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NOVEMBER 2024
No. 324

Research papers

Quantifying Green Job Potential in Colombia

A Task-Based Approach

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Quantifying Green Job Potential in Colombia

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Abstract
This paper examines the impact of the green transition on the Colombian labor market. Using a task-based approach and data from the 2022 Colombian Household Survey, we find that approximately 22.6% of Colombian employment is linked to green tasks, with 15.9% directly affected by the green transition. While these figures are in line with global estimates, most jobs will not change significantly. Green jobs are concentrated among men, urban residents, and higher-educated workers with STEM degrees in managerial roles, who also earn more and are located at the top of the income distribution. In addition, the tasks and skills of occupations of workers with a lower prevalence of jobs limit their mobility to green jobs. This suggests a need for targeted training programs to facilitate the transition of non-green workers to green occupations, given the limited transferability of skills between these types of jobs.

Keywords
Green jobs, energy transition, task-based approach, Colombia

JEL codes
Q52, Q56, J24, O13

Acknowledgements
We would like to thank to Allison Benson, Anda David, and Manuel Fernandez, the Ministry of Finance, and participants of the UNU-WIDER 2024 Conference and the Congreso de Economía Colombiana for their useful comments and suggestions. This work has been supported by the Agence Française de Développement (AFD) through the Extension of the EU-AFD Research Facility on Inequality under the re-search proposal ID PROPC-0697-23 (ISR/ECO/844-2023). The authors have no conflicts of interest to declare.

Accepted
July 2024

Résumé
Cet article examine l'impact de la transition "verte" sur le marché du travail colombien. En utilisant une approche basée sur les tâches et les données de l'enquête sur les ménages colombiens de 2022, nous constatons qu'environ 22,6% des emplois colombiens sont liés à des tâches 'vertes', dont 15,9% sont directement affectés par la transition "verte". Bien que ces chiffres soient conformes aux estimations mondiales, la plupart des emplois ne changeront pas de manière significative. Les emplois "vert"s sont concentrés chez les hommes, les résidents urbains et les travailleurs plus instruits, titulaires de diplômes STEM et occupant des postes de direction, qui gagnent également plus et se situent au sommet de la répartition des revenus. En outre, les tâches et les compétences des professions des travailleurs ayant une faible prévalence d'emplois limitent leur mobilité vers les emplois "verts". Cela suggère la nécessité de programmes de formation ciblés pour faciliter la transition des travailleurs "non verts" vers les emplois "verts", étant donné la transférabilité limitée des compétences entre ces types d'emplois.

Mots-clés
Emplois verts,
transition énergétique,
approche par tâches,
Colombie

1. Introduction

Climate change has put the transition to sustainable energy production and consumption at the top of the economic policy agenda. While there is a general consensus on the importance and urgency of transitioning from current production processes to an economy with lower emissions, its long-term sustainability will critically depend on the distributional effects of such a transition and its economic justice (Bowen and Hancké, 2019; Marin and Vona, 2019). A critical issue in both policy and academic discussions is the effect of the green transition on the labor market. Some recurrent elements in these debates are whether the green transition is beneficial for workers, which types of workers may benefit from the green transition, and how easily workers can transition into occupations with green potential (Lim et al., 2023).

From an economic perspective, the greening of the economy implies a structural shift from carbon-based production technologies, processes, and goods to less polluting practices with a smaller environmental footprint. Such a transformation requires that current and future workers develop skills to meet the increasing demands of these practices. Inevitably, some will adapt and benefit from the adoption of low-carbon technologies, while others may be left behind (Vandeplas et al., 2022; Cavallo et al., 2024). A relevant concern in this discussion is whether those left behind will be the most vulnerable, exacerbating existing inequalities. If so, what types of policies can be implemented to navigate towards a transition with economic justice?

In this paper, we present an assessment of the current situation of occupations likely to be affected by the green transition in Colombia, a middle-income economy characterized by high levels of informal employment and economic inequality. To do this, we use a task-based approach, in which we characterize the environmental properties of jobs based on the task content of their occupations, rather than the industry they perform in. We link the occupations of Colombian workers to a classification of occupations that may be affected by the green transition, developed by O*NET[1] in the U.S., and quantify and characterize the current level of green jobs that exist in Colombia. We take advantage of the granularity of the Colombian Household Survey of 2022 (GEIH by its Spanish acronym), which provides detailed information on a worker's occupation, economic sector, and demographic characteristics, to estimate the number of green jobs and describe their attributes. Although this paper is descriptive in nature, it presents an analysis of the types of green jobs that exist in the economy and sheds light on the future challenges that middle-income economies face in implementing a fair transition.

We present three main findings throughout the paper. First, approximately 22.6% of employment in Colombia has the potential to perform tasks that are either directly or indirectly affected by the greening of the economy. When we focus on occupations in which the task contents are going to be directly affected by the green transition, about 15.9% of total employment in Colombia has the potential to perform these tasks. These figures are comparable to those observed in other developed and

[1]The Occupational Information Network (O*NET) program was developed in the late 1990s and has become the main source of occupational information in the U.S. It contains detailed information about an occupation's required knowledge, skills, abilities, interests, preparation, contexts, and tasks (Mariani, 1999).

developing economies. For example, in the United States, it was estimated that 19.4% of current jobs could be considered part of the green economy (Bowen et al., 2018). In European countries, the total number of green jobs represents between 17% and 22% of total employment (Valero et al., 2021). Recent estimates for Indonesia, India, and Argentina indicate that green jobs account for between 14% and 25% of total employment (de la Vega et al., 2024; Granata and Posadas, 2024; Ham et al., 2024).

Second, there exist significant inequalities in the prevalence of green jobs that need to be addressed to reach a just transition. Given the current sectoral and occupational distribution of employment in Colombia, the prevalence of green jobs in high-skilled occupations of particular sectors favors the development of jobs with green potential for certain groups of workers. We document three dimensions in which the gaps are sizable: gender, region, and educational attainment. The share of green jobs for women is 8.4 percentage points (p.p.) lower than for men, while the share of green jobs for workers in rural areas is 7.4 p.p. lower than for workers in urban areas. Regarding educational attainment, while there is a positive gap in the prevalence of jobs with green potential in favor of workers with tertiary education, not all degrees have the same prevalence. Workers with University and Postgraduate degrees, especially in science, technology, engineering, and mathematics (STEM) careers, have a higher likelihood of working in occupations with green potential. In contrast, workers with Technical and Vocational (TVET) degrees have a lower prevalence of jobs directly affected by the green transition (14% of total), even lower than the prevalence for workers without a degree (about 15%). Since women tend to have lower participation in STEM careers, these differences may contribute to explaining the significant gender gaps in the prevalence of green jobs (Alexander et al., 2024).

Third, the general attributes of green jobs indicate that the green transition is not neutral at the skill level, and high-skilled workers are more likely to benefit from it. Green jobs are positively correlated with wages and job quality. Even after controlling for observable determinants, wages in occupations likely to be directly affected by the green transition are about 10% higher than in non-green occupations. In addition, workers in green jobs have higher quality indicators. On average, workers in green jobs are 1.3 percentage points (p.p.) less likely to work excessive (60+) hours, 2.3 p.p. less likely to have a pay below 2/3 of the minimum wage, and 1.5 p.p. more likely to work in the formal sector. Taken together, the systematic differences between green and non-green occupations map into the income distribution, as workers in green occupations are more likely to be located at the top of the income distribution (up to 8 percentage points more likely to be in the highest decile of Colombia's income distribution). Prospectively, measures of proximity of non-green jobs to green jobs suggest that women, rural workers, workers with TVET degrees, and informal workers are the ones for whom their skill content is less suitable to transition to green jobs.

This paper is related to a growing literature characterizing jobs depending on the potential effects of the green transition and their inequalities. Works like Vona et al. (2018, 2019) and Vona (2021) used the task-based approach of occupations in labor markets (Autor, 2013) to characterize the environmental properties of jobs. These

efforts have been extensively documented, especially in developed economies, for example in Valero et al. (2021) and Causa et al. (2024), and new prospective studies are also applied for some developing economies (de la Vega and Gasparini, 2021; Granata and Posadas, 2024; Ham et al., 2024). Most of these works document the differential patterns in the prevalence of green jobs among workers. Recent efforts show that the results hold in cross-country comparisons (Bluedorn et al., 2023; Winkler-Seales et al., 2024). Our paper documents these differences for Colombia, a middle-income country with high informality and strong income inequality, contributes to the discussion by providing evidence of barriers at the educational level, especially related to TVET programs and STEM careers, and, following a similar methodology proposed by Bowen et al. (2018), documents sizable differences in the possibility to transition between non-green and green occupations.

The rest of the paper is organized as follows. Section 2 presents the approaches used to define green jobs and the methods to measure them. Section 3 details the implementation and the data used for measuring and characterizing green jobs in Colombia. Section 4 presents our results on the measurement of green jobs and the heterogeneity analysis. Finally, Section 5 concludes.

2. A framework for green jobs

Despite their growing popularity in political and academic discussions, the definition and measurement of a green job remain open fields of research. The current view on green jobs has shifted towards a broad definition guided by the type of analysis to be conducted, rather than adhering to a standard definition (Vona, 2021; Granata and Posadas, 2024).

One of the earliest definitions of a green job is proposed by the Green Jobs Initiative, a joint project of the International Labor Organization (ILO), the United Nations Environment Programme (UNEP), the International Organization of Employers (IOE), and the International Trade Union Confederation (ITUC). In the Green Jobs Initiative, a green job is defined as *"work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution."* (UNEP; ILO; IOE; ITUC, 2008). In addition, the definition includes considerations related to the quality of jobs, in which the job must contribute to the greening of the economy, but must also be decent.[2]

While other definitions are available in the literature, many of them share elements with the one presented by the Green Jobs Initiative: Green jobs are directly or indirectly related to

[2]According to the International Labor Organization's Decent Work Agenda, decent work *"sums up the aspirations of people in their working lives. It involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for all, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men."*. See International Labor Organization (2024).

reducing negative environmental impacts by promoting sustainable production processes and producing environmentally friendly goods and services. While the general idea is straightforward, the measurement of green jobs depends on the particular policy question at hand, and each choice has its advantages and disadvantages (Granata and Posadas, 2024).

One measure that is prominent in the literature identifying the environmental characteristics of jobs is the so-called task approach. In this approach, the analysis focuses on the tasks that workers perform in their occupations rather than where they work (their industry) (International Monetary Fund, 2022).[3] Building on the ideas of the general task approach to labor markets (Acemoglu and Autor, 2011; Autor, 2013), the task-based approach classifies a job as green depending on whether the activities workers perform in these occupations contribute to reducing environmental impacts (green tasks).

The task approach is informative for addressing policy issues related to the preparation and development of the skills that workers will need at the onset of the green transition. By looking at occupations rather than industries, the task approach overcomes some of the limitations of industry-based measures because the greenness of the job is related to the contribution of that particular job to reducing pollution, which should be considered an economy-wide goal. For example, working as a security guard for a company that manufactures electric cars would be considered a green job under the industry-based definition, while an engineer in charge of water recycling in a company that manufactures leather would not.

In practice, the task approach requires knowledge of a worker's occupation and the green content of their tasks. One of the most prominent research projects in classifying worker tasks at the occupational level is the Occupational Information Network's (O*NET) Green Occupations Program, which examines the impact of the adoption of green economy activities and technologies on occupational requirements for the U.S. (Dierdorff et al., 2009, 2011). The program reviewed multiple sources of academic, industry, and government analysis to understand the impact of the greening of the economy on the task content of occupations.

Given a set of 12 economic sectors related to the green transition,[4] the program explored the implications of developments in these sectors for occupations based on desk reviews conducted by O*NET experts.

The Green Employment Program classified occupations (reported at the Standard Occupational Classification (SOC) 2010 8-digit level) into three categories according to how they are affected by the green transition (Dierdorff et al., 2009):

- Green New and Emerging (GNE): The green economy creates the need for unique work and worker requirements, resulting in the creation of new occupations. These new occupations are added to the existing SOC list of occupations. Examples of these types

[3]The task approach is also referred to in the literature as the "bottom-up" approach, as opposed to the "top-down" (industry) approach (see Valero et al., 2021). Using the canonical production function as a starting point (Autor, 2013), Granata and Posadas (2024) classify definitions of green jobs according to whether they are based on the environmental impact of firms, either due to the output they produce or the technology they use, or on the environmental impact of workers, either due to the tasks they perform or the skills they have.

[4]The selected sectors are: Renewable Energy Production; Energy Efficiency; Energy Trading; Research, Design, and Consulting; Agriculture and Forestry; Recycling and Waste Reduction; Transportation; Green Building; Energy and Carbon Capture; Environmental Protection; Manufacturing; and Government and Regulation.

of occupations include fuel cell engineers and technicians, solar photovoltaic installers, logistics managers, and environmental economists.

- Green Enhanced Skills (GES): The green economy is changing the work and worker requirements of existing occupations. While the purpose of the occupation remains the same, the tasks, skills, knowledge, and external elements such as credentials have changed. Examples of these types of occupations include architectural and engineering managers, financial analysts, electrical engineering technicians, construction and building inspectors, and bus and truck mechanics and diesel engine specialists.
- Green Increased Demand (GID): The green economy increases employment demand for existing occupations but does not significantly change the work and worker requirements of the occupation. Examples of these occupations include electrical powerline installers and repairers, chemical engineers, forest and conservation technicians, electricians, and bus drivers, transit and intercity bus operators.

The previous categories encompass different effects of greening the economy on workers. While GES and GNE occupations require the creation of new occupations or changes to existing ones, GID occupations are indirectly affected by the expansion of the greening of the economy and do not face changes in their requirements. Since the GID occupations do not change their occupational requirements, several authors consider that these occupations are not part of green employment (Vona et al., 2018). Note that this classification implies that non-green occupations are not necessarily considered polluting (or brown); they are simply not affected by the green transition.

Along with the classification of green occupations, the O*NET Green Employment Program identified the specific green tasks included in each occupation (by definition, the number of specific green tasks in GID and in non-green tasks is zero). Using this information, Vona et al. (2018) proposes a continuous measure of the greenness of an occupation k as

$$Greenness_k = \frac{\text{\# of green specific tasks}_k}{\text{\# of total specific tasks}_k}. \tag{1}$$

Thus, the O*NET Green Employment Program provides tools to measure the extent and intensity of green jobs using the task approach.

Although the O*NET Green Employment Program is widely recognized and used to characterize green jobs in the United States, its application to other economies has limitations (see section 3). First, while O*NET provides a comparable framework for understanding and measuring green jobs, its application could introduce errors in the measurement of green jobs in developing countries. This is because the occupational content of jobs in developing countries may differ significantly from that in the U.S., leading to incorrect estimates of the true environmental characteristics of jobs in these countries. Although previous literature has shown similarities between the occupational content of jobs in developed economies (Forstmeier and Maercker, 2008; Paolillo et al., 2022; Vona et al., 2019), there is no extensive analysis related to developing economies. A second shortcoming is related to the fact that the occupational classifications used by developing economies (usually a version of the International Standard Classification of Occupations, ISCO) tend to be less granular than those presented by O*NET. This granularity difference can introduce measurement error due to the

additional assumptions required to relate SOC occupations to ISCO occupations.

To overcome these shortcomings, Granata and Posadas (2024) proposed a systematic approach to characterizing green jobs based on general descriptions of the task content of occupations in the ISCO classification. Their approach uses text analysis to identify tasks that may contain green-specific elements and calculates the green task intensity of an occupation at the 4-digit level of ISCO-08. To achieve this, the authors use a language-based model in which they first review several sources (including O*NET) to develop a green dictionary, i.e., a dictionary with environmentally friendly terms that can describe occupations. The dictionary has a narrow version, which only includes strictly green terms, such as carbon sequestration and climate change, and a broad version, which also includes terms that are potentially but not necessarily green, such as planter and wooden construction. After creating the dictionary, they apply both the narrow and broad versions to the task descriptors of the ISCO-08 task database. Green jobs are then defined based on the relative frequency of green terms (the green task intensity, an equivalent measure of equation (1)) in the description of each occupation.

Because Granata and Posadas (2024)'s definition is applied to each of the ISCO-08 occupations, which is the typical classification used by statistical agencies in developing economies, it can be directly applied to the data of developing economies. This reduces concerns of measurement error in the crosswalks between the SOC-10 and ISCO-08 classification systems. Note that, given this definition, the green occupations identified in the narrow dictionary are more similar to O*NET's GNE occupations.

3. Empirical approach

The ideal scenario for applying the task approach to green jobs involves a detailed characterization of occupations and worker characteristics, including the green task content of their roles. Unfortunately, as in many developed and developing economies, Colombia lacks country-specific data on the tasks included in various occupations.

To overcome this limitation, we follow the literature on green jobs and obtain the environmental properties of jobs by combining information on workers' occupations and characteristics from national household surveys with data about task contents from an international classification. The two main sources of information used in this study are:

- The Colombian Household Survey for 2022 (GEIH by its Spanish acronym): The GEIH is the official source of statistics on employment, poverty, and income distribution in Colombia. It is a sample of approximately 300,000 Colombian households that is representative of the Colombian population and includes information on the demographic characteristics of household members, labor force status, job characteristics, labor earnings, and other sources of income. Following a methodological change in 2022, the Colombian National Statistics Institute (DANE) began classifying workers' occupations using the ISCO-08 classification at the 4-digit level. The data are collected as a repeated cross-section, which does not allow for longitudinal analysis.

- The O*NET Green Occupations dataset (O*NET Center, 2021): The Green Occupations dataset reports the green classification discussed in section 2 at the 8-digit level of the SOC-10 classification. It includes information on the occupation's green category (Increased Demand, Enhanced Skills, and New and Emerging). The data can also be supplemented with O*NET data on green tasks and other occupational characteristics.

Using these data sources, we can generate binary measures of green jobs and continuous measures of the green intensity of jobs at the occupational level. By linking this information to each worker based on their occupation, we can document the size of green employment, its attributes, and the potential gaps in this type of employment depending on workers' characteristics.

In order to merge the two datasets using the occupational classifications (ISCO-08 in the GEIH and SOC-10 in Green Occupations), we first aggregate the Green Occupations dataset at the SOC-10 6-digit level and merge this dataset with the ISCO-08 classification using the crosswalks provided by the U.S. Bureau of Labor Statistics (BLS).[5] Since ISCO-08 and SOC-10 classifications do not match one-to-one, we have to perform additional steps whenever two or more occupations are matched in the other dataset. On the one hand, we follow a similar approach as in the literature and calculate the share of green jobs in an ISCO-08 occupation as the average of the share of green jobs in the SOC-10 occupations matched to that ISCO-08 occupation, weighted by the level of US employment by SOC-10 as reported by the BLS. On the other hand, to avoid overweighting SOC-10 occupations that match multiple ISCO-08 occupations, whenever a SOC-10 occupation matches multiple occupations in the GEIH, we split the total employment in that O*NET occupation based on the share of employment in the matched occupations (Dingel and Neiman, 2020; de la Vega et al., 2024).

As discussed above, while this approach allows us to overcome the limitations related to the lack of detailed information on occupations and tasks, it also carries important caveats that need to be considered in the analysis (Granata and Posadas, 2024). To test the sensitivity of our results, we also include in our analysis the classification of green jobs proposed by Granata and Posadas (2024).

4. Results

The jobs with green potential estimated using the methodology described in the previous section are presented in Table 1. In the table, we present the share of workers in occupations likely to be affected by the greening of the economy according to the O*NET classification, distinguished by the types of green jobs (GNE, GES, and GID, see section 3) and the average greenness of GNE and GES occupations (equation (1)). We also include columns reporting the share of occupations with a positive green task intensity (GTI) and the average GTI as calculated by Granata and Posadas (2024) under the narrow and broad dictionaries (see section 2).

[5]This approach is commonly used in the literature analyzing employment characteristics based on occupation data, such as occupational mobility (Consoli et al., 2016; Dahlke et al., 2022), green employment (Valero et al., 2021; International Monetary Fund, 2022; de la Vega et al., 2024), remote work (Dingel and Neiman, 2020; Alfaro et al., 2020; de la Vega and Gasparini, 2021), and automation (Granata and Posadas, 2024; Valero et al., 2021).

	O*NET Center (2021)		Granata and Posadas (2024) Narrow		Broad	
	Share of employ-ment (%)	Average Greenness (%)	Share of employ-ment (%)	Average GTI (%)	Share of employ-ment (%)	Average GTI (%)
Total	22.6	2.6	4.27	29.4	27.8	38.3
New & Emerging	1.9	28.4	–	–	–	–
Enhanced Skills	14	9.6	–	–	–	–
Increased Demand	6.6	–	–	–	–	–

Table 1: Green job potential in Colombia, 2022

Out of a total of 22 million workers in Colombia, the number of workers in occupations directly or indirectly affected by the green transition is about 4.7 million, or 22.6% of total employment. Most of these jobs are in occupations classified by O*NET as directly affected by the greening of the economy: 14% of total employment is in Enhanced Skills (GES) and 1.9% in New & Emerging (GNE) occupations. Among occupations with the potential to be indirectly affected by the green transition, about 6.6% of jobs are in the Increased Demand (GID) category. The estimates based on Granata and Posadas (2024) indicate that about 4.3% (27.8%) of total employment is directly affected by the green transition under the narrow (broad) dictionary. Naturally, since the definition of green jobs by Granata and Posadas (2024) tends to be more stringent regarding the environmental properties of a job, the figures under these measures are more in line with those observed when considering only O*NET occupations that are created to meet the new demands of the green transition (GNE).

Compared to the related literature, the share of employment in occupations with green job potential in Colombia is comparable to the shares reported in other developed and developing countries. For example, Bowen et al. (2018) find that the share of workers in green jobs is about 19.4% of total employment in the U.S., while Valero et al. (2021) find that the share of green jobs in European countries varies from 17% in Greece to 22% in Germany. In their studies of developing countries, Granata and Posadas (2024) also find that the share of green employment using the O*NET methodology is about 14% for Indonesia, de la Vega et al. (2024) estimate that the share is about 25% for urban Argentina, and Ham et al. (2024) estimate 15% for India.

While there is a significant share of jobs that may be affected by the green transition, they are not radically affected by the transition. As Table 1 shows, 14% of jobs are GES jobs, which are existing jobs likely to change their tasks to meet the requirements of the greening of the economy, 6.6% are jobs likely to increase their demand due to the greening of the economy but do not change their skills and requirements, and only 1.9% are new and emerging jobs. In addition, Colombian employment has an average low green intensity. About 2.6% of the tasks of occupations are related to green tasks. As expected, the higher green intensity is found in the GNE occupations, where 28.4% of their tasks are green, while the GES occupations show a moderate green intensity (9.6%). Compared to the Green Task Intensity (GTI) index of Granata and Posadas (2024), the share of green jobs is lower (4.27% in its narrow definition) but their intensity is higher (29.4%). Granata and Posadas (2024) also includes a broader (less stringent) definition of green jobs, in which case the share of green jobs represents 27.8% of employment and their average intensity increases to 38.3% of total tasks.

The observed differences in the likelihood of being affected by the green transition are

related to the occupational and industrial composition of the economy. In Figure 1, we show the share of employment in green jobs by major occupational (ISCO) and industrial (ISIC) groups, distinguishing between sectors directly affected by the green transition (GNE and GES) and those indirectly affected (GID). Panel (a) shows the distribution of green jobs by major occupational group. In general, the distribution of green jobs by occupation is heterogeneous, but it is clear that most of the jobs directly affected by the transition are concentrated in occupations that require higher levels of education and skills, mostly managers, professionals and technicians. In fact, almost all of the jobs in the new and emerging category are concentrated in these three groups. In contrast, other middle-skill groups, such as agricultural workers and craft and related trades workers, will mostly be indirectly affected by the transition. The occupations with a lower incidence of green jobs (direct or indirect) are those related to services and sales (12% of total employment in these occupations), a group that typically absorbs a significant share of employment, especially informal employment.

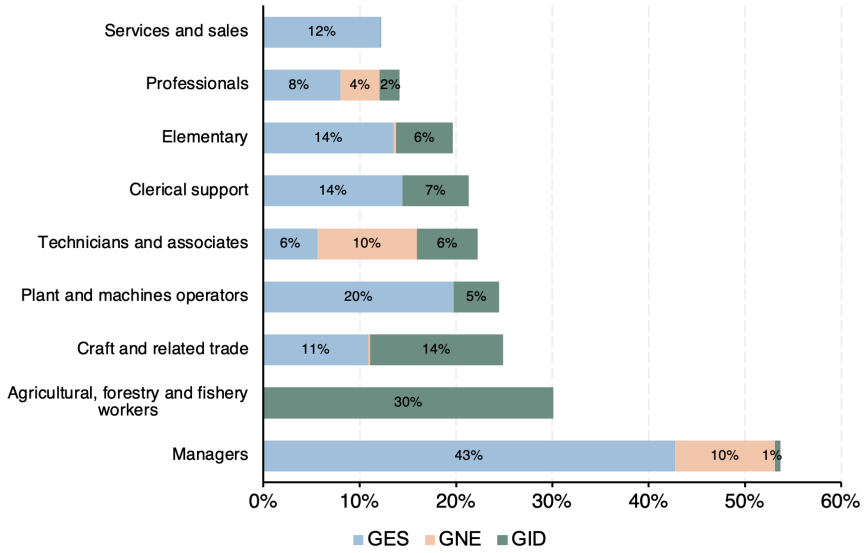
Regarding the sectoral distribution of green jobs, panel (b) of Figure 1 shows the distribution of green jobs by major industry groups. The highest prevalence of green jobs is in mining and quarrying (including electricity) and construction, two sectors whose technological transformation is central to the roadmap for decarbonizing the economy. Consistent with the idea that the major changes in the transition to a low-carbon economy will take place in high-emitting industrial sectors, Figure 2 shows a positive relationship between the share of green jobs (horizontal axis) and the level of greenhouse gas emissions (vertical axis) by economic sector. Sectors such as construction, electricity, and mining have a higher concentration of green jobs and are also among the sectors with higher overall emissions. While manufacturing and services also have a significant prevalence of green jobs, the levels of green jobs are lower than those in high-emission sectors and, in the case of manufacturing, it is more likely that these jobs are affected indirectly by the green transition.

4.1. Inequality in the prevalence of green jobs

The general attributes of green jobs described above indicate that, given the labor market structure of the Colombian economy, green jobs are more prevalent in high-skilled occupations and certain economic sectors. Consequently, it is likely that the green transition will benefit workers differently, depending on their individual opportunities to access these types of occupations. In this section, we document observed differences in the prevalence of green jobs by workers' demographic characteristics, such as gender, education, age, and region.

To do this, we rely on the demographic information reported in the GEIH data and estimate the differences in the prevalence of green jobs across these dimensions. In particular, we estimate linear models where the dependent variable is the implied share of direct green jobs (GNE and GES) per occupation for each worker (obtained from the O*NET data), and the covariates are variables describing the worker's gender, education, age, and region. Table 2 presents the estimation results. Each column represents a different estimate associated with

(a) Green jobs by major occupations



(b) Green jobs by industry

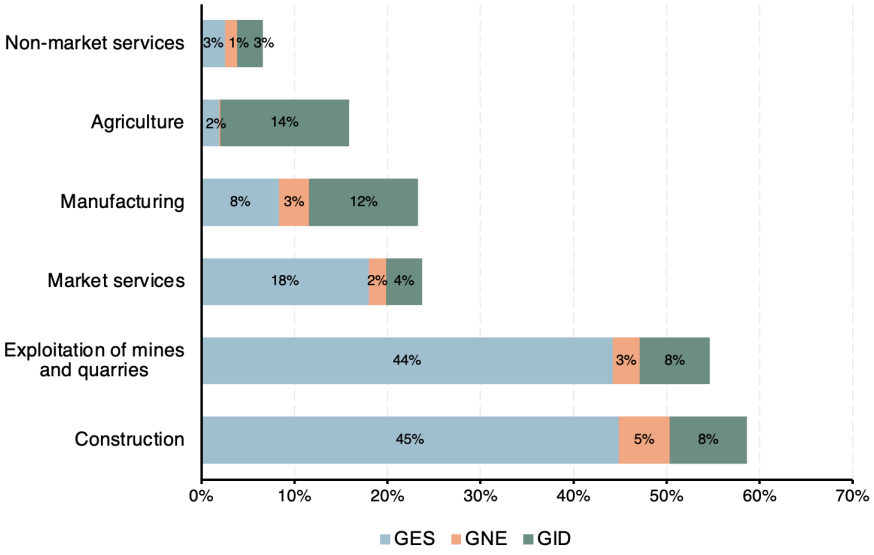


Figure 1: Share of green jobs by occupation and industry

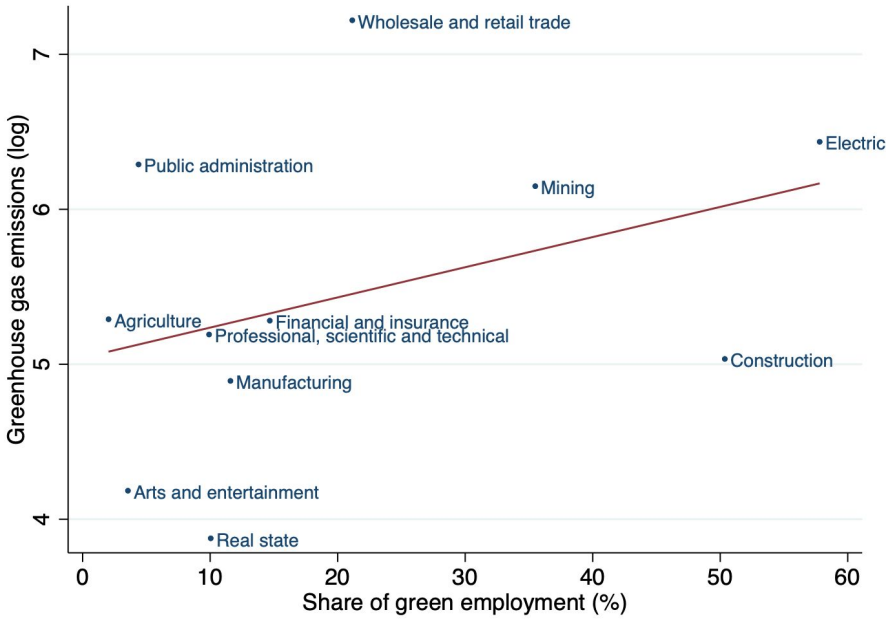


Figure 2: Greenhouse gas emissions and share of green employment by sector

a specific worker's characteristic. The estimated effect can be interpreted as the average (unconditional) difference in the likelihood that a worker with the given characteristic (for example, female) is working in an occupation with direct green potential compared to workers in a base category (male, in this example). The average prevalence of direct green jobs in the base category is presented in the row labeled "constant" in each column.

The largest gap in the prevalence of direct green jobs is related to gender, where women are 8.4 percentage points (p.p.) less likely than men to work in occupations with direct green potential. While women have an average prevalence of direct green jobs of 11.1% of total female employment, men have a prevalence of 19.5% of total male employment. This result is consistent with the extensive literature related to gender economics documenting occupational and sectoral segregation of women in labor markets and its implications (Blau and Kahn, 2017; Cortes and Pan, 2018; Borrowman and Klasen, 2020), which in this case is represented by a lower prevalence of direct green jobs.

After the gender gap, the second largest gap in the prevalence of direct green jobs is based on the region of residence of the worker. Consistent with the sectoral distribution of direct green jobs, where the lower prevalence of direct green jobs is found in the agricultural sector and agricultural occupations (Figure 1), the gap in the prevalence of direct green job potential between workers living in rural areas and workers living in urban areas is -7.66 p.p. (column (6)).

In addition, while the largest differences are observed by gender and region, Table 2 also shows that the likelihood of working in a job with green potential in Colombia is correlated with higher levels of education and age. In terms of educational attainment, workers with at least some tertiary education are 1.43 p.p. more likely to work in a job with direct green potential compared to high school graduates, while high school dropouts have a similar

Dependent Variable: share of green jobs (GNE and GES)			
	(1)	(2)	(3)
Gender			
Female	-0.0843***		
	(0.00188)		
Schooling			
High School dropout		-0.00315	
		(0.00227)	
More than High School		0.0143***	
		(0.00253)	
Years of schooling			0.00257***
			(0.000209)
Constant	0.195***	0.157***	0.134***
	(0.00136)	(0.00171)	(0.00219)
Observations	364,070	364,059	364,059
R-squared	0.016	0.001	0.001

Dependent Variable: share of green jobs (GNE and GES, Cont.)			
	(4)	(5)	(6)
Age			
30–39	0.0194***		
	(0.00280)		
40–49	0.0236***		
	(0.00292)		
50–59	0.0187***		
	(0.00304)		
Age (years)		0.000689***	
		(0.0000673)	
Region of residence			
Living in a rural area			-0.0766***
			(0.00201)
Constant	0.145***	0.132***	0.177***
	(0.00197)	(0.00288)	(0.00114)
Observations	313,716	364,070	364,070
R-squared	0.001	0.001	0.009

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Likelihood of working in a job with green potential by demographic characteristics

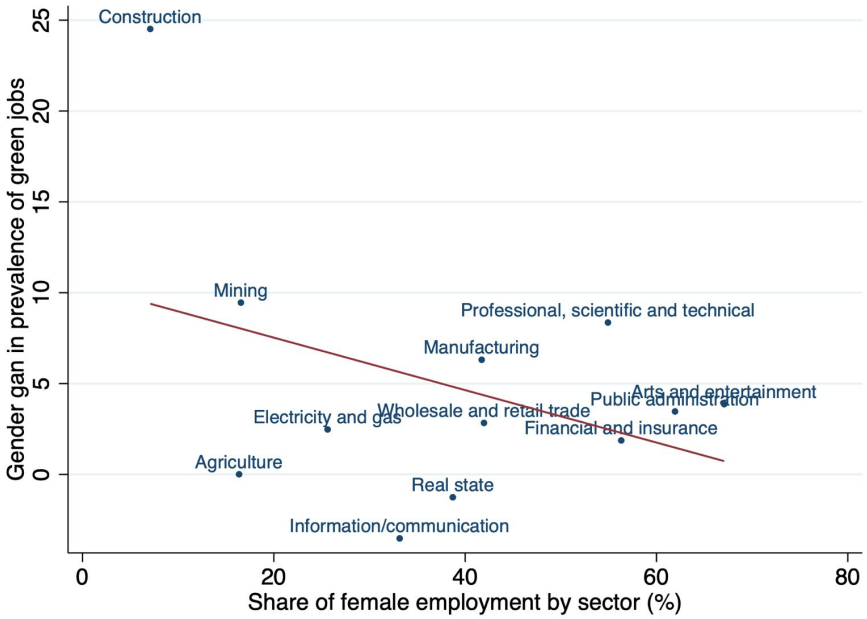


Figure 3: Gender gaps in green jobs and female participation by industry

prevalence of direct green potential. Similarly, workers aged 30 and over are between 1.9 and 2.4 p.p. more likely to work in jobs with direct green potential than workers under 30 (who are the base category).

In Figure 3, we further explore differences in the prevalence of direct green jobs by gender by plotting the relationship between gender gaps in direct green jobs (vertical axis) and the share of female employment (horizontal axis) by major industry groups. With the exception of the agriculture, real estate, and information and communication sectors, gender gaps in direct green jobs are positive in all sectors. There are striking differences between workers within sectors, such as construction, mining, and professional, scientific, and technical services, where the gaps are about 25 p.p., 10 p.p., and 9 p.p. of employment, respectively. The results suggest that both occupational and sectoral segregation may play a role in explaining the gender gap in the prevalence of green jobs.

We also use the detailed information in the GEIH to characterize the differences in the prevalence of green jobs by education. In Figure 4, we show the share of green jobs based on a worker's educational attainment. Consistent with the evidence presented in Table 2 and previous literature (e.g., Causa et al., 2024), the share of jobs likely to be directly affected by the green transition (GES and GNE) is higher for more educated workers, but this pattern holds only for workers with college and postgraduate degrees. In particular, the jobs created by the green transition (the New and Emerging category) are concentrated in these two groups. In contrast, workers with low educational attainment (high school and less) are more likely to be affected by the green transition directly through changes in the skill content of their occupations (GES) or indirectly through increased demand resulting from the development of the green transition (GID). Workers with Technical and Vocational Education and Training (TVET) degrees are those with a lower overall prevalence of green jobs (especially GES jobs), although this educational attainment level has been identified as a tool for providing skills

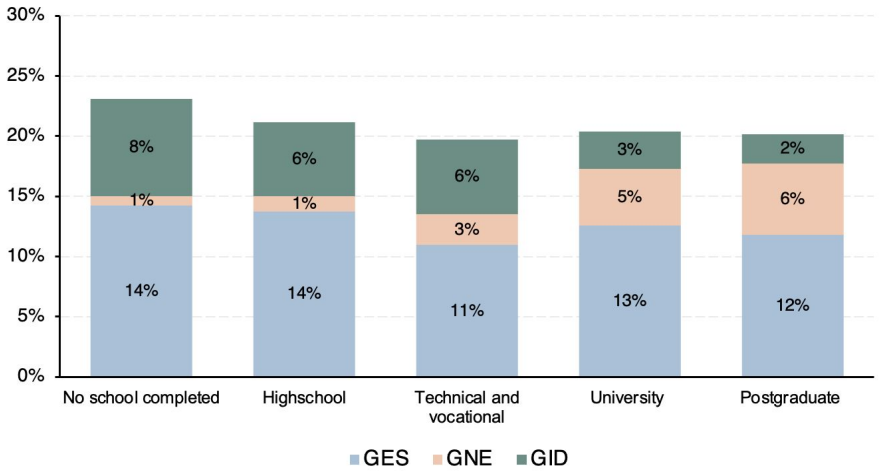


Figure 4: Share of green jobs by worker's educational attainment

and competencies that will be required in the greening of the economy (International Labor Organization, 2022).

In addition to the results by educational attainment, we can also characterize the prevalence of green jobs by the field of study of the worker. The GEIH records information on both educational attainment and, for workers with post-secondary degrees, the dataset also records their choice of field of study using the International Standard Classification of Education (ISCED). Figure 5 shows the share of green jobs by major field of study. Overall, the highest prevalence of green jobs, particularly GNE and GES, is observed in science, technology, engineering, and mathematics (STEM) occupations, as about 40% and 25% of workers in engineering, manufacturing and construction, and science, mathematics, and statistics, respectively, are likely to be directly and indirectly affected by the green transition. This high prevalence is driven by the prevalence of new and emerging occupations, as 10% and 8% of jobs for engineering and science workers, respectively, are in this category of green jobs.

The high prevalence of green jobs among workers with STEM degrees is a structural factor that may explain the gender gap in the prevalence of green jobs. The literature on gender gaps in the labor market has documented that although women tend to have higher educational attainment than men, there are significant gaps in women's access to STEM careers compared to men (Bertrand, 2020). These structural differences in educational choices have labor market consequences, as they prevent women from entering high-paying occupations that tend to have narrower gender wage gaps (Goldin, 2014). In this case, the high prevalence of STEM jobs is a potential driver of occupational sorting into sectors and occupations with green potential, creating barriers to closing these gaps in the near future (Alexander et al., 2024).

Taken together, our results indicate that the attributes of jobs with green potential generate differences in the prevalence of green jobs for certain demographic groups. Our estimates show that jobs with green potential are more likely to be found among men, the population with higher education (in particular in STEM fields), the middle-aged population (30 years

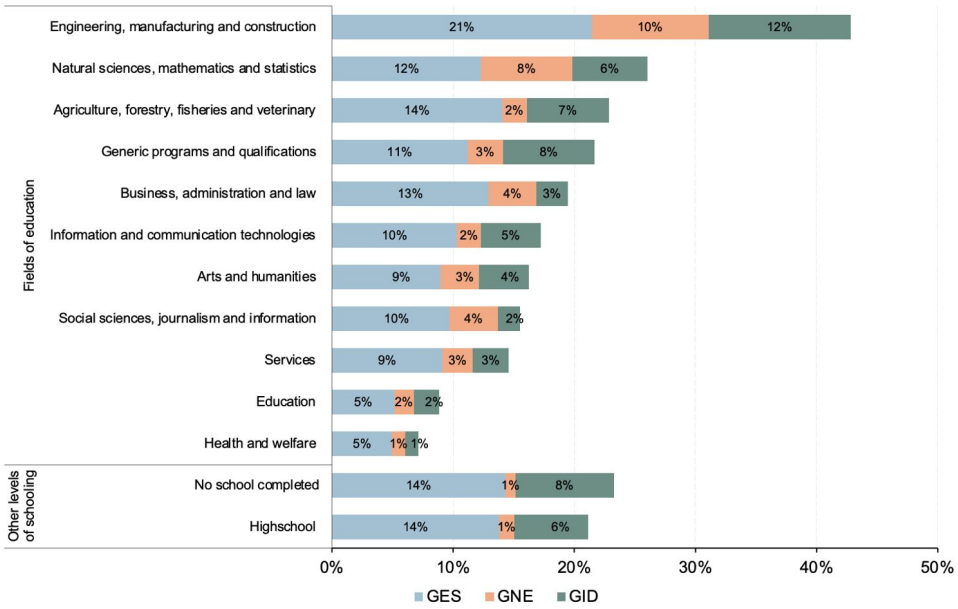


Figure 5: Share of green jobs by worker's field of study

and older), and the population living in urban areas. In addition, we also document a low prevalence of green jobs among workers with TVET degrees. These significant differences in worker characteristics and the likelihood of working in a green job suggest that the green transition may have differential effects on the labor force. Since these characteristics are positively correlated with higher wages (see Table 3), the green transition may have additional effects on the wage distribution and overall income inequality.

4.2. Wages and quality of green jobs

The occupational and sectoral distribution of employment and the attributes of green jobs described in the previous sections suggest that there are considerable differences in the prevalence of green jobs depending on the characteristics of the workers. In particular, jobs with the highest green potential are concentrated in high-skilled occupations in certain industries, and these characteristics lead to differences by gender, region, and educational attainment. Consistent with these findings, Consoli et al. (2016) present evidence for the United States suggesting that, relative to non-green jobs, green jobs tend to use more cognitive and interpersonal skills and have higher human capital measures such as formal education, experience, and on-the-job training. Typically, these features are positively correlated with wages, and several studies have found positive wage differentials in favor of green jobs even after controlling for their observed determinants (International Monetary Fund, 2022; Curtis et al., 2023).

To further examine the average wage differences between green and non-green jobs, we

estimate a wage regression of the form

$$w_i = \alpha + \delta Green_i + \beta_1 school_i + \beta_2 exper_i + \beta_3 exper_i^2 + \gamma' \mathbf{x}_i + u_i, \quad (2)$$

where w_i is the log of the hourly wage for worker i, $Green_i$ is the share of green jobs in the occupation of i, $school_i$ is their years of schooling, $exper_i$ is the potential labor market experience of the worker,[6] $\mathbf{x}_i$ is a vector of additional controls, such as gender and region fixed effects, and u_i is an error term. Our coefficient of interest is δ, which is the average (log) difference in wages of green jobs compared to non-green jobs. Although δ cannot be interpreted as causal evidence due to the potential self-selection of highly skilled workers into green occupations, it is suggestive of the benefits that workers may receive from working in the green sector. To test the sensitivity of our results to the selection of the measure of green jobs, we also run additional specifications in which we use the continuous measure of greenness (equation (1)) instead of the share of green employment.

Table 3 presents the estimation results of equation (2) using GEIH data. In our estimation, we focus on full-time workers (working at least 30 hours per week)[7] aged 20 to 60 and trim the top and bottom 1% of wages per hour. In column (1), we report the unconditional green/non-green wage gap, and in columns (2) and (3), we add controls for demographic characteristics and major industry group (ISIC). In columns (4) to (6), we repeat the same analysis but focus on the measure of green task intensity (greenness).

The results show that compared to non-green jobs, green jobs tend to have an unconditional average wage premium of 13% per hour. When we control for observable worker characteristics, the gap narrows to 6%. To account for potential sorting across industries, we also control for major industry groups, but the wage gap remains positive and significant at about 10%. Similarly, when we estimate the regression (2) using the measure of green task intensity, we find a positive correlation between green task intensity and wages.

A common concern in the prospective analysis of labor market changes at the onset of the green transition is how to reconcile these changes with fair conditions for workers. In fact, the International Labour Organization includes the idea that jobs must be "decent" in its definition of green jobs, implying that not only their task content but also job quality are necessary conditions for sustainable development (International Labor Organization, 2024). Valero et al. (2021) compare several dimensions of job quality for green and non-green jobs in the UK and find that workers in green jobs are more likely to have permanent contracts, but the likelihood of receiving on-the-job training is similar between the two groups of workers. In contrast, de la Vega et al. (2024) document the relationship between green employment and informal employment in urban Argentina, finding that about half of employment with green potential is in the informal sector.

We use information about job attributes recorded in the GEIH data to estimate differences in variables indicating the quality of jobs between green and non-green occupations. We estimate linear probability models on three indicators of job quality. First, an indicator of whether the worker works an excessive number of hours (more than 60 hours per week);[8]

[6] We approximate the potential labor market experience as $exper_i = age_i - school_i - 6$.
[7] About 12.7% of workers work less than 30 hours per week.
[8] According to regulation, the maximum number of hours that a worker can work full time in Colombia is 48 hours

Dependent Variable: wages per hour (in logs)			
	(1)	(2)	(3)
Green	0.13***	0.06***	0.10***
	(0.01)	(0.01)	(0.01)
Constant	8.52***	7.34***	7.41***
	(0.00)	(0.01)	(0.01)
Individual controls	No	Yes	Yes
Fixed effects			
Educational attainment	No	Yes	Yes
Department of residence	No	Yes	Yes
Major ISIC groups	No	No	Yes
Observations	263,411	263,299	263,299
R-squared	0.00	0.33	0.34
Dependent Variable: wages per hour (in logs)			
	(4)	(5)	(6)
Greenness	0.87***	0.41***	0.43***
	(0.04)	(0.03)	(0.03)
Constant	8.54***	7.36***	7.42***
	(0.00)	(0.01)	(0.01)
Individual controls	No	Yes	Yes
Fixed effects			
Educational attainment	No	Yes	Yes
Department of residence	No	Yes	Yes
Major ISIC groups	No	No	Yes
Observations	231,843	231,739	231,739
R-squared	0.01	0.33	0.34

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Wages regression

Dep. variable	*Excessive Hours*		*Low Pay Rate*		*Formal Job*	
Green	0.032***	-0.013***	-0.050***	-0.023***	0.029***	0.015**
	(0.003)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Constant	0.067***	0.067***	0.379***	0.812***	0.488***	0.109***
	(0.001)	(0.018)	(0.002)	(0.022)	(0.002)	(0.023)
Controls	No	Yes	No	Yes	No	Yes
Observations	263,411	263,406	263,411	263,406	263,411	263,406
R^2	0.002	0.015	0.001	0.211	0.000	0.240

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Correlation between green jobs and indicators of job quality

Figure 6: Prevalence of green jobs over the income distribution

second, an indicator of whether the worker receives low pay (less than 2/3 of the minimum wage); and third, an indicator of whether the worker is informal, defined as a worker who is not covered by the labor rights and protections established by law, such as social security, formal employment contracts, or registration of their income with the tax authorities.[9] Since these jobs are characterized by precariousness, lack of social protection, and vulnerability for those engaged in them, a large share of green jobs in these categories poses a trade-off between greening the economy and creating high-quality jobs. We restrict our sample to the same group of workers presented in Table 3 and include gender, years of schooling, a quadratic trend in age, and fixed effects by educational attainment and by department as control variables.

Table 4 shows the estimation results of the linear probability models. Each cell represents an estimate from a separate regression of the dependent variable against the share of green jobs in the occupation, both with and without controls. Our results are consistent with the idea that occupations more likely to be positively affected by the green transition are concentrated in high-skilled jobs with better working conditions. Compared to non-green jobs, workers in green occupations are 1.3 p.p. less likely to work excessive hours, 2.3 p.p. less likely to receive low pay, and 1.5 p.p. more likely to work in a formal job.

The higher representation of high-skilled, better-paid workers in green occupations is positively correlated with a higher representation of these types of workers at the top of the income distribution. We illustrate this relationship using the household income of workers reported by the GEIH. Figure 6 displays the share of green jobs by household income decile. The share of green jobs increases in the top three deciles of the income distribution: while the share of green jobs is around 20% in the lower deciles, it increases to up to 23% in the upper part of the income distribution. However, the differences are pronounced when we assess the jobs directly affected by the green transition, especially the new and emerging ones. Jobs with improved skills (GES) and new and emerging jobs (GNE) are more common in high-income households, where these types of jobs account for 20% of jobs in the top decile of the income distribution, compared to 12% of jobs in households in the first decile.

per week.

[9]The informal sector includes both self-employed workers and those who work for unregistered companies without receiving the corresponding benefits.

4.3. Worker's mobility

In addition to predicting which jobs and workers could benefit from the green transition, a second important issue in the literature studying the impact of the greening of the economy on labor markets is identifying the extent to which workers in non-green jobs could move to occupations with green potential. In studying occupational mobility, labor economics highlights two main frictions that affect labor market outcomes: skill and geographic frictions.

The first challenge in this context is that the employment boost from the green transition may be delayed if the current workforce lacks the skills to perform the tasks required in the green economy. The literature on occupational mobility has found that workers tend to move between occupations with similar task requirements, making the proximity of task requirements across occupations a relevant predictor of future job transitions (Gathmann and Schönberg, 2010). Evidence from the US has focused on whether task requirements and skills in non-green (especially "brown" or polluting) sectors are close to those in green jobs (Consoli et al., 2016; Bowen et al., 2018; Vona et al., 2018).

Following Bowen et al. (2018), we use the O*NET taxonomy of occupations to assess the potential for workers to transition from non-green to green jobs. To do this, we use O*NET's Related Occupations Matrix (ROM), a matrix that matches each occupation with up to 10 related occupations based on the similarity of the occupation's tasks, skills, and knowledge (Allen et al., 2012). By identifying occupations related to those with direct green potential (GES and GNE), we measure a worker's potential for transitioning to green jobs.

Using data from the ROM, we derive three variables to characterize the proximity of non-green jobs to jobs likely to be affected by the transition. We focus only on GNE and GES occupations. First, we compute a matrix to find the distance between any two occupations in the O*NET data. A distance of 1 between occupations i and j means that the two are directly related in the ROM, a distance of 2 means that occupations i and j are related through another occupation, and so on. If two occupations are not related, either directly or indirectly, the distance is set to infinity. Based on the distance matrix, we determine (a) whether a non-green occupation has a direct link to at least one green occupation (so the distance to a green occupation is equal to 1); (b) whether a non-green occupation has a link (direct or indirect) to at least one green occupation (so the distance to a green occupation is finite); and (c) in case there is a link to a green occupation, the distance to reach the nearest green occupation. We merge these measures with the GEIH data and compare these proximity measures across different characteristics.

Table 5 shows the average of the proximity measures derived from our analysis. We report our proximity measures by industry, gender, educational attainment, and whether the worker has a formal job. The results suggest that mobility across occupations is heterogeneous, depending on the worker's current job and characteristics. About 48% of non-green workers are in occupations with at least one direct link to a green occupation, and 93% of non-green jobs have at least one indirect link. In addition, conditional on having at least one link to a green occupation, the average distance between non-green occupations and the nearest green occupation is 1.65. Proximity is highly concentrated in sectors with a high

	Has one green direct related occupation	Has at least one green related occupation	Distance to the nearest green occupation
Sector			
Agriculture	0.63	0.86	1.3
Mining	0.75	0.90	1.2
Construction	0.87	0.98	1.1
Manufacturing	0.40	0.96	1.7
Non-market services	0.37	0.88	1.8
Market services	0.42	0.98	1.8
Gender			
Men	0.61	0.93	1.4
Women	0.31	0.94	1.9
Educational Attainment			
No school completed	0.50	0.92	1.6
High School	0.45	0.94	1.9
Technical and Vocational	0.35	0.94	1.8
University	0.53	0.96	1.5
Postgraduate	0.72	0.96	1.3
Type of employment			
Formal	0.53	0.96	1.6
Informal	0.44	0.92	1.7
Total	0.48	0.93	1.65

Table 5: Non-green jobs' proximity to green jobs

prevalence of green jobs (such as construction and mining), suggesting that the tasks, skills, and knowledge of workers in these sectors can be more easily applied to occupations with green content than workers in other sectors. Non-green workers in construction (87%) and mining (75%) have the highest proximity to green jobs, while workers in manufacturing (40%) and services (37% and 42%) have the lowest proximity to green occupations.

We also report our proximity measures based on dimensions with significant differences between green and non-green jobs. In particular, we report our proximity measures by gender, educational attainment, and formality status. Because these dimensions show substantial disparities in the prevalence of green jobs, the proximity measures provide complementary evidence on how easily the skills and tasks of these groups' current occupations can be used to transition to green jobs. Women, workers with TVET degrees, and informal workers in non-green occupations have lower proximity to green occupations than other non-green workers. Workers in these groups are less likely to be in occupations with a direct link to a green occupation, and on average, the nearest green occupation is further away than for other non-green workers. Specifically, 31% of women, 35% of workers with TVET degrees, and 44% of informal workers are in non-green occupations with at least one direct link to a green occupation, which is systematically low compared to men (61%), workers with university and postgraduate degrees (53% and 72%), and formal workers (53%). This is a worrying prospect for these groups of workers in the early stages of the green transition, not only because they are less likely to be in occupations with high green potential, but also because the skills and tasks of their occupations are less suited to transitioning to a green job.

A second challenge relates to the potential obstacles to regional development associated

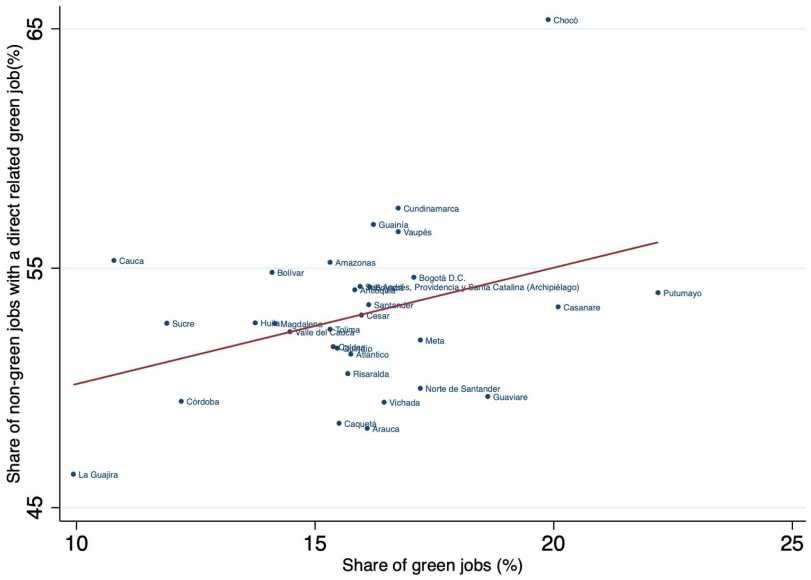


Figure 7: Green jobs and proximity to green jobs by region

with the green transition. The green transition may have different regional impacts, which may lead to frictions in the movement of workers across sectors (even if they have the skills to take up these jobs). For example, using administrative data from the US, Lim et al. (2023) find evidence that workers in the fossil fuel extraction industry have transferable skills to move to green jobs but are not located in current sources of energy production.

We explore this hypothesis by presenting the relationship between the share of green jobs (GNE and GES) and the proximity measures at the department (region) level in Figure 7. The figure shows a large regional variation in the prevalence of green jobs (horizontal axis), where the share of green jobs varies from 10% of employment in La Guajira to 23% in Putumayo. The figure also shows that non-green workers in regions with a high prevalence of green jobs have skills that are transferable to green jobs. This result suggests that regional variation is not a significant factor for the development of green jobs within a region (i.e., the transition creates jobs in regions with a high prevalence of green jobs). However, it may be a significant barrier if the country faces a transition between regions.

5. Final remarks

In this paper, we present a first assessment of the green potential of jobs in Colombia. Using an approach based on the task content of occupations, we quantify the share of Colombian workers in occupations likely to be directly and indirectly affected by the green transition. We find that about 22.6% of Colombian workers are currently employed in such occupations. Approximately 15.9% of these jobs are in occupations where their task content will be directly affected. Most of these (14%) are in occupations where the green transition will require changes in skill content, while a small share (1.9%) relates to new jobs responding to the green transition's needs.

The transition is concentrated in occupations requiring higher levels of education and skills and in certain industries, generating inequalities among workers. Jobs with direct green potential are more likely to be held by men, middle-aged workers, better-educated workers (especially those with STEM degrees), and workers living in urban areas. Additionally, green jobs tend to have higher wages, are more likely to be in the formal sector, and are higher quality jobs. Consistent with these findings, green jobs also have a higher prevalence in the upper part of the income distribution.

The evidence calls for the implementation of public policies aimed at understanding and addressing potential labor market inequalities at the onset of the green transition. In particular, education policies and skills upgrading of the workforce to meet the demands of the greening of the economy are necessary for a just transition. These policies should include additional considerations to empower workers from typically excluded and vulnerable groups. In the Colombian example, the data suggest that strengthening green-based STEM education in TVET programs with a gender and regional focus could be a promising way to achieve a more sustainable economy with economic justice (International Labor Organization, 2022). This type of policy must be complemented by an effective safety net to mitigate the negative consequences of the transition for excluded workers (World Bank, 2023; Cavallo et al., 2024).

While our assessment sheds light on existing inequalities related to the green transition, there are additional elements that need to be considered in future research, especially for developing economies. First, while the O*NET information system is a natural starting point for this type of study, it is important for national statistical offices to develop their own information systems that represent the true nature of the tasks performed in developing economies and allow authorities to monitor the evolution of green jobs over time. The Skill Council for Green Jobs program in India is an initiative to follow in other middle and low-income countries (Ham et al., 2024).

Second, there are several open questions that the growing literature on green jobs needs to address. Current information shows that the green transition appears to favor skilled workers, which may have several implications for income inequality, but it lacks a dynamic component to understand its consequences. For example, it is not yet possible to disentangle whether these changes will exacerbate income inequality, as in the discussion of skill-biased technical change (Acemoglu and Autor, 2011), or can be a disruptive force that opens new opportunities for labor reallocation of certain groups (Cortés et al., 2024).

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Publication Director Rémy Rioux
Editor-in-Chief Thomas Melonio

Legal deposit 4th quarter 2024
ISSN 2492 - 2846

Graphic design MeMo, Juliegilles, D. Cazeils
Layout Denise Perrin, AFD
Printed by the AFD reprography service

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