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THE GREEN TRANSITION AND THE ITALIAN LABOUR MARKET

by Gaetano Basso*, Fabrizio Colonna*, Domenico Depalo* and Graziella Mendicino**

Abstract

The paper discusses the role of labour in the transition to a net zero economy and provides an analysis for Italy over the period 2011-2021. First, we observe that the emissions generated from production activities declined over this period. We estimate that the contribution of employment reallocation across sectors was modest, while that of sectoral efficiency – particularly the shift in the energy mix towards cleaner sources – was decisive. Second, we show that the share of employment in the environmental goods and services sector was small in 2020 and has remained broadly stable since 2014. Our results suggest that, so far, labour has not played a prominent role in the green transition. However, this trend could change in the near future, as CO2 emission reduction targets take on an increasingly key role in production activities.

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1. Introduction*

The transition towards a sustainable economy to contain, and possibly revert, climate change and environmental degradation is on top of the policy markers' agenda. This paper provides an overarching overview of the implications of the green transition for labour input and then focus on the trends observed in Italy and in the other main euro area economies in the period 2011-2021.

Defining the green economy, the transition to it and characterizing the role of labour poses theoretical and empirical challenges. These phenomena are on-going and multifaceted, while data on these topics are lacking. According to the ILO's definition (ILO, 2018), in a green economy "the capacity to satisfy tomorrow's needs is not limited by today's resource use, emissions and waste." Central to the transition is the abatement of greenhouse gas (GHG) emissions, as stated by the 1992 UN Convention on Climate Change (UN, 1992): "[t]he ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve […] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The reduction of GHG emissions is also the main goal of the European Green Deal.[1] Coherent with the policy goal, the focus of the paper is on climate-altering emissions.[2]

The existing literature on the role of labour as a factor of production largely focused on providing a definition of "green" jobs. However, an agreement on a unique and yet comprehensive definition has not been reached so far. For instance, the ILO defines "green jobs" 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" (ILO 2016).[3] Such definition, however, does not distinguish the process of reducing emissions during production activities from that of the production of environmental goods and services. Both aspects imply direct and indirect effects on the labour market that can be hardly captured by a unique definition of "green" job. Owing to the complexity of the phenomenon, we do not provide a single reading framework, but we focus on the most relevant aspects, separately one from the other.

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[1] European Commission, The European Green Deal, COM(2019) 640 final, Brussels, 2019.

[2] The containment of the earth's temperature rise as defined by the agreement at the 21st Conference of the Parties (COP21) in Paris in 2015 and the United Nations' 2030 Agenda for Sustainable Development is, more generally, accompanied by a lower use of primary natural resources and a reduction in air pollution. Also because of the lack of data on many of these aspects, we leave these complementary aspects of the transition towards a greener economy for future research.

[3] The ILO stresses also the role of jobs decency and social equity during the transition towards a green economy. Although monitoring such aspects is extremely important to ensure a more equitable growth, it goes beyond the scope of this paper.

More specifically, we first look at the reduction of GHG emissions directly deriving from production activities. We use decomposition techniques to assess how much of the change in emissions is attributable to employment reallocation across sectors and how much to sectoral efficiency, i.e., the reduction of the production process' carbon footprint (IMF, 2022). We dig deeper into sectoral efficiency, by analysing the contribution of various inputs: the labour factor and its composition, other environmental goods and services, and emissions from energy production. Second, focusing on the production of air and climate-protecting goods and services, we exploit data from Environmental goods and services accounts of the National Statistical Institute (ISTAT), to provide a snapshot of environmental goods and services produced in Italy and what sectors and occupations are more involved. Finally, we provide a discussion of what are the possible next steps of the green transition and the implication for the labour market. In particular, we will focus on the investments in projects that aim at abating emissions as planned by the Italian National Recovery and Resilience Plan (NRRP) and provide a quantification of the labour demand activated by these policy actions.

We find that most of the reduction in GHG emissions that occurred in the period 2011-2021 – down from 18 to 15 tonnes of CO_2-equivalent per full-time worker – was due to increased efficiency within sector rather than to employment reallocation away from high-emitting sectors. In particular, the use of a greener input mix in energy production is associated to a reduction of emissions, consistently across empirical specifications. On the contrary, the contribution of labour has not been significant, possibly due to very limited changes in the occupational composition towards jobs more involved in greener production processes. Regarding the production of environmental goods and services explicitly aimed at reducing emissions, we find that the employment share in these activities was below 2 per cent in 2020, only slightly higher than in 2014. We further find that both aspects of the transition towards a zero GHG emission economy are associated to reallocation of jobs towards high-skilled occupations, mainly related to science and engineering – more than in the rest of the economy.

The paper is organized as follows. In Section 2, we present the conceptual framework that links labour as a factor of production to the transition to a zero emissions economy. In Section 3, we focus on the evolution of GHG emissions in Italy and in the other main euro area economies. First, we describe the data used and present the main descriptive statistics. Second, we run two statistical exercises to disentangle the main determinants of the reduction of emissions and provide additional statistics on the evolution of the occupational composition associated to the transition. In Section 4, we describe the environmental goods and services sector in Italy and in the other main euro area economies. In Section 5, we document the interventions included in the Italian NRRP and provide estimates of their effects on labour demand. Section 6 concludes.

2. The various aspects of green transition and the role of labour

The contribution of labour to reducing GHG emissions, and more broadly to the transition to a green economy, is essentially twofold. First, the adoption of more efficient and less carbon-intensive technologies could foster or depress the demand of specific jobs or tasks. Second, labour (and other inputs) can be reallocated to the production of environmental goods and services that directly support the transition towards a sustainable economy. The first channel, called "process (or bottom-up) approach", requires identifying the contribution of each input to the variation in GHG emissions in a given process. The second, called "output (or top-down) approach", aims to estimate the contribution of different sectors and factors of production to the environmental goods and services sector (EGSS).

Quantifying the labour contribution to each channel requires taking into account that they are distinct and complementary. Once the labour contribution to each of the two channels has been characterised, they should not be added together to avoid double counting: in fact, an input to the reduction of GHG emissions can be an EGSS output (Vona, 2021).

In order to provide a complete picture of the phenomenon, the first part of this section describes the process approach, while the second part describes the output approach. In the last subsection, we digress briefly to describe the task-based approach which – as an alternative to the two previous approaches – aims to provide a unique definition of green jobs. Although we highlight the limitations of such an approach, we will use it to some extent to characterize the labour contribution to the process-side of the green transition.

2.1 The process-side: reducing emissions

The reduction of GHG emissions during the production process can be obtained using low-emitting inputs, adopting environmentally friendly production processes, and adapting existing processes to technologies that produce fewer GHG emissions.[4] These channels can be divided into four main categories, which we group according to whether they relate to labour or other inputs:

- Labour-related:
  - A shift in employment towards jobs whose tasks are strictly related to a greener process and that are new with respect to the tasks of the baseline jobs (i.e. new emerging jobs);

[4] In this Section and in the rest of the paper, we refer to the so-called Scope 1 emissions according to the definition of the United States Environmental Protection Agency – i.e., those derived from sources that an organisation (a firm or sector in our context) owns or controls.

- A shift towards jobs where the tasks are unchanged, but the green subset is core to the job, or where demand increases due to complementarity with other low/zero emission inputs (i.e. green task enhancing).
- Related to other inputs:
  - The use of more emission-efficient technologies and more sustainable intermediates – including EGSS products (i.e. greener intermediates);
  - The use of more sustainable energy sources, including renewables (i.e. low-emission energy mix).

Unfortunately, the measurement of all these channels and their correlation with the change in GHG emissions at the micro level is severely limited by the lack of specific data designed for this purpose (see Appendix A for more details). Indeed, the only data currently available on GHG emissions are only at sectoral level. More information is instead available on the energy sources input-mix and the related GHG emissions, which records the full flows of energy products, from inputs to use and the resulting emissions.

Despite these limitations, the available data allow us to analyse the GHG emissions that derive from the production process (Section 3) and to disentangle the main determinants at sectoral level (Section 4).

2.2 The production-side: environmental goods and services

The green transition also requires the creation of goods and services designed to be cleaner and more resource-efficient than conventional products, reducing environmental pressures, and helping maintaining the stock of natural resources. Notable examples are electric cars, bicycles, solar panels, but also various management practices related to energy efficiency. Products international classifications and definitions – more common for the manufacturing than for the service sector – are the cornerstone of the analysis of the EGSS sectors. Labour contributes to the production side of the transition by being an input of these activities.

The most important data framework for these analyses is the UN System of Environmental-Economic Accounting Central Framework (SEEA, 2012; OECD, 2023) that lead to the production of EGSS accounts in Europe (Eurostat, 2016).[5] These, also known as ecoindustries accounts, measure output,

[5] EGSS accounts are an integral part of the European System of National Accounts, allowing for cross-country comparisons. Eurostat ensures comparability of EGSS statistics.

value added, exports and employment related to the supply of environmental products and services for the market sector (own-account environmental good and services activities, i.e. those used in the own production process, have been included only recently in the EGSS accounts).[6] The activities are divided according to two main environmental purposes: environmental protection activities, whose international classification adopted by Eurostat is CEPA, and natural resource management activities (CReMA).

Even within this framework, the characterisation of the labour contribution has some limitations, mainly related to the absence of micro-data on the production process. Data are only available in an aggregated form at the sectoral level and based on rather coarse assumptions. In particular, as highlighted in Vona (2021), these data allow estimating employment indirectly from the amount of EGSS value added. These estimates imply that all the jobs involved in environmental activities are direct contributors to the process. For instance, in the case of solar panels, the administrative staff contributes to the creation of this specific EGSS good as much as the engineer who designed it and the metalworker who assembled it. Thus, deducing the share of "green jobs" in a sector from the share of green products of that same sector requires a proportionality assumption between the two definitions that cannot be tested in the data (further details are given in Appendix A). Furthermore, the actual GHG emissions of the production process are not taken into account because the scope of the indicator is only the measurement of the production of environmental goods and services.

Because of these data limitations and aggregation, the literature has largely overlooked EGSS accounts data. Nevertheless, as highlighted by Vona (2021), to understand the structural transformations associated with the green transition it is important to study also the dynamics of output in environmental goods and services on top of analysing the emissions reduction process. Therefore, the EGSS data can provide an important contribution to the full understanding of job creation and this is what we aim to do in the rest of the paper.

2.3. Task-based approach: an attempt to define jobs as green

The literature that measures the labour contribution to the green transition is consolidating around the use of information on occupational tasks, a long-established approach in labour economics originally designed to study the impact of information and communication technology, digitalization and automation on employment (Autor, Levy and Murnane, 2003; Acemoglu and Autor, 2011). The idea

[6] At the time of publication of this note, the data on own account activities have a limited time span, 2018-2020.

is to represent the production function as a set of complementary tasks, relying on the information contained in O*NET.[7] In the case of the green transition, O*NET has been developing since 2009 a module ("Green Economy Program", GEP) to assess the impact of certain tasks (i.e., "green tasks") that have the potential to contribute to the green transition. Based on this type of tasks, O*NET's GEP distinguishes green occupations that are new (defined as Green New and Emerging), those that require new skill (Green Enhanced Skills), and those that will be in increasing demand (Green Increased Demand; Dierdorff, 2019; Dierdorff, 2011).[8]

Although widespread (IMF, 2022), the task-approach has several limitations (Vona et al., 2018; Verdolini and Vona, 2022; Vona, 2021). From a theoretical point of view, the scope of this methodology is not clearly defined. The definition of green transition is unspecified and could be inspired by either a process perspective – i.e., fewer emission and pollution in the production process, which itself can be represented as a set of complementary activities – or, alternatively, by proxing for the production of environmental goods and services (i.e., an output approach). From a more technical standpoint, three aspects are worth emphasizing. First, the O*NET classification is time-invariant: the definition of green tasks was developed in 2009 and it is subject to periodic additions; however, the structuring of the database does not allow keeping track of the evolution over time of the occupations under the three categories. Second, it gives equal weight to each task. Third, and more important, such classification does not capture the job destruction aspect of the transition, as there is no task-based definition of polluting jobs.[9]

Given these limitations, we prefer to provide an overview of the green transition based on the process and output approaches described above. In the analyses, we will only use the share of green occupations derived from O*NET as proxies for new emerging, green task enhancing jobs and green increased

[7] The Occupational Information Network (O*NET) is developed under the sponsorship of the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA). It contains hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy.

[8] Green New and Emerging (GNE) are new jobs that did not exist before, directly engaged in promoting the spread of green technologies and practices (which should capture a green transition-induced direct effect on labour), such as, for example, engineers who develop solar panels, waste recycling coordinators, mechatronics engineer, environmental economists. Green Enhanced Skills (GES) are existing jobs that will experience an evolution in the skills/tasks required, such as urban planners, construction workers or refuse workers (a second source of a direct effect on labour). Green Increased Demand (GID) are existing jobs that will be in greater demand because of the green transition but will not require new skills/tasks (a source of indirect effect on the labour market). This group contains occupations with very general application, such as software developers, customer service clerks, chemical plant operators, hydrologists, zoologists, botanists, bus drivers.

[9] The application of the O*NET methodology to the Italian context entails further challenges, which are largely common to the literature that analyses job tasks. First, this classification is US-specific, so applying it to Italy, or more generally to European countries, implies relevant assumptions, such as the hypothesis that the relationship with available technology is the same across countries. Second, it is based on the American Standard Occupational Classification (SOC) system characterised by a large level of detail and the linkage with the International Standard Classification of Occupations (ISCO) adopted in Europe implies a high degree of approximation.

demand jobs in a very parsimonious way, to characterise the labour contribution to GHG emissions abatement (see Section 3.1).

3. Empirical evidence on Italian green transition and the role of labour

3.1. GHG emissions: data and summary statistics

The data source of our analysis on GHG emissions is the Atmospheric Emission Accounts (AEA) compiled by Eurostat in compliance with the principles and standards of the National Accounts (as defined by the European System of National Accounts). The data are obtained by the merge of different sources, including the national emission inventory available for every year (Ispra, 2022), and emission intensity of production, value added, and employment. The AEA data have two important advantages over other data sources. First, they are suitable for integrated environmental-economic analyses being part of the National Accounts (Istat, 2022). Second, they can be compared across different EU countries.

Notwithstanding the advantages of these data in terms of coverage and comparability, we are aware of an important limitation: the information is available at a high level of aggregation, both sectoral and territorial. Therefore, even though we can draw conclusions on the overall economy, we are unable to dig deeper into some relevant dimensions at job, firm or fine sectoral level. The data are currently available for all economic activities at an aggregate sector level (one-digit NACE rev. 2) up until 2021; disaggregated data (two-digit NACE rev. 2 sectors) are available only up to 2020.[10]

The indicator we use in the rest of the analysis is the emission of greenhouse gas, in carbon dioxide (CO_2)-equivalent tonnes, that is composed of CO_2, nitrous oxide (N_2O), methane (CH_4), chlorinated and fluorinated hydrocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluorides (SF_6), and nitrogen trifluoride ($NF3_3$).[11] To compare emissions across countries, sectors and over time, we divide the normalized GHG by full-time full-year equivalent (FTE) workers. The latter is defined as total hours worked divided by the number of weekly hours of a full-time worker, available in the national accounts.[12]

[10] We start in 2011, rather than 2008 (the first year the data are available), because the definition of occupations used in the rest of the analysis has a structural break in 2011.
[11] In the rest of the paper, the abbreviation CO_2 refers to carbon dioxide-equivalent gases even if not specified.
[12] Results are robust if we measure intensity over value added rather than over FTE. It follows that the findings do not depend on the different economic activity trends across countries.

Figure 1 shows the amount of GHG emissions per FTE worker in the four major euro area economies, Germany, France, Spain and Italy, in 2011 and 2021.[13] Two aspects are worth emphasizing. First, in both years, emissions in Germany are higher than in the other countries. In Italy, Spain, and France, the emission levels are quite similar despite Italy has a sector composition relatively more tilted to manufacturing. Second, emissions decline in all four countries by a comparable amount in relative terms: in Germany, the reduction is of almost 6 tonnes of CO_2 per FTE worker, while in Italy, Spain and France is about 3 tonnes.

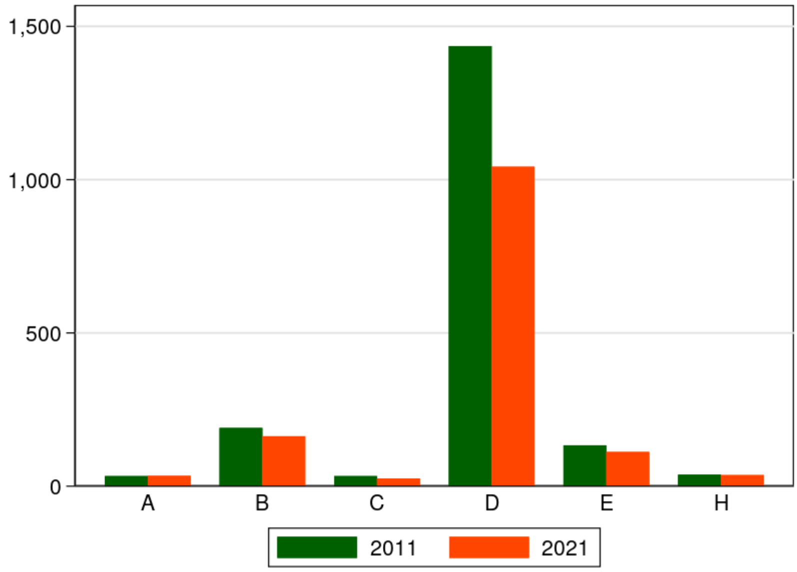
Figure 1. GHG emissions in the four main euro area economies, 2011-2021
(tonnes of CO_2–equivalent per FTE)

Notes: based on Eurostat's Environmental physical accounts – Air Emissions Accounts (AEA).

Focusing on Italy, Figure 2 shows the main six sectors by GHG emissions per FTE in 2011 and 2021. The ranking of the sectors is constant over time, with the energy production industry (NACE rev. 2 code D) being the one with the highest level of emission intensity (at about 1,000 tonnes of CO_2 per worker in 2021). Over the last decade, the energy production sector also experienced the largest reduction in emissions, by almost one third. Improvements were observed in almost all main emitting sectors: manufacturing (C), water and waste management (E) and mining and quarrying (B). The same qualitative considerations apply to the other EU countries in Figure 1.

[13] These economies represent jointly more than 70 per cent of the euro area GDP.

Figure 2. GHG emissions in the most emitting sectors in Italy, 2011-2021
(tonnes of CO_2-equivalent per FTE)



Notes: based on Istat's Environmental physical accounts – Air Emissions Accounts (AEA). The graph shows the six sectors who contribute the most to GHG emissions in Italy. The sectors are classified by NACE rev. 2 at one-digit level, as follows: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage; waste management and remediation activities; H - Transporting and storage.

3.2. A statistical decomposition of the GHG emission variation in Italy, 2011-2021

The descriptive statistics in Section 3.1 show an aggregate reduction in emissions per FTE worker. We thus implement a shift-share analysis to quantify and describe the role of the labour factor for the reduction of total emissions. Following the IMF World Economic Outlook (IMF, 2022), we decompose the variation in CO_2 emissions per FTE worker into two pieces:

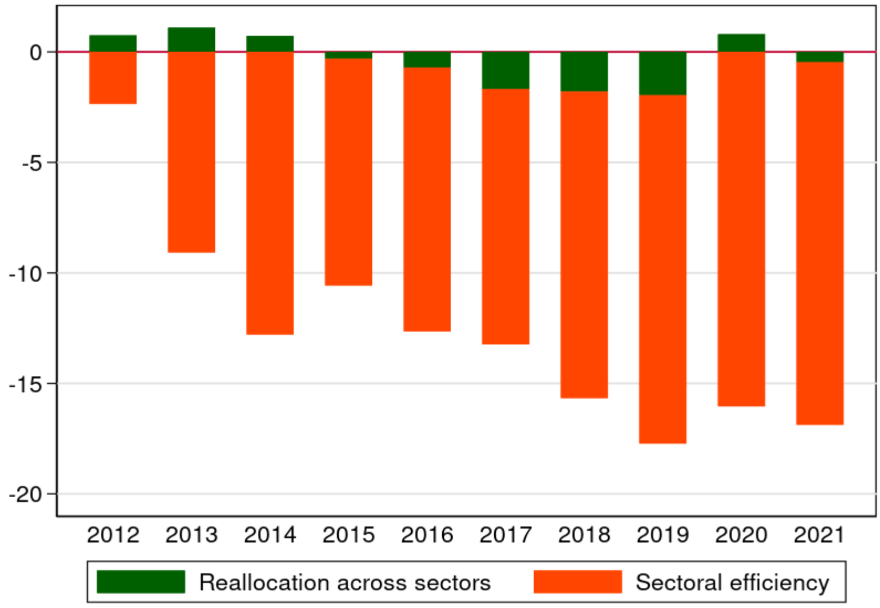
$$\Delta\left(\frac{E_t}{L_t}\right) = \frac{E_t}{L_t} - \frac{E_{t-1}}{L_{t-1}} = \underbrace{\sum_s \Delta\left(\frac{L_{st}}{L_t}\right) \cdot \frac{E_{st}}{L_{st}}}_{Labour\ reall.} + \underbrace{\sum_s \Delta\left(\frac{E_{st}}{L_{st}}\right) \cdot \frac{L_{st-1}}{L_{t-1}}}_{sectoral\ eff.} \tag{1}$$

where E_t refers to the amount of total emission and L_t to the number of workers; subscript *s* uniquely identifies a sector. The overall variation in emission intensity is the sum of two components: 1) the "labour reallocation" across sectors, i.e., the change in employment shares $\Delta\left(\frac{L_{st}}{L_t}\right)$, fixing the emissions per worker $\frac{E_{st}}{L_{st}}$ at period *t*; 2) the "sectoral efficiency" in emissions, i.e., the variation in the emission intensity, fixing the sectoral composition of workers at period *t*. The cumulated percentage variation in CO_2-equivalent emissions per FTE worker between 2011 and 2021 is about 17 per cent (Figure 3).

From the shift-share analysis, two main results follow. First, the contribution towards a lower emission intensity of both the sectoral efficiency and the labour reallocation improved over time, as shown by the increasingly negative values of the green and orange bars. However, the contribution of the sectoral reallocation was partly reversed in 2020 due to changes in the employment composition that followed the pandemic. Second, the relevance of sectoral efficiency is much larger than that of labour reallocation. The contribution of the former component increased between the beginning and the end of the period, reaching a peak in 2019, just before the Covid-19 pandemic.[14] This pattern is common to that of Germany and a sample of advanced economies over the period 2005-2015 (IMF, 2022), but different from that of France and Spain, where labour reallocation is more relevant than sectoral efficiency (Figure A2 in Appendix A).

Figure 3. Labour reallocation and sectoral efficiency contributions to the variation in GHG emissions

(cumulative percentage change in tonnes of CO_2-equivalent/FTE with respect to 2011)



Notes: based on Istat's Environmental physical accounts – Air Emissions Accounts (AEA). The statistical decomposition of the emission intensity relative to the 2011 level reported in the graph is described in equation (1).

In what fallows, we characterize the sectors that contributed the most through each channel and how the occupations composition changed over time. We can further disentangle the main inputs of the efficiency component and quantify the role of the green labour factor.

[14] Reallocation across sectors even contributed against the reduction in GHG emissions in 2020 due to the temporary shift of relative production towards manufacturing and energy production away from low-emission intensive service sector. However, such reallocation episode seems temporary, as the contribution of reallocation to a reduction in GHG emissions intensity was again positive in 2021.

3.2.1. Labour reallocation across sectors

Labour reallocation contributes only slightly to a reduction of GHG emissions by lowering the employment share of high-emission sectors (i.e., the green bar of Figure 3), mainly through a destruction of jobs in air polluting industries. In Figure 4, we show the employment and occupational composition changes in sectors that contributed the most to the labour reallocation. In 2019 – the year of the largest contribution of this component before the pandemic changes in overall sectoral composition – the sectors that contributed the most in terms of labour reallocation were mining and quarrying, some manufacturing sectors (glass, iron and steel and wood production), electricity supply, construction, public administration and some service sectors (wholesale and retail trade, air transportation).[15] Panel (a) shows that these sectors lost almost 800,000 workers, mostly among the medium-skilled. Panel (b) shows that most of the job destroyed were in construction and yet other sectors were negatively affected: the occupations that declined by about 50,000 units or more encompass several activities in the manufacturing sector – such as electrical workers, metalworkers, food process workers and drivers. It is interesting to notice that construction sector generates GHG emissions in the production process. If shrinking, under the process lens of the green transition, it contributes to the reduction of the emissions. However, as we will see in Section 5, it is also the third main contributor to the EGSS as it provides inputs to the energy efficiency of buildings, among other products and services. This example highlights the multi-layered aspects of the transition as a single sector can have different effects on the emissions, depending on the approach adopted.

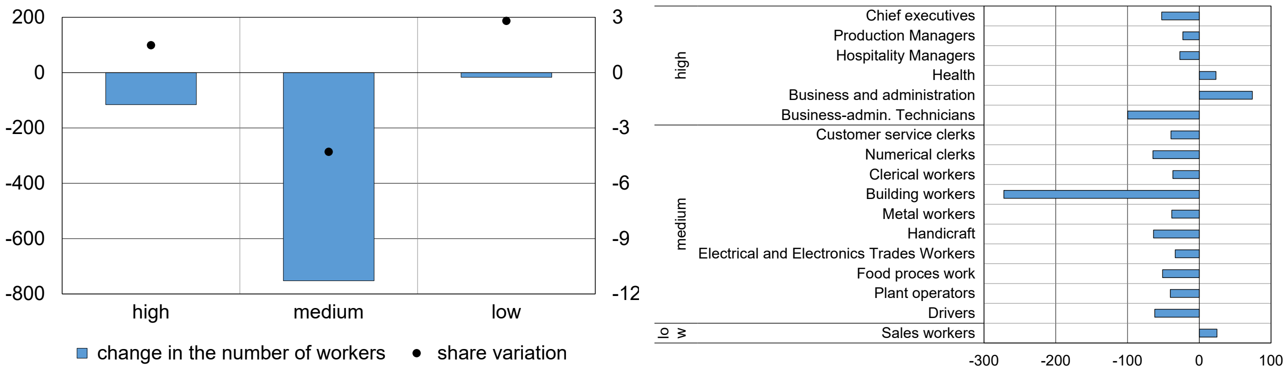
The automotive sector deserves a separate consideration. Although its production process is not among the highest-emitting ones, the sector needs to undergo a major transformation in order to limits CO_2 emissions by end users as road transport accounts indeed for 24 per cent of carbon dioxide emissions into the atmosphere (Orame and Pianeselli, 2023). Therefore, the sector has been adapting to reconvert the production process to the new technologies; the Italian companies are investing into the development of the workforce's skills needed for the transition to new automotive products (Orame and Pianeselli, 2023). According to our estimates, the sector was among those with the largest reduction of GHG emissions in the period 2011-2020 but it did not shrink: rather, employment increased quite steadily (except between 2019 and 2020).

[15] Detailed two-digit sectors are not available in 2021. For this and the following analysis, we thus use 2019 as the ending year to avoid confounding factors of the 2020 pandemic-led recession.

Figure 4. Employment composition in sectors contributing to the green transition through labour reallocation

(a) changes in employment by qualification
(thousands of persons and percentage points)

(b) changes in occupations
(thousands of persons)



Notes: based on Istat's Environmental physical accounts – Air Emissions Accounts (AEA) and Istat's Labour force survey for employment. The sectors analysed in this graph are those whose labour reallocation component positively contributed to a reduction in GHG emissions over the period 2011-19 (as depicted by the green bars in Figure 4). The most relevant sectors are: mining and quarrying, some manufacturing sectors (glass, iron and steel and wood production), electricity supply, construction, public administration and some two-digit sectors in services such as wholesale and retail trade, air transportation. Following the OECD Employment Outlook (2017), high-skill occupations include jobs classified under the ISCO-08 major groups 1, 2, and 3 (i.e., legislators, senior officials, and managers; professionals; technicians and associate professionals). Middle-skill occupations include jobs classified under the ISCO-08 major groups 4, 7, and 8 (i.e., clerks; craft and related trades workers; plant and machine operators and assemblers). Low-skill occupations include jobs classified under the ISCO-08 major groups 5 (service workers and shop and market sales workers) and 9 (elementary occupations). Panel (b) shows occupations that changed by at least 50,000 units.

3.2.2 The role of labour in sectoral efficiency

We characterize the second component of the shift-share analysis through the correlation between sectoral level change in emission intensity (i.e., the orange bar of Figure 3, labelled $\Delta\left(\frac{E_{st}}{L_{st}}\right)$) and its main determinants:

$$\Delta\left(\frac{E_{st}}{L_{st}}\right) = \Delta\, \mathrm{f}(\mathrm{X}_{\mathrm{st}}) + \varepsilon_{st} \qquad (2)$$

where $\mathrm{f}(\mathrm{X}_{\mathrm{st}})$ indicates the main potential channels that affect emission intensity; ε_{st} is an error term. In Section 2.1, we identified four potential channels: hiring people to make the processes green – which we proxy with both the change in the share of new emerging green jobs and of existing jobs for which demand has been increased, as measured by the O*NET variables (Section 2.3); a greater centrality of the green transition in the tasks performed by each worker involved in the production process – which we proxy with the change in the share of enhanced green task from O*NET (Section 2.3); buying more efficient technologies and more sustainable intermediates, including the products of "eco-industries" – which we proxy with air-protection EGSS investments, although only for industrial sectors (included only in Appendix A, Table A2); and adopting more sustainable energy sources – which we proxy with a measure of the potential emissions occurring from product use for energy production by industry, using the Eurostat Physical Energy Flow Accounts (PEFA).[16]

Table 1 reports the main results of such correlation for two periods of analyses, 2011-19 and 2011-20, in order to account separately for the role of the pandemic-related reallocation of 2020. It should be clear at the outset that the results between the two samples are different, but these differences are not a cause of concern, for reasons that we discuss below. Columns (1) and (4) include only controls for the changes in the share of green jobs as defined by O*NET; columns (2) and (5) add controls for the change in energy production and related emissions; column (3) and (6) are identical to columns (2) and (5), but exclude the energy production sector, the major contributor to GHG emissions. Although the sample size of these regressions is small, and therefore one should be wary to draw firm conclusions from them, we believe that two important results emerge. First, the labour factor per se does not correlates much with the sectoral variation in emission intensity. Indeed, the R-squared is close to zero in columns (1) and (4), thus suggesting a low explicative power of the model specification, and the estimated coefficients are very sensitive to the inclusion of additional variables (comparing columns 1 and 2, or columns 4 and 5), thus suggesting that omitted variable bias may be substantial.

Second, most relevant to the dynamic of emission intensity is the contribution of the energy production component at the sectoral level – i.e., the change in the mix of energy product over the period – which are positively correlated with the GHG emissions. In our estimates, 1,000 fewer tonnes of potential CO_2-equivalent emissions of energy production – slightly less than one percent of energy-related emissions in 2011 – would lead to about 0.01 decrease in tonnes of CO_2-equivalent emissions per FTE worker. The explanatory power of this variable is relevant as both the R-squared jump from zero to around 0.9. Moreover, the effects are robust to the exclusion of the energy production and distribution sector – the one with the highest emission intensity – signalling that this sector is not the only driver of the reduction in GHG emissions. This last exercise also shows that for sectors other than energy production and distribution, additional dimensions are useful to explain the variance. In additional analyses, we include the investments and self-production in air-protection goods and services as control variables (Table A2): the sign of the correlation is negative as expected and these variables increase

[16] More specifically, we calculate the potential CO_2-equivalent emissions of energy production for each energy input. To convert TJ of energy by input into CO_2-equivalent emissions, we use the default atmospheric emission factors for CO_2, CH_4 and N_2O elaborated by Intergovernmental Panel on Climate Change (IPCC) for its guidelines (IPCC, 2006) as reported by ISPRA in its annual report on electricity generation trends (ISPRA, 2020, Table 4.1, page 53). Notice that the CO_2-equivalent emissions of energy varies by energy product over time according to the quality of the energy production process. However, coherent to the aim of proxing for the energy-production input mix, we use a fixed amount of CO_2-equivalent emissions at the beginning of our period (as reported by ISPRA, 2020) and we abstract from energy-production technological innovations.

the amount of variation explained (even excluding the energy production sector).[17] This last result must be taken with great caution, however, because of the extremely small sample size underlying the correlations. Still, it is indicative of an important role played by EGSS investments and technology directly aimed at reducing GHG emissions.

It is worth discussing the differences in the results between the two samples periods, i.e. columns 1-3 referring to 2011-19 versus columns 4-6 referring to 2011-20, which are a direct consequence of the Covid-19 pandemic. To this aim, we ran two robustness checks. First, we successfully verified that the results are stable between 2011-18 and 2011-19, suggesting that the coefficients of columns 4-6 depends greatly on what happened between 2019 and 2020. Second, we use the sample 2011-20 controlling for a different set of covariates, e.g. the change in covariates between 2011-19 and their difference between 2019 and 2020, and we confirm all the conclusions presented above. Besides the sample period, we also checked the sensitivity of our results using alternative definition of green jobs: we tested the binary definition of green jobs from O*NET (Dierdorff, 2011) and the index of tasks' green intensity (Vona et al., 2018), confirming all the conclusions presented above (Table A3).

Yet, we emphasize that our results would benefit from more data. Additional information would allow us to better identify the potential channels that affect emission intensity, and shed more light on the interaction between sectors or occupations and emission intensity. We leave these improvements for future research if such data will become available. Finally, we do not control for potentially relevant factors that may affect the emission intensity, like the foreign trade, or input-output linkages. We do not add these controls because of the small sample size. Nevertheless, as we focus on Italy only and we verified that the results do not depend on specific sectors, we believe that the bias from the omitting these variables should be negligible. Again, as more data will be available over time, we will be able to test this hypothesis.

[17] The data on investments and self-production on air-protection goods and services come from the Eurostat Environmental protection expenditure accounts. We consider the investments and self-production most directly related to CO_2 emissions, i.e., those classified as air and climate protection-related and waste-management related. Unfortunately, this information is available only from 2014 onwards and only for the industry sector severely limiting the scope of this exercise.

Table 1. Determinants to changes in GHG emissions

	Δ tonnes of CO_2–equivalent emissions per FTE worker					
		2011-19			2011-2020	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ share of enhanced green	176.730	143.925	140.767	-732.174	-612.608	-619.954
skill occupations	(243.735)	(156.383)	(153.763)	(495.222)	(423.041)	(418.039)
Δ share of emerging green	-157.924	-165.745	-169.252	147.518	-217.583	-208.884
occupations	(359.489)	(366.182)	(367.228)	(603.350)	(308.604)	(302.043)
Δ share of enhanced	132.160	321.794	350.459	-554.849	-517.575	-484.227
demand green occupations	(371.241)	(235.208)	(269.760)	(497.801)	(359.301)	(391.600)
Δ CO_2-eq. potential emissions		0.008**	0.010*		0.005	0.009*
of energy product use (th. ton.)		(0.003)	(0.004)		(0.003)	(0.005)
Δ of energy production (th. tj)		0.196	0.082		0.574	0.337
		(0.326)	(0.134)		(0.339)	(0.193)
Constant	-8.065	-2.121	-2.027	-11.501	-2.830	-2.545
	(6.301)	(1.392)	(1.448)	(8.794)	(2.286)	(2.504)
R-squared	0.003	0.904	0.211	0.023	0.864	0.0386
Adjusted R-squared	-0.049	0.895	0.139	-0.027	0.852	-0.049
Sectors	All	All	No Energy	All	All	No Energy
Observations	62	62	61	62	62	61

Notes: The definition of enhanced green skill, emerging green, and enhanced green demand occupations follows Vona et al. (2018) and IMF (2022). CO_2-equivalent emissions per TJ of energy product use are obtained from Eurostat, Physical energy flow accounts (PEFA): conversion factors from TJ to CO_2 are obtained from ISPRA (2020, Table 4.1, page 53). Robust standard errors in parentheses. ** p<0.01, * p<0.05.

3.3 Characterization of the sectors that improved emission intensity due to better efficiency

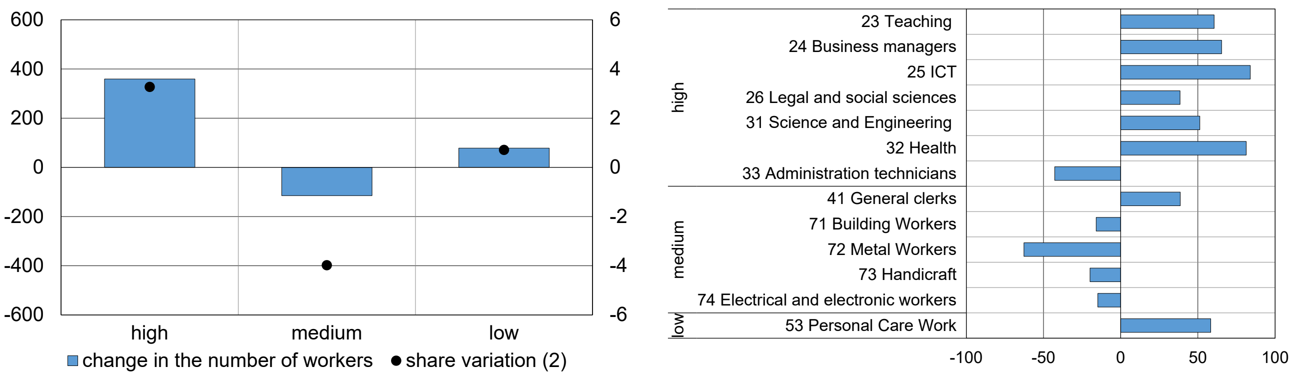
We classify the sectors that improved emission intensity based on the change in emissions between 2011 and 2020. As we did for the labour reallocation component, we define the most efficient sectors as those in the first third of the distribution. In these sectors, the sharp increase in the share of high-skilled occupations is compensated by the slight reduction of mid-qualification occupations (Figure 5, panel a). This change in the occupational composition is more pronounced than in the least efficient industrial sectors.

In term of occupations, we observe a reallocation within the most efficient sectors towards highly qualified jobs in STEM and ICT fields but also in legal and social sciences (Figure 5, panel b), which is slightly higher than in the rest of the economy. Jobs were destroyed mainly in medium-qualification occupations, such as craftsmen, clerks, and metalworkers – the latter suffering the largest drop. However, the destruction of medium-skilled occupations was not specific to the sectors that are more involved into the green transition but it emerged also in the least efficient sectors.

Figure 5. Employment composition within sector that have decreased GHG emissions

(a) changes in employment by qualification (1)
(thousands of persons and percentage points)

(b) changes in occupations
(thousands of persons)



Notes: calculations based on Istat's Labour force survey for employment and GHG emissions from the Atmospheric emission accounts (AEA). (1) Figure refers only to sectors whose GHG emission variation is included in the first third of the distribution and therefore to those in which GHG emissions have been reduced more between 2011-2020. – (2) Change in the share of employment between 2011 and 2020; right-hand scale.

4. The production side of the transition: Air-protection environmental goods and services

The analysis so far has highlighted the dynamic of emission intensity variation over the last decade and the different contribution of production factors. While this is an important aspect of the transition, the analysis of the emission reduction process neglects its mirror image, i.e. the production of environmental goods and services aimed at air and climate protection.

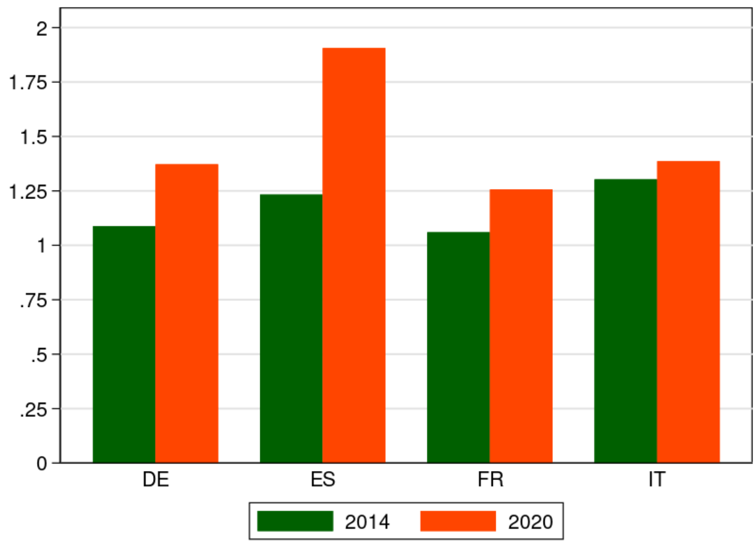
Notwithstanding the lack of microdata and the imputation of employment from value added (Section 2.2), the Environmental Goods and Services Sector Accounts (EGSS) compiled by Eurostat and Istat allow us to investigate the output approach at sectoral level. Consistent with the main policy target of a reduction of the GHG emissions, the analysis focuses only on business activities aimed at the production of environmental goods and services for air and climate protection, waste management and energy resource management.[18] Furthermore, we take into account only production intended to be sold on the market, for the available period (2014-2020).

Figure 6 shows that the share of employment involved in air-protection EGSS activities increased only slightly in the period considered in all four major euro area economies. The largest increase is in Spain (almost 0.7 percentage points). In Italy, the share was broadly constant increasing by about 0.1 percentage points: in 2020, the incidence of these activities was rather low, at 1.4 every 100 FTE workers. As of 2020, the difference between Italy and Spain – the leader among the four large euro area economies – is 0.5 percentage points and is completely due to a lower incidence of EGSS activities, holding constant the sectoral composition.

Focusing on Italy, the small increase in the EGSS employment share is mainly attributable to an expansion of the water supply and waste management sectoral employment (NACE rev. 2 code E) – despite a mild drop in the share of EGSS activities within that sector (Figure 7) – and to both a growth of the professional services sector and its within-share EGSS activities (M). Minor contribution also came from the manufacturing (C) and construction (F) sectors..[19]

Figure 6. Share of FTE employment in air-protection EGSS activities in the four main euro area economies, 2014-2020

(percentage points)

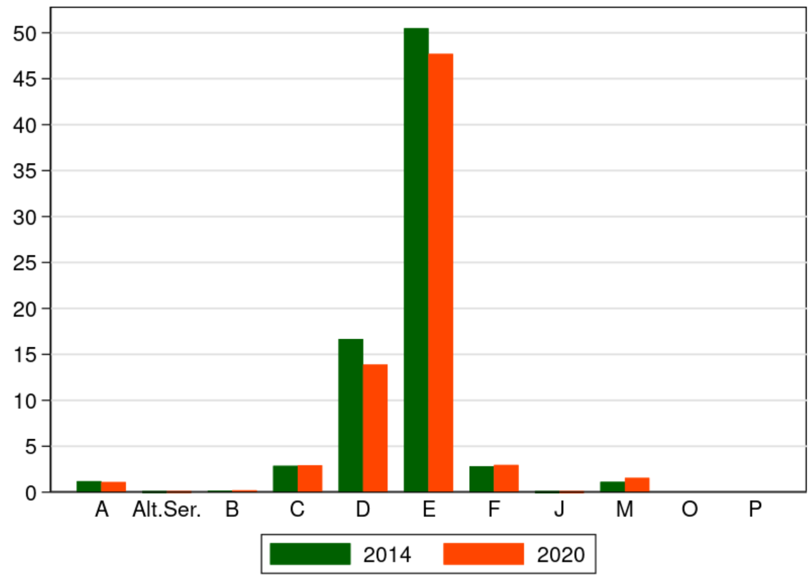


Notes: based on Eurostat's Environmental goods and services sector accounts (EGSS).

[18] The three categories herein considered correspond to the Eurostat European environmental economic accounts Classification of Environmental Protection Activities Expenditure (CEPA) groups 1 (air protection) and 3 (waste management) and the Classification of Resource Management Activities (CReMA) group 13 (energy resource management).

[19] The results are similar if we do the same exercise between 2014 and 2019 instead of 2020.

Figure 7. Share of employment in air-protection EGSS activities by sector in Italy, 2014-2020 *(percentage points)*



Notes: based on Eurostat's Environmental goods and services sector accounts (EGSS). Sectors are classified by NACE at one-digit level, as follows: A - Agriculture, forestry and fishing; B - Mining and quarrying; C – Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage; waste management and remediation activities; F – Construction; J - Information and communication; M - Professional, scientific and technical activities; O - Public administration and defence; compulsory social security; P – Education. Remaining sectors were aggregated in "other services".

Over the period 2014-2020, the small increase in the air-protection EGSS employment share is largely due to an increase in the incidence of EGSS employment across different sectors (rather than to an increase in the employment share of EGSS-intensive sectors). Employment growth in the air-protection goods and services activities was associated with job creation in highly skilled occupations, the share of which increased by almost three percentage points (Figure 8, panel a). In contrast, the number of workers in medium-skilled jobs declined, while the number of low-skilled workers remained rather steady.

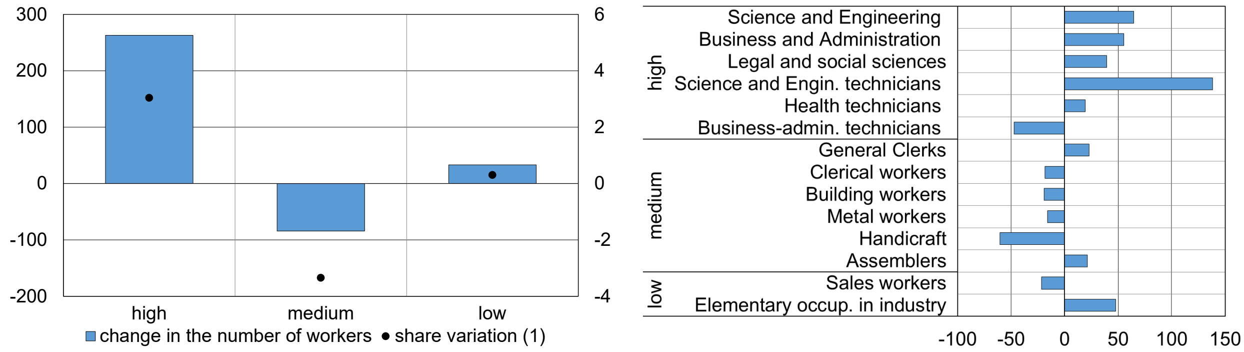
In terms of occupations (Figure 8, panel b), the increase in highly skilled occupations was primarily due to science and engineering professionals and technicians and, to a lesser extent, to managerial profiles related to social sciences and business administration. Among the lowest-skilled occupations, net job creation has been concentrated in elementary occupation in industry. On the other hand, the reduction in medium-skilled employment was largely concentrated among handcraft.

For the shorter period 2018-2020, Istat also provides data on the non-market activities contribution (i.e., that related to own final consumption of environmental goods and services by enterprises, institutions or households). This component contributes by about 25 per cent to the overall EGSS employment share: it is concentrated in the public administration sector and it increased by 0.62 percentage points between 2018 and 2020).

Figure 8. Employment composition within sectors with increased output of EGSS

(a) changes in employment by qualification
(thousands of persons and percentage points)

(b) changes in occupations
(thousands of persons)



Notes: based on Istat's Labour force survey for employment and Eurostat's Environmental goods and services sector accounts (EGSS). The analysis compares the employment figures for the years 2011 and 2019. The sector of interest, which contributed the most to the increase in air-protection EGSS employment, are waste management (NACE E), professional services (NACE M) and manufacturing (NACE C). – (1) Right-hand scale.

Instead, according to patent data, which complement the information provided by national accounts, the level of specialisation in green technologies in Italy is higher than in other European countries – despite an overall negative trend in patent production since 2008. The production of patents related to green technologies is concentrated in innovations aimed at mitigating the effects of climate change related to the transport sector and reducing greenhouse gas emissions in the energy sector (De Luca, Greco and Lotti, 2021). Unfortunately, there is no empirical evidence on the job creation effects of such patent activities so far.

5. Some considerations on the future of green transition and the role of the NRRP

Looking to the future of the green transition, all of the above channels will need to be active – and possibly strengthened – to achieve the goal of zero emissions by 2050. First, high-emitting sectors will undergo structural change. This is likely to lead to a further decline in their share of employment, the destruction of some jobs and changes in the tasks required in many occupations. In addition, changes in the energy mix in favour of cleaner energy sources, investments in energy efficiency and emission-reducing products and services will be accompanied by job creation and changes in the composition of tasks. Unfortunately, all these channels are difficult to quantify and characterise at this stage. However, the public investment component of them can be approximated by looking at existing economic policies aimed at bolstering the green transition contained in the Italian NRRP.

The Italian NRRP will play a key role in driving the transition in the short term. The Plan allocates almost 72 billion euro to environmental sustainability (37.5 per cent of the total, according to European Commission estimates) to be spent in the period 2021-26; most of these resources are provided through the Recovery and resilience facility (RRF), the main tool of the Next Generation EU program.[20] The set of relevant interventions is quite diverse, but it aims at a direct reduction of carbon dioxide emissions through investments in cleaner energy production (Mission 2 Component 2 "Renewable energy, hydrogen, sustainable mobility and network") and improving energy efficiency (Mission 2 Component 3 "Energy efficiency and building modernisation") as well as intervention for more sustainable modes of transportations.[21] However, the future discounted benefits in terms of emission reductions could be high relative to the investment costs according to recent estimates based on the social cost of carbon (Alpino et al., 2022). The least cost-effective measure is the generous tax credit for improving the energy efficiency of private buildings and similar measures planned for public buildings. On the other hand, investments to promote innovative renewable energy sources are estimated to be particularly cost-effective.

Following the methodology of Basso et al. (2023), we quantify the occupation generated by the green interventions of the NRRP focusing on those not already planned before the Plan approval. Through a static input-output model, we estimate the amount of employment generated based on (i) the provisional expenditure of each policy action by sector of final use and (ii) the value added-to-employment ratio of each sector as of 2019, before the pandemic. Accounting for the inter-sectoral linkages, the estimates provide a figure of the GHG-emission abatement-related employment generated by the Plan. We provide two scenarios: a conservative one, which includes only the main interventions for which the Plan report the expected CO_2 emissions abatement (Appendix B), and a more general one, which includes all green measures as identified by the European Commission and that are most likely to contribute to emission abatement.[22]

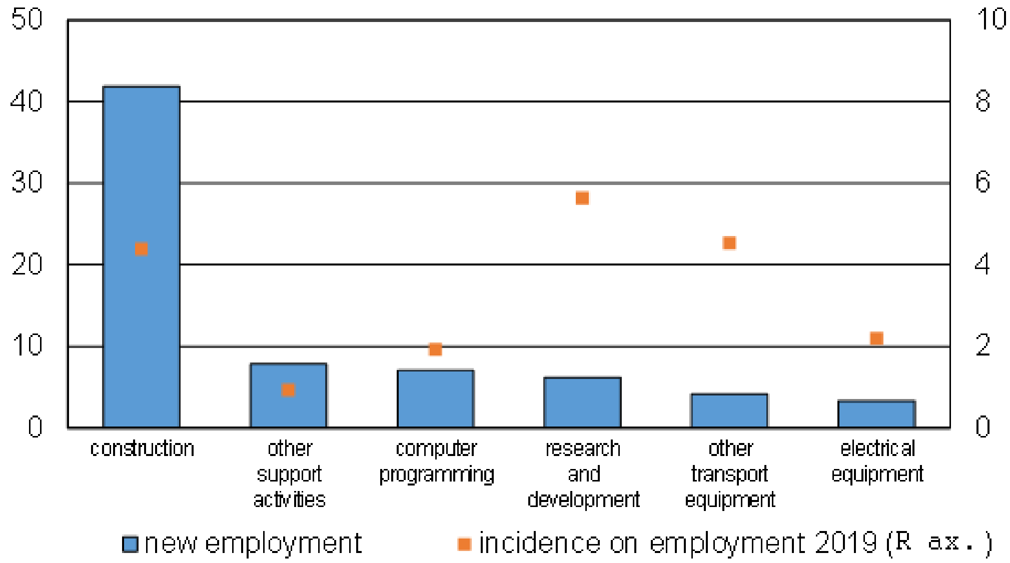
[20] The objectives of the Plan are in line with the objectives of the 2020 National Integrated Energy and Climate Plan (PNIEC). Additional resources, subject to less conditionality, are made available through the React-EU programme and the Italian Complementary National Fund.

[21] For a description of the main interventions, see Appendix B and Alpino et al. (2022).

[22] In particular, we include the interventions that were tagged as green by the European Commission in its evaluation of the Italian NRRP. These are included in Mission 2 Component 1, Mission 2 Component 2, Mission 2 Component 3, Mission 2 Component 4, Mission 3 Component 1 and Mission 4 Component 2 and their aim is that of reducing carbon dioxide emissions. We further include few minor interventions that are not in the European Commission list but involve the adoption

According to our estimates, the gross number of jobs created by all the green interventions of the NRRP amounts to approximately 122,000 units in the year of the highest expenditure (2025). If we consider only the interventions explicitly aimed at reducing CO_2 emissions, the number of gross jobs created would be around 51,000. The construction sector, which includes both civil engineering and specialty engineering, would experience the highest increase in green employment in absolute terms, averaging about 4 percent of the sector's total employment level in 2019 (see Figure 9 and Table A5), about half of the total job creation associated with NRRP funds (Basso et al., 2023). In the other sectors, the increase in employment in green projects would be smaller in absolute terms. However, in two of these sectors, research and development and other transport equipment, the change is large in relative terms – about 5 per cent of the sectors' employment level in 2019. Overall, green-related employment growth will be rather concentrated in the most affected sectors.

Figure 9. Labour demand for green projects generated by NRP funds



Notes: based on ItaliaDomani data, Ragioneria Generale dello Stato and Istat, National Accounts. Only new projects tagged as green by the European Commission and financed through the entire PNRR funds are taken into account for the estimates. The figure shows the first six sectors by level of employment generated in the peak year of green expenditure for each sector (2025), net of sectors with a predominant public component. "Other support activities" include supervisory activities, services for buildings and landscapes, administrative and support activities for offices and businesses. The incidence on 2019 employment is calculated by relating the new labour demand activated to total employment in 2019 in the relevant sector (right axis).

6. Conclusions

The transition towards a zero GHG emission economy is a very complex and multifaceted process that involves changes in the way goods and services are produced and generate itself new demand for

of renewable energy sources, especially in the agricultural sector. The estimates are run both considering only the RRF funds and the total resources allocated also through other programmes (React-EU and Complementary National Fund; see Table A5).

environmental products. In this paper we attempt to provide an overarching view of the transition and its implications for the labour market. First, we documented that in the last decade GHG emissions generated by economic activities decreased in all major euro area economies. In Italy, the role of sectoral reallocation – the decline in the employment share of high-emitting sectors – was very limited. Therefore, emissions were reduced without any clear impact on total employment in the sectors concerned. By contrast, sectoral efficiency has been the main driver of abatement and its contribution increased over the period: the key factor was the reduction in emissions created from energy production. We further show that the contribution of the labour factor to the increase in sectoral efficiency has been minimal in driving these changes so far. We then show that occupation in the air and climate-protection goods and services activities represents a small and constant share of the Italian economy since 2014. Both results are indicative of a limited involvement in the green transition so far.

Demand conditions, however, might change soon given the centrality of the emission reduction in the policy agenda at the national, European and global level. The Italian NRRP will likely boost labour demand in EGSS thanks to the large amount of resources devoted to the green transition. Estimates of the potential labour demand activated indicate between 51.000 and 122.000 additional jobs mostly concentrated in the construction and research and development sectors.

Richer data at firm and possibly occupational level, currently unavailable, will allow improving dramatically the depth of analysis and opening rooms for future research. Several topics could not be addressed with the data available so far. Among many others, the geographical distribution of GHG emission intensity and its abatement will affect local labour markets differently depending on their sectoral composition. The extent of workers' reallocation between occupations affected by sectoral reallocation and due to increased demand of EGSS will allow quantifying the worker-level gains and losses from the transition, even though the reduction in emissions does not appear to have yet any clear impact on total employment in the sectors concerned. Last, the interactions between employment dynamics and investments aimed at the green transition will provide estimates of labour-capital complementarities in achieving a zero emission economy. The literature, which pursued an endless journey toward a unique definition of "green" jobs so far, will necessarily expand across all these dimensions.

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Appendix A. Insights on data issues, additional tables and figures

Data issue

Process approach – The lack of information on the contribution of a specific occupation to the production of emissions is a serious limitation for green transition analyses. Economists often rely on alternative definitions based on tasks that can only proxy the labour contribution to the green transition process (see also Section 2.3 and the next section in this Appendix). However, even the jobs tasks data have no information on the direct involvement of workers into greener production processes nor on how tasks change over time (Vona et al., 2018; IMF, 2022; OECD, 2023). A recent strand of the literature extends the task approach by looking into the content of online vacancies and the demand of green skills (Saussay et al., 2022). This avenue is promising to analyse the content of newly created jobs, but does not allow describing the evolution of GHG emissions over time and the contribution of the labour.

The absence of data on the adoption of greener technologies and on environmental goods and services as intermediates further limit the analyses of the evolution of GHG emissions deriving from the production processes. Data on this aspect are usually available through surveys or product classifications (such as Eurostat's Community Innovation Survey and PRODCOM or the US Bureau of Labor Statistics' Green Good and Service Surveys). These surveys often cover only a limited number of firms or sectors, mainly in manufacturing.[23] Patents could also be used to study innovation in the field of green technologies (Gagliardi et al., 2016; De Luca et al., 2021), although they are less suited to analyse the use of such technologies because innovating firms may not be those using the innovation itself (Vona, 2021).

Overall, these data allow only an indirect link to the change in emissions, while do not measure the direct effect of environmental goods, services and processes on the climate-altering gases release.

Output approach – Quantifying the contribution of the labour factor to the production of environmental goods and services (EGSS) also has some limitations, mainly related to the absence of micro-data on the production process. In addition to those mentioned in Section 2.2, EGSS includes all producers who engage in environmental activities without considering that they may also be engaged in other non-green ones. Ideally, secondary activities should be separated but this is not possible in practice given the limited data granularity (OECD, 2023). The estimates are in fact only conducted on aggregated sector level data (one-digit NACE rev. 2 classification). Furthermore, this approach does not take into account that the same product can have different usages and thus different environmental impacts. Finally, at least other three limitations can be identified: (a) any differences in the levels of labour intensity between green and non-green productions are not taken into account; (b) it is not possible to identify the occupations that contribute to the EGSS activities nor their evolution over time; (c) most of the data is available only for the manufacturing sector.

[23] The recent Istat's permanent census of enterprises asks firms several qualitative questions on the adoption of greener production processes, but capture only the self-reported extensive margin.

*Additional measures based on O*NET and the share of O*NET's green jobs in Italy*

In addition to the classification of green-tasks mentioned in section 2.3, the O*NET data allow to measure the green intensity of a job through a summary index. The index, ranging from zero to one, is calculated by relating the number of green-tasks to that of the total number of tasks for each occupation k (Vona et al., 2018). A main limitation of this approach is that it can be calculated only on a subset of green occupation (GNE and GES):[A2]

$$Greenness_k = \frac{\#\,green\,specific\,tasks_k}{\#\,total\,tasks_k}$$

Table A1 reports the top 30 green occupations in Italy according the greenness index of Vona et al. (2018).

Figure A1 reports the share of green jobs by sectors in 2020 according to O*NET's binary definition, which considers occupations belonging to one of the three categories mentioned in Section 2.3 as green. In an attempt to analyse the green employment trend in Italy using this methodology, we matched O*NET green job definitions – i.e., the binary indicator, its three components (Dierdorff, 2011) and the greenness index (Vona et al., 2018) – to the Istat Labour Force Survey (LFS) data at the 3-digit occupation level. According to this proxy, green jobs represent less than 20 per cent of total employment if we rely on the binary definition of O*NET (Appendix A, Figure A1, horizontal lines). Distinguishing by sectors, the incidence of green occupations seems to be much higher in construction, followed by manufacturing. Among employees, the share of green occupations is higher for those with permanent contracts. If we consider the more restrictive definition connected only to the direct effects of the green transition (therefore excluding "Green Increased Demand" workers), the overall employment share drops to about 10 per cent. The incidence of green jobs is further reduced if we use the *greenness* indicator of Vona et al. (2018): green jobs would represent less than 5 per cent of the total occupation. If we focus on occupations (at 3-digit ISCO level; Appendix A, Table A1), the most prominent green job categories are managers, occupations in engineering and technology, physics, but also workers in the building sector and in manufacturing. Regardless of the definition adopted, the share of *green employment* is rather constant in the last decade.

Additional analyses

The following Tables report additional analyses of the determinants of efficiency improvements in greenhouse gas emissions in Italy in the decade 2011-2020 at the sectoral level. In Table A2, we include

[A2] As highlighted in Vona et al. (2018), the construction of such index can be interpreted as a proxy of the relative importance of a particular class of job tasks, related - more or less directly - with environmental sustainability, according to O*NET classifications. In what follows, we use a simplified version of the index, as developed by Vona et al. (2018): we did not consider their manual cleaning of that occupations with different greenness score at 8-digit SOC belonging to the same more aggregate level (Vona, 2021), we used instead the median value. We further experimented the use of employment weights from BLS in our aggregations but the average index does not change significantly.

as control variables the changes in investments and self-production of goods and services aimed at protecting the air and reducing greenhouse gases, obtained from Istat, Enviromental goods and services sector accounts (EGSS) expenditure series. Unfortunately, the data are available only for the industry sector greatly reducing the number of the observations.[A1] The results are largely robust showing that a higher level of investments and self-production in air-related EGSS goods and services contribute to a reduction in greenhouse gas emissions per FTE worker (considering both 2019 and 2020 as final year of the analysis).

In Table A3, we replicate the analysis of Table 1, but we use different measures of labour market composition. First, in columns (1)-(2) (and (3)-(4) when using 2020 as final year), we use the share of all green-related jobs and the index of tasks' green intensity (Vona et al., 2018; Vona, 2021), respectively. As in Table 1, both measures are imprecisely estimated and indicate a mild contribution to the reduction of greenhouse gas emissions only in the period 2011-2020 (1.38 tonnes of CO_2 emission per FTE worker per one percentage point more green-related jobs). In columns (3) and (6), we control for the change in the share of high and medium-skill jobs (the omitted category is low-skill occupations) rather than for the changes in the share of green-related jobs. Once again, the labour market variables are imprecisely estimated. However, there seems to be an association between a larger share of high-skill jobs and a mild reduction in emissions in both periods analysed. Overall, all these additional results confirm the positive contribution of greener energy.

Last, in Table A4, we further test the robustness of the results. First, we exclude the waste and water management sector (the second contributor to overall greenhouse gas emissions in Italy; columns (1) and (3)); we then control for sector-group linear trends (columns (2) and (4)); third, we replicate the main specification on a shorter time-period farther away from the pandemic (2011-18; column (5)). All results are largely confirmed.

[A1] More recently, Istat published figures for EGSS consumption since 2018, also including the aggregate of the service sector. More granular data (1 or 2-digit sector level) and a longer time series would greatly enrich the analyses in the future.

Table A1. Top-30 ISCO 3-digit occupations by greenness index

Isco 3-digit		Greenness
132	Manufacturing, mining, construction, and distribution managers	0.68
961	Refuse workers	0.67
711	Building frame and related trades workers	0.27
213	Life science professionals	0.24
314	Life science technicians and related associate professionals	0.20
932	Manufacturing labourers	0.20
214	Engineering professionals (excluding electrotechnology)	0.19
243	Sales, marketing and public relations professionals	0.17
143	Other services managers	0.16
811	Mining and mineral processing plant operators	0.15
122	Sales, marketing and development managers	0.14
332	Sales and purchasing agents and brokers	0.13
211	Physical and earth science professionals	0.13
142	Retail and wholesale trade managers	0.12
311	Physical and engineering science technicians	0.11
313	Process control technicians	0.10
216	Architects, planners, surveyors and designers	0.09
241	Finance professionals	0.09
962	Other elementary workers	0.09
242	Administration Professionals	0.07
712	Building finishers and related trades workers	0.07
112	Managing directors and chief executives	0.06
741	Electrical equipment installers and repairers	0.06
111	Legislators and senior officials	0.05
723	Machinery mechanics and repairers	0.05
215	Electrotechnology engineers	0.05
121	Business services and administration managers	0.04
134	Professional services managers	0.04
522	Shop salespersons	0.03
333	Business services agents	0.03

Notes: based on O*NET Green Task Development Project.

Table A2. Controlling for air and climate EGSS investments and self-production in the industry sectors

	Δ tonnes of CO_2 emissions per FTE worker					
	2011-19			2011-2020		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ share of enhanced green skill occupations	198.704	470.660	1,276.197**	-867.123**	-947.557*	-1,140.615**
	(383.757)	(401.051)	(324.844)	(271.787)	(315.156)	(317.839)
Δ share of emerging green occupations	562.147*	563.862*	55.068	-269.350	-297.539	-126.376
	(223.253)	(219.494)	(225.265)	(232.135)	(242.368)	(278.161)
Δ share of enhanced green demand occupations	518.298	350.685	-289.926	-478.722*	-461.691*	-301.831
	(284.690)	(248.642)	(157.353)	(195.364)	(179.106)	(200.400)
Δ CO_2-eq. potential emissions of energy product use (th. ton.)	0.008*	-0.009	-0.009	0.005	0.012	0.010
	(0.003)	(0.007)	(0.007)	(0.003)	(0.006)	(0.007)
Δ of energy production (th. tj)	-0.331	0.754	0.965	0.198	-0.227	-0.164
	(0.402)	(0.475)	(0.462)	(0.365)	(0.422)	(0.480)
Δ air protection investments (million euro)	-0.149*	-0.163*	0.020	-0.067	-0.058	-0.105
	(0.058)	(0.057)	(0.087)	(0.037)	(0.041)	(0.061)
Δ air protection self-production (million euro)	-0.290**	-0.267**	-0.483**	-0.329**	-0.338**	-0.289**
	(0.066)	(0.068)	(0.106)	(0.041)	(0.046)	(0.064)
Constant	-0.002	-0.748	-0.210	12.248**	12.772**	12.622**
	(2.829)	(2.761)	(2.107)	(2.988)	(3.301)	(3.435)
R-squared	0.990	0.888	0.942	0.995	0.949	0.955
Adjusted R-squared	0.985	0.827	0.905	0.993	0.922	0.926
Sectors	Industry	No Energy	Manufact.	Industry	No Energy	Manufact.
Observations	22	21	19	22	21	19

Notes: The definition of enhanced green skill, emerging green, and enhanced green demand occupations follows O*NET (Dierdorff, 2011) and IMF (2022). Potential CO_2-equivalent emissions of energy product use are obtained from Eurostat PEFA: conversion factors from TJ to CO_2 are obtained from ISPRA (2020, Table 4.1, page 53). Air protection EGSS investments (in million euro) are obtained from Istat, Enviromental goods and services sector accounts (EGSS). Robust standard errors in parentheses. ** p<0.01, * p<0.05.

Table A3. Controlling for different definitions of green occupations and by the job skill composition

	Δ tonnes of CO_2 emissions per FTE worker					
	2011-19			2011-2020		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ share green occupations	138.115 (120.642)			-470.246 (251.012)		
Δ index of green intensity		44.376 (344.953)			-668.620 (421.128)	
Δ share of high-skill occupations			-49.306 (64.487)			-17.153 (75.955)
Δ share of mid-skill occupations			-13.584 (67.867)			136.086 (124.335)
Δ CO_2-eq. potential emissions of energy product use (th. ton.)	0.009^{**} (0.002)	0.010^{**} (0.003)	0.010^{**} (0.003)	0.005 (0.003)	0.003 (0.003)	0.002 (0.004)
Δ of energy production (th. tj)	0.077 (0.283)	-0.047 (0.345)	-0.061 (0.425)	0.580 (0.323)	0.714^{*} (0.341)	0.911 (0.485)
Constant	-2.174 (1.469)	-1.410 (1.611)	-0.741 (1.551)	-2.436 (2.025)	-3.145 (2.182)	-0.871 (1.636)
R-squared	0.900	0.897	0.899	0.844	0.834	0.837
Adjusted R-squared	0.895	0.892	0.892	0.836	0.825	0.826
Sectors	All	All	All	All	All	All
Observations	62	62	62	62	62	62

Notes: The definition of green jobs is that of O*NET (Dierdorff, 2011) and IMF (2022); the index of tasks' green intensity is that of Vona et al. (2018), which excludes all enhanced green demand occupations. Following the OECD Employment Outlook (2017), high-skill occupations include jobs classified under the ISCO-08 major groups 1, 2, and 3 (i.e., legislators, senior officials, and managers; professionals; technicians and associate professionals). Middle-skill occupations include jobs classified under the ISCO-08 major groups 4, 7, and 8 (i.e., clerks; craft and related trades workers; plant and machine operators and assemblers). Low-skill occupations include jobs classified under the ISCO-08 major groups 5 (service workers and shop and market sales workers) and 9 (elementary occupations). Potential CO_2-equivalent emissions of energy product use are obtained from Eurostat PEFA; conversion factors from TJ to CO_2 are obtained from ISPRA (2020, Table 4.1, page 53). Robust standard errors in parentheses. ** $p<0.01$, * $p<0.05$.

Table A4. Sample selection, controlling for sectoral trend and shorter time period

	Δ tonnes of CO_2 emissions per FTE worker				
	2011-19		2011-2020		2011-18
	(1)	(2)	(3)	(4)	(5)
Δ share of enhanced green skill occupations	196.633	321.835	-612.351	-519.179	75.661
	(161.133)	(165.529)	(466.048)	(561.047)	(107.536)
Δ share of emerging green occupations	-333.404	-224.457	-231.596	-387.534	-123.266
	(407.111)	(376.888)	(341.793)	(316.509)	(224.638)
Δ share of enhanced green demand occupations	408.222	388.236	-532.902	-432.754	241.094
	(238.124)	(276.236)	(379.111)	(436.143)	(218.694)
Δ CO_2-eq. potential emissions of energy product use (th. ton.)	0.007*	0.008	0.005	0.011*	0.013**
	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)
Δ of energy production (th. tj)	0.292	0.205	0.567	0.317	-0.433
	(0.353)	(0.271)	(0.348)	(0.256)	(0.355)
	196.633	321.835	-612.351	-519.179	75.661
Constant	(161.133)	(165.529)	(466.048)	(561.047)	(107.536)
R-squared	0.914	0.930	0.847	0.857	0.864
Adjusted R-squared	0.906	0.908	0.833	0.810	0.852
Sectors	No Waste	All	No Waste	All	All
Sector group FE	-	YES	-	YES	-
Observations	60	62	60	62	62

Notes: The definition of enhanced green skill, emerging green, and enhanced green demand occupations follows O*NET (Dierdorff, 2011) and IMF (2022). Potential CO_2-equivalent emissions of energy product use are obtained from Eurostat PEFA: conversion factors from TJ to CO_2 are obtained from ISPRA (2020, Table 4.1, page 53). Air protection EGSS investments (in million euro) are obtained from Istat, Enviromental goods and services sector accounts (EGSS). Robust standard errors in parentheses. ** $p<0.01$, * $p<0.05$.

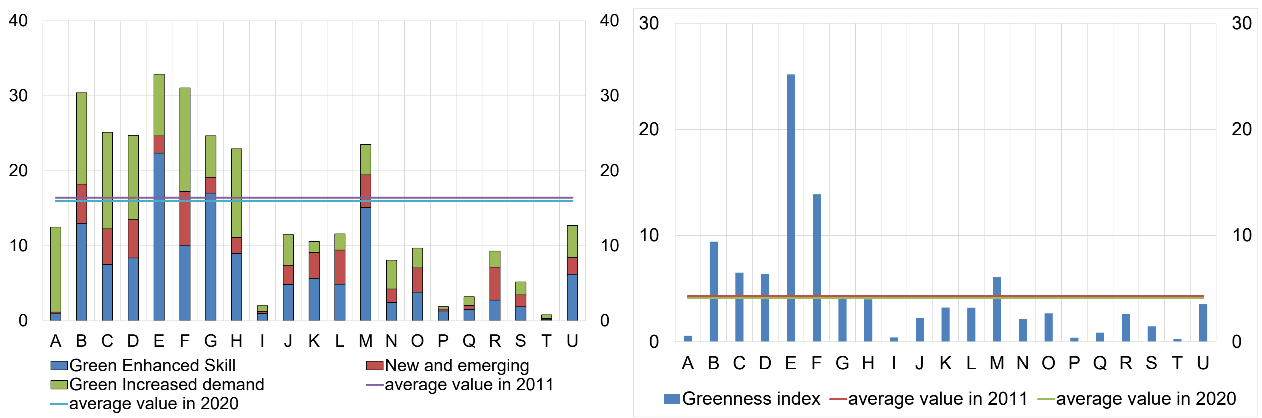
Table A5. Potential employment activated in the six main sectors and overall

Sector (NACE 2-digit)	Scenario RRF funds: explicit CO_2 emissions abatement projects	Scenario RRF funds: all green interventions	Scenario NRRP funds: explicit CO_2 emissions abatement projects	Scenario NRRP funds: all green interventions	Payroll employment in 2019
Construction	21.900	36.700	23.800	41.800	955.000
Other support activities	3.100	6.900	3.400	7.800	845.600
Computer programming	600	6.900	700	7.000	364.800
Research and development	60	6.200	60	6.200	109.500
Other transport equipment	90	3.700	100	4.100	91.300
Electrical equipment	1.900	3.200	1.900	3.300	151.300
Total	*46.800*	*108.800*	*51.000*	*122.000*	*17.966.300*

Notes: based on ItaliaDomani data, Ragioneria Generale dello Stato and Istat, National Accounts. Estimates take into account only projects newly introduced by the NRRP. The table shows the first six sectors by the level of employment created in the peak year of expenditure for the sectors reported (which is 2025 for all sectors) and in the year of maximum overall expenditure for the overall figures. Sectors with a predominant public component are excluded. The RRF funds are the funds disbursed through the Recovery and Resilience Facility, which is the main instrument of the Next Generation EU programme. In the other scenario, the additional funds made available through the React-EU programme and the Italian Complementary National Fund are also included. “Other support activities” includes surveillance, services for buildings and landscapes, administrative and support activities for offices and businesses. All estimates have been rounded.

Figure A1. Share of green jobs by sectors in 2020
(percentage points)

(a) by O*NET categories	(b) by index of greenness (1)

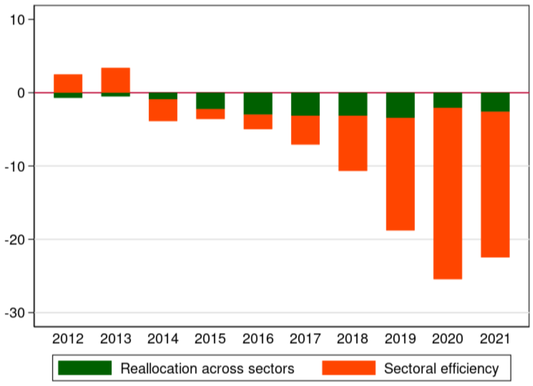


Notes: based on Istat's Labour force survey for employment and O*NET definitions (see Section 2.1.1 for further details). Sectors are classified by NACE at one-digit level, as follows: A - Agriculture, forestry and fishing; B - Mining and quarrying; C - Manufacturing; D - Electricity, gas, steam and air conditioning supply; E - Water supply; sewerage; waste management and remediation activities; F – Construction; G - Wholesale and retail trade; repair of motor vehicles and motorcycles; H - Transporting and storage; I - Accommodation and food service activities; J - Information and communication; K - Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities; O - Public administration and defence; compulsory social security; P - Education; Q - Human health and social work activities; R - Arts, entertainment and recreation; S - Other services activities; T - Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use; U - Activities of extraterritorial organisations and bodies. – (1) Green jobs are defined on the basis of the greenness indicator (Vona et al., 2018).

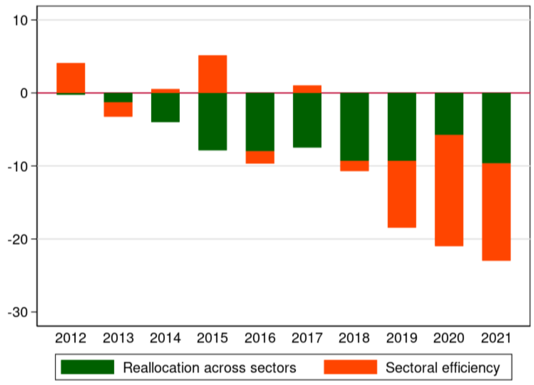
Figure A2. Labour reallocation and sectoral efficiency contributions to the variation in GHG emissions in the main European countries

(cumulative percentage change in CO_2-equivalent/FTE with respect to 2011)

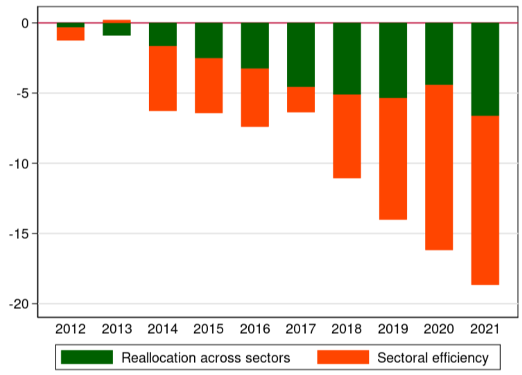
(a) Germany



(b) Spain



(c) France



Notes: based on Istat's Environmental physical accounts – Air emissions accounts (AEA). The statistical decomposition of the emission intensity relative to the 2011 level reported in the graph is described in equation (1).

Appendix B. Main green interventions in the Italian National Recovery and Resilience Plan

The main policy measures of the NRRP aim at a direct reduction of carbon dioxide emissions through investments in cleaner energy production (Mission 2 Component 2 “Renewable energy, hydrogen, sustainable mobility and network”) and energy efficiency (Mission 2 Component 3 “Energy efficiency and building modernisation”).[B1] The abatement effects of these policy measures is expected to be 3.304 million tonnes of CO_2-equivalent per year by 2026, according to the figures in the plan and the calculations of Alpino et al. (2022). In particular:

- The actions under Mission 2, Component 1 (M2C1) “Sustainable agriculture and circular economy' (5.3 billion euro) are also likely to contribute to GHG emission reductions through improvements in waste management. Actions include both reforms (such as the publication of the national waste management programme to improve waste recycling and waste management governance) and other small-scale interventions.[B2] The Plan does not provide a figure for CO_2-equivalent emission abatement of M2C1 (Alpino et al., 2022).
- Mission 2, Component 2 (M2C2) is a very complex and diverse action plan that aims to increase the production of renewable energy, develop the production, distribution and end use of hydrogen, as well as promote sustainable mobility by investing in zero emission vehicles and electric charging infrastructure. The component includes a total investment of 24 billion euro: 2 billion is dedicated to research and development of hydrogen technologies, batteries and electric transport, as well as support for green business start-ups. Interventions whose expected CO_2 reduction is reported in the Plan amount to 4 billion euro (development of agro-voltaic systems, promotion of energy communities, promotion of innovative systems including off-shore).
- Improving the energy efficiency of public buildings (1.2 billion euro) and private dwellings (about 14 billion euro) is the main focus of Mission 2, Component 3 (M2C3). The latter has been implemented by a tax credit up to 110 per cent for expenses incurred in increasing the energy efficiency of private buildings (“superbonus”). A third programme of a smaller scale concerns district heating (200 million euro).

Environmental protection is also the motivation behind the infrastructure investments in the transport networks (just under 25 billion euros), which support the shift from road to rail for both passenger and freight transport (Mission 3, Component 1, “Investments in the rail network”). These investments are expected to reduce emissions by 2.3 million tonnes of CO_2 per year. Last, about 10 per cent of the resources devoted to the research projects included in the Mission 4, component 2 (“From research to business”) have a positive climate contribution. These is a very heterogeneous set of actions and the Plan does not provide a figure for CO_2-equivalent emission abatement of these interventions (Alpino et al., 2022).

[B1] The fourth component of the Mission 2 (“Land and water resource protection”) puts in place actions to make the country more resilient to the climate change. Although these aspects are central to the overall transition towards a greener economy, they are not directly related to the reduction of GHG emissions. Therefore, they are not described in this Section.

[B2] Among the investments of M2C1, it is worth mentioning: (i) the investments to adapt roofs of buildings in the agricultural, livestock and agro-industrial sectors for renewable energy production (1.5 billion euro for a total of 4.3 million square meters of solar panels); (ii) the investments to optimize waste sorting, generating electricity from renewable sources, installing storage devices in rural areas and small islands (about 340 million euro).