Rest of EU
% Undertaking Any Digital Tasks	0.52	0.5
% Undertaking Basic Digital Tasks	0.72	0.78
% Undertaking Intermediate Digital Tasks	0.62	0.6
% Undertaking Advanced Digital Tasks	0.18	0.16

***Source**: 2021 European Skills and Jobs Survey (second wave)*

Table 11: Task Content of Green Jobs

	Ireland	Rest of EU
Job often involves doing short repetitive tasks	26.7	19.8
Can often choose methods for doing work	29.1	31.3
Can often plan own work activities	53.5	46.6
Job often involves learning new things	27.9	24.5
Received training in previous 12 months	74.4	67.3

***Source**: 2021 European Skills and Jobs Survey (second wave)*

5. Summary and Conclusions

EU policy aims to make Europe the first climate-neutral continent by 2050. The so-called 'green transition' relates to the decarbonisation process of the economy and the transition to clean and renewable energies. It is likely that the green transition will impact on employment and the way people work. To achieve climate neutrality, changes will need to occur within high-emission occupations (brown jobs). This may involve adopting new green technologies which could change the nature of the tasks undertaken within occupations. For example, the Teagasc Climate Action Strategy seeks to engage 50,000 farmers to assist them in adopting new technologies that can help meet Ireland's target of reducing greenhouse gas emissions in agriculture by 25 per cent by 2030. In some instances, brown occupations may be phased out, such as the phasing out of peat harvesting in recent years.

This paper uses a range of data sources to assess the incidence and nature of green and brown jobs in Ireland to gain an understanding of the potential labour market adjustments arising from the ongoing decarbonisation process. Both green and brown jobs are identified using a definitional approach developed in recent work at the OECD carried out by Causa et al. (2024). We find that the share of green jobs in Ireland has been trending slightly upwards over time, from approximately 8 per cent of total employment in 2011 approximately 10 per cent in 2023. The share of brown jobs has been relatively stable over time, with an estimated share of total employment in 2023 of approximately 3 per cent. However, the approach of Causa et al. (2024) to measuring brown jobs does not account for methane pollution and therefore excludes agriculture. When we expand the definition to include high methane emitting occupations in agriculture, the estimated incidence of brown jobs in Ireland in 2023 increases to approximately 5.5 per cent.

At a sectoral level, we find that brown jobs in Ireland are highly concentrated in the transport and agriculture sector. Many jobs in the transport sector will likely transition from brown to green over time. For example, Dublin Bus recently introduced 280 plug-in hybrid buses which qualify as 'clean vehicles' under the European Union's revised Clean Vehicles Directive. These changes may not significantly impact employment, as the skills required for driving a low-emission vehicle are similar to a diesel vehicle. We find that the vast majority of brown jobs in agriculture relate to one occupation – mixed crop and animal producers. Effective upskilling and training measures will be needed to allow workers in agriculture to benefit from the opportunities of the green transition.

In terms of green jobs, the occupation with the largest overall share of green employment is ISCO 132 - manufacturing, construction and distribution managers, which accounts for approximately 15 per cent of all green jobs. Other occupations that account for a relatively high number of green jobs include: finance professionals (13 per cent); administration professionals (9 per cent); engineering professionals (9 per cent); sales, marketing and public relations professionals (8 per cent).

When comparing the share of green and brown jobs in Ireland to other European countries, we find that in 2022 Ireland had the third highest incidence of green jobs after Sweden and Estonia and recorded the second largest increase in green jobs over time from 2011. In terms of brown jobs, in 2022 Ireland had the fifth highest incidence of brown employment, after Czechia, Slovakia, Hungary and Greece. When using the expanded methodology which includes agricultural occupations, the incidence of brown jobs appears higher for all EU countries, however, the ranking remains unchanged, with Ireland remaining in fifth place.

Men make up a disproportionate number of workers in both green and brown jobs in Ireland. Workers in green jobs are also found to have higher levels of educational attainment than those in brown jobs. The educational profile of green jobs suggest that they are typically higher skilled and higher value added in nature relative to both brown jobs. This is reflected in the fact that green jobs are associated with higher wages compared to brown jobs. Furthermore, green jobs in Ireland were found to be of somewhat better quality compared to the EU green job average, particularly when measured in terms of educational entry requirements, job autonomy, and training intensity. However, green jobs in Ireland had a higher incidence of repetitive tasks compared to the EU average.

Our analysis shows that the potential labour market impacts of the green transition are unlikely to be evenly distributed across regions, with brown jobs disproportionately located in rural areas. Indeed, we find that brown jobs appear to be overrepresented in the Border, West and Southeast regions. While these regions may be more exposed to the impacts of the green transition, measures to encourage the adoption of sustainable practices can help mitigate these impacts. The impacts are also likely to vary by gender, educational attainment and sector. These findings underscore the role for well-targeted policies for specific socio-demographic groups and territories, to ensure that all workers are equipped with the skills needed to take advantage of the opportunities presented by the green transition. Finally, it should be noted that, in addition to the labour market impacts, meeting our environmental targets will be challenging and will require continued urgency, ambition, and action by all sectors of society.

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Appendix A

O*NET classifies green occupations based on their task content. The taxonomy identifies three categories of green occupation:

- The first category is *New and Emerging Green* and includes new occupations with unique worker and task requirements as a result of the green transition.
- *Green Enhanced Skills* captures those existing occupations that will require a shift in tasks as a result of the green transition.
- The final category, *Green Increased Demand,* covers existing occupations likely to experience increased demand due to the green transition but not expected to see significant changes in tasks or worker requirements. As this category does not involve green tasks it is excluded from this analysis.

Further detail on O*NET green occupations and the green tasks involved in these occupations are set out in Appendix Table A1 below.

Appendix Table A1: Examples of '*New and Emerging Green*' and '*Green enhanced skills*' Occupations and 'Green' tasks according to the O*Net classification.

O*NET category	Occupation	Description	Green tasks
Green Enhanced Skills	General and operations managers	Plan, direct or coordinate operation of organisations; formulate policies, manage daily operations and plan the use of material and human resources.	• Implement / oversee environmental management or sustainability programmes addressing issues such as recycling, conservation, or waste management. • Manage the movement of goods into and out of production facilities to ensure efficiency, effectiveness, or sustainability of operations.
Green Enhanced Skills	Heavy and tractor-trailer truck drivers	Drive a tractor-trailer combination or a truck with high capacity. May be required to unload truck.	• Drive electric or hybrid-electric powered trucks or alternative fuel-powered trucks to transport and deliver products, livestock, or other materials. • Operate idle reduction systems or auxiliary power systems to generate power from alternative sources, to reduce idling time, to heat/cool truck cabins, or to provide power for other equipment.
Green Enhanced Skills	Construction labourers	Perform tasks involving physical labour at construction sites. Duties include: operating hand and power tools of all types, cleaning and preparing sites, cleaning up rubble, debris and other waste materials.	• Perform building weatherisation tasks, such as repairing windows, adding insulation, or applying weather-stripping materials. • Perform construction labourer duties at green building sites, such as renewable energy plants

			or wind turbine installations.
New and Emerging Green	Recycling and reclamation workers	Prepare and sort materials or products for recycling. Identify and remove hazardous substances. Dismantle components of products.	• Operate automated refuse or manual recycling collection vehicles. • Clean materials, such as metals, according to recycling requirements.
New and Emerging Green	Transportation engineers	Develop plans for surface transport projects, according to engineering standards and construction policy. Prepare designs, specifications and modification for transport facilities. Plan modifications of existing roads to improve traffic flow.	• Inspect completed transport projects to ensure safety or compliance with applicable standards or regulations, including environmental regulations. • Develop plans to deconstruct damaged or obsolete roadways / transport structures in a manner that is environmentally sound or prepares the land for sustainable development.
New and Emerging Green	Sustainability specialists	Address organisational sustainability issues, such as waste management, green building practices and green procurement plans.	• Assess or propose sustainability initiatives, considering factors such as cost effectiveness, technical feasibility, and acceptance. • Create marketing or outreach media to communicate sustainability issues, procedures, or objectives.

*Source: O*NET Green Task Development Project (2010).*

Appendix B

Appendix Table B1: ISCO 3-digit Occupations with a Positive Share of Green Employment

ISCO 3-digit code	Green Occupations - Causa et al., 2024, methodology
111	Legislators and senior government officials
112	Managing Directors and Chief Executives
121	Business Services and Administration Managers
122	Sales, Marketing and Development Managers
132	Manufacturing, Mining, Construction and Distribution Managers
134	Professional Services Managers
143	Other Services Managers
211	Physical and Earth Science Professionals
213	Life Science Professionals
214	Engineering Professionals (excluding Electro-technology)
215	Electro-technology Engineers
216	Architects, Planners, Surveyors and Designers
235	Other Teaching Professionals
241	Finance Professionals
242	Administration Professionals
243	Sales, Marketing and Public Relations Professionals
251	Software and Applications Developers and Analysts
252	Database and Network Professionals
263	Social and Religious Professionals
264	Authors, Journalists and Linguists
311	Physical and Engineering Science Technicians
313	Process Control Technicians
314	Life Science Technicians and Related Associate Professionals
315	Ship and Aircraft Controllers and Technicians
325	Other Health Associate Professionals
332	Sales and Purchasing Agents and Brokers
333	Business Services Agents
335	Government Regulatory Associate Professionals
352	Telecommunications and Broadcasting Technicians
711	Building Frame and Related Trades Workers
712	Building Finishers and Related Trades Workers
721	Sheet and Structural Metal Workers, Moulders and Welders, and Related Workers
723	Machinery Mechanics and Repairers
741	Electrical Equipment Installers and Repairers
811	Mining and Mineral Processing Plant Operators
821	Assemblers
931	Mining and Construction Labourers
932	Manufacturing Labourers

961	Refuse Workers
962	Other Elementary Workers

Source: Causa et al., 2024.

Note: not the full ISCO 3 category is green, but green scores have been applied.

Appendix Table B2: ISCO 4-digit Brown Occupations

ISCO 4-digit code	**Brown Occupations - Causa et al., 2024, methodology**
1311	Agricultural and forestry production managers
1322	Mining managers
3131	Power production plant operators
3152	Ships' deck officers and pilots
5112	Transport conductors
6121	Livestock and dairy producers
7211	Metal moulders and coremakers
7221	Blacksmiths, hammersmiths and forging press workers
7314	Potters and related workers
8111	Miners and quarriers
8113	Well drillers and borers and related workers
8114	Cement, stone and other mineral products machine operators
8121	Metal processing plant operators
8181	Glass and ceramics plant operators
8182	Steam engine and boiler operators
8311	Locomotive engine drivers
8312	Railway brake, signal and switch operators
8322	Car, taxi and van drivers
8331	Bus and tram drivers
8332	Heavy truck and lorry drivers
8341	Mobile farm and forestry plant operators
8350	Ships' deck crews and related workers
9213	Mixed crop and livestock farm labourers
ISCO 4-digit code	**Additional Brown Occupations when Including Agricultural Occupations- ESRI methodology**
3142	Agricultural Technicians
6122	Poultry Producers
6130	Mixed Crop and Animal Producers
6320	Subsistence Livestock Farmers
6330	Subsistence Mixed Crop and Livestock Farmers
9212	Livestock Farm Labourers

Source: Causa et al., 2024; authors' elaboration.

Appendix Table B3: highly polluting NACE sectors for Ireland.

A01	Crop and animal production, hunting and related service activities
A03	Fishing and aquaculture
B	Mining and quarrying
C19	Manufacture of coke and refined petroleum products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
D	Electricity, gas; steam and air conditioning supply
H49	Land transport and transport via pipelines
H50	Water transport

Source: Causa et al., 2024