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Andres García-Suaza

Pamela Caiza-Guamán

Alexander Sarango-Iturralde

Bernardo Romero-Torres

Catalina Buitrago

Universidad del Rosario, Facultad de Economía
Cl. 12c #4-59. Bogotá, D. C., Colombia
PBX: (031) 2970200 ext. 4163

facultadeconomia@urosario.edu.co
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Green Jobs and the Green Transition in Latin America and the Caribbean: A Labor Market Analysis Using Job Vacancy Data

Andres García-Suaza* Pamela Caiza-Guamán†
Alexander Sarango-Iturralde‡ Bernardo Romero-Torres§
Catalina Buitrago¶

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Abstract

The green transition represents one of the most significant transformational forces in the labor market in the coming years. This paper analyzes the incidence of green jobs in four Latin American countries using information from job vacancy data. The results reveal a low incidence of demand for jobs with green potential or for new and emerging occupations related to the green transition. Such occupations are characterized by requiring high levels of education and offer a significant wage premium. These results highlight the main challenge of the green transition, which lies in the need to implement training processes, while revealing opportunities for the creation of high-quality jobs in the region.

Keywords: Labor demand, green jobs, green transition, climate change, skills.
JEL codes: J24, J62, Q52, Q58.

*Associate Professor, Universidad del Rosario and GLO research fellow.. Email: andres.garcia@urosario.edu.co.

†Master's student in Economics and research assistant, Universidad del Rosario. Email: raiza.caiza@urosario.edu.co.

‡Ph.D. candidate, Université Paris I, Panthéon-Sorbonne. Email: alexandersarangoiturralde@outlook.com.

§Master's student in Economics and research assistant, Universidad del Rosario. Email: bernardo.romero@urosario.edu.co.

¶Research assistant, Universidad del Rosario. Email: catalina.buitragog@urosario.edu.co.

1 Introduction

Climate change is likely one of the primary global concerns today, as climate stability, biodiversity, and economic development are at stake (Porto et al., 2022). Factors such as rising temperatures, an increase in extreme weather events, among others, could weaken and alter the economic structure, thereby affecting different dimensions of the economy (BID, 2021). The labour market is not immune to these impacts, prompting research on how the transition to a green economy influences labour supply and demand dynamics, and how these changes affect productivity, inequality, and other economic and social variables (Bohnenberger, 2022). Therefore, conducting analyses of potential labour market transformations is crucial for anticipating changes, seizing job creation opportunities, and mitigating potential negative impacts (OCDE, 2023).

In Latin America and the Caribbean, this process of productive transformation has begun to emerge. The region is a particularly relevant subject of study due to its comparative advantages for transitioning to a more sustainable economy. Countries in the region are rich in natural resources for biomass, wind, and solar energy production, yet they also face structural challenges such as high informality and stagnant productivity over the past decades (BID, 2021). This makes the impacts of the green transition difficult to predict, particularly in a context where the implementation of policies and regulations, such as carbon taxes and the promotion of sustainable practices, affects the labour market.

The discussion around the labour market has been framed within the concept of green jobs. This is due to the fact that increased investment in cleaner and more sustainable technologies will lead to a demand for skills that will inevitably shape the labour market. According to the International Labour Organization (ILO), green jobs refer to decent jobs that contribute to preserving and restoring the environment, whether in traditional sectors such as manufacturing or construction, or in emerging sectors like renewable energy and energy efficiency. While the concept is well established, the instruments proposed to measure it have varied.

On this regard, Porto et al. (2022) present several ways to measure the degree of green potential that a job or occupation has, including three distinct approaches: process-based approach, the final goods or service-based approach, and the task-based approach. The latter has been more extensively studied in the literature, e.g., Lobsiger & Rutzer (2021) construct a green potential index associating a measure for each occupation based on tasks and skills. Granata & Posadas (2024) and Vona (2021) argue that green jobs are better understood as those involving specific tasks aimed at reducing the environmental impact of consumers or firms, either by generating greener outputs or minimizing environmental footprints. Furthermore, Scholl et al. (2023) build on this task-based approach by constructing greenness scores and complementing them with industry-based brownness measures

Recent empirical studies have largely focused on the supply side of green jobs due to limited availability of demand-side data. In Latin America, Porto et al. (2022) and Ernst et al. (2019) analyze Argentina and find that while 25% of workers have high green potential, but only 15% are employed in formal green jobs. Green workers tend to be men with higher education levels, concentrated in construction, transport, mining, and

industry. Ernst et al. (2019) also document a green wage premium of 20%. In Colombia, findings of OCDE (2023) are aligned with those from Argentina. In addition, they show that green workers are less likely to be informally employed. Across six Latin American countries, Alfonso et al. (2022) use LinkedIn data to assess the evolution of green skills and occupations, reporting slow but steady growth in green job demand.

For Europe, Lobsiger & Rutzer (2021) estimate that between 7.1% and 16.8% of jobs in EU countries have high green potential, with concentrations in manufacturing, energy, and construction. In Switzerland, green potential reaches 16.7% of the employed population and 18.8% of full-time equivalents. The proportion of green jobs varies across different settings due to differences in methodological choices and the specific criteria employed to define green jobs.

Although less frequent, demand-side studies offer important insights (Curtis & Marinescu, 2022; Sato et al., 2022; Song et al., 2021). In the U.S., Curtis & Marinescu (2022) show that green jobs are concentrated in oil- and gas-intensive regions and are associated with a 21% wage premium, even after adjusting for education (Sato et al., 2022). Song et al. (2021) examine both supply and demand in South Korea, finding that green jobs are clustered in the Seoul metropolitan area, particularly in sectors related to air and water quality.

Building on this emerging literature, this paper provides novel demand side evidence for Latin America, a region where such analyses remain limited, We analyse the characteristics of labour demand through the lens of green jobs using Ecuador, Colombia, Mexico, and Peru as case studies. Due to the difficulty of accessing information on labour demand systematically, data from online job advertisements are used. A demand study allows for the exploration of key questions regarding the energy transition, such as: What skills are required to perform a green job? Do green jobs demand higher levels of education? Can the low-carbon transition improve labour market conditions for low-skilled workers? What role do reskilling and upskilling play in reducing inequality in the context of the green transition?.

To provide insights into addressing these questions, information on job vacancies is collected from online job portals to capture labour demand characteristics, such as occupation and the potential for green task content. To quantify the demand for green jobs, using natural language processing, we assign an occupation code and a level to a green potential index. For this purpose, we use two different alternative measures. First, a continuous measure of the green potential of an occupation proposed by Lobsiger & Rutzer (2021) and named as GOJI (Greenness-of-Jobs Index) by Bachmann et al. (2024), and second, the green categories according to the Occupational Information Network (O*NET), which distinguishes three types of green occupations: New and Emerging, Enhanced Skills and Increased Demand.

Our study focuses on four representative countries in the region, where recent efforts have also been observed to promote the green transition. The initiatives taken by these countries to achieve carbon neutrality are based on the understanding that the effects of transitioning to a green economy are diverse. The literature indicates that these effects can be positive, reflecting on economic growth and employment, as well as the reduction of greenhouse gas emissions. However, the OCDE (2023) states that while the green

transition may have a positive impact on job creation in some potentially green sectors, it is also possible that it generates uncertainty and leads to a contraction of growth and employment in non-green sectors. Similarly, Sato et al. (2022) argues that a transition to low-carbon emissions will involve the reallocation of workers to low-carbon activities, while the skills demanded by high-carbon activities may be lost as jobs shift.

In light of these potential trade-offs, understanding the current state of green labour demand becomes essential to guide policy and workforce development. Our results suggest that the green potential component of demand in the studied countries reaches levels below 10%. This indicates that there is latent demand for green skills, but highlights the need and opportunity to expand green job creation. Green jobs are characterized by high educational requirements and a significant wage premium. Additionally, skills associated with energy adoption, environmental practices, and ecosystem conservation are consistently observed in all four countries. These results serve to identify emerging trends in the green labour market.These findings will help policymakers to align their economic development and employment strategies with the needs of the green labour market, thus promoting a just transition.

The paper is structured as follows. The second section provides a general context of the green jobs definitions. The third section briefly discusses the context of the studied countries, while the fourth presents details on data and methodology. The results are presented in section five, and the concluding remarks are detailed in the sixth section.

2 Green jobs: definition and general considerations

According to the OIT (n.d) green jobs are defined as decent jobs that contribute to preserving and restoring the environment, whether in traditional sectors such as manufacturing or construction, or in emerging sectors like renewable energy and energy efficiency. However, obtaining measurements that capture this definition presents significant challenges particularly in identifying the characteristics that define whether a job qualifies as green. According to Vona et al. (2019) identifying a green job is complex for two reasons. The first is deciding whether a green job focuses on reducing the harmful consequences of pollution and resource exploitation or if it is an activity dedicated to preventing pollution by reducing the use of energy and materials. The second challenge arises from limitations in data collection by national statistical offices. Nevertheless, some authors have noted that the lack of a standardized global measurement of green jobs hinders efforts to estimate the number of people working in green industries or performing green-related tasks (Sulich et al., 2020).

In methodological terms, different dimensions have been considered to categorize a job as green. In particular, classification can be based on the sector where the activity is conducted or on the tasks performed by a worker. From the sectoral perspective, jobs in sectors such as water, sanitation, waste collection, or those associated with renewable electricity generation are classified as green jobs (Sato et al., 2023). However, this sector-level approach is not granular enough to accurately capture low-carbon activity. Furthermore, it provides an incomplete definition because decarbonization affects all corners of the economy (Vona et al., 2019; Sato et al., 2022). Alternatively, Janser

(2018) proposes an approach based on the final product or service produced. However, this approach is limited by the fact that many companies do not exclusively produce or deliver environmental goods and services, even if they use methods that contribute to environmental preservation.

Despite the lack of consensus on how to define or identify a green job, the task-oriented approach has emerged as the most comprehensive method in the literature.Consoli et al. (2015) and Vona et al. (2018) were pioneering studies in applying this approach to identify green jobs. Similarly, Levinson (2015) and Bachmann et al. (2024) argue that the task-oriented[1] approach is more suitable for capturing heterogeneity within sectors, i.e., defining all jobs within a sector as green overlooks the contribution of each occupation within the sector to the goal of preserving the environment and reducing emissions.

Lobsiger & Rutzer (2021) introduce the concept of green potential, which refers to occupations where workers already possess the skills required to perform green tasks. Vona et al. (2019) show that occupations with higher green potential depend largely on technical and engineering skills to address and implement solutions to specific environmental problems. These studies are based on the construction of a greenness potential index, which is based on the skills and the number of green tasks relative to the total number of tasks performed in an occupation.

An alternative analytical perspective is the one proposed by the Occupational Information Network (O*NET), which provides three categories of occupations with a policy-oriented focus[2]. This approach classifies occupations into three groups: Green New and Emerging, Green Enhanced Skills, and Green Increased Demand. The first category, Green New and Emerging occupations, includes new roles that have arisen as a direct result of the green transition. Green Enhanced Skills, refers to existing occupations that are evolving due to new environmental requirements. The core functions remain the same, but additional skills or knowledge are now necessary. Green Increased Demand, encompasses traditional occupations that do not necessarily change in content but are expected to grow in volume as sustainability efforts expand.

This classification has been adopted in empirical studies aiming to understand how the green economy reshapes occupational structures. The original framework was developed by the U.S. Department of Labor and detailed by Dierdorff et al. (2009). Consoli et al. (2015) also use this taxonomy to examine the skill composition of green occupations and find that both Green New and Emerging and Green Enhanced Skills occupations are associated with higher levels of education compared to non-green jobs. Similarly, Tsironis (2023) using these three groups highlight how occupations differ in terms of reskilling needs, with Green New and Emerging jobs requiring entirely new profiles, Green Enhanced Skills involving substantial task changes, and Green Increased Demand reflecting traditional roles growing in prevalence.

[1]For the task-oriented approach, it is necessary to distinguish the differences between tasks and skills. According to Autor & Dorn (2021), a skill is the endowment of capabilities in a worker to perform various tasks. Workers apply their skill endowment to tasks in exchange for wages, and the skills applied to tasks yield outcomes. Therefore, both workers' skills and job tasks can change over time and can be reallocated if skills and/or tasks change within the work context

[2]Green occupation classifications are available at: https://www.onetcenter.org/dictionary/22.0/excel/green_occupations.html.

3 Context of the cases of study

In the last decade, the term green economy, focusing on resource efficiency and social inclusion, has been driven by the international agenda and multilateral agencies (UNEP, 2011; Scholz & Fink, 2022). Many countries have adopted policies to move towards a circular economy with economic benefits, job creation and reduction of greenhouse gas emissions (Martinez-Fernandez et al., 2010). Global efforts to achieve green transition have been evident through initiatives like the Paris Agreement, which aims to prioritize climate change on the political agenda. The agreement came into effect on November 4, 2016, with its primary goal being to achieve a carbon-neutral economy by 2050, mainly by reducing global warming (ONU, 2015). This agreement encouraged all countries to commit to a common cause. However, when the focus is on Latin American and Caribbean countries, it is clear that to achieve the goal of a carbon neutral economy, it is necessary to decouple the positive association between greenhouse gas emissions and population growth, GDP and energy consumption(Saget et al., 2020; Galindo et al., 2022).

Specifically, in our four analysed countries, such as the case of Colombia, policy frameworks have been implemented to promote the green transition and address climate change. Globally, the country participates in the United Nations Framework Convention on Climate Change (ONU, 1992), the Kyoto Protocol (ONU, 1998) and the Paris Agreement (ONU, 2015). At the national level, the 2017 National Climate Change Policy (MADS, 2017) established the strategic guidelines for promoting a climate-resilient and low-carbon development model across sectors and territories and the 2018 Climate Change Law (Congreso de Colombia, 2018) that establish the base guidelines for climate change management in Colombia. More recently, Law 2169 of 2021 (Congreso de Colombia, 2021), known as the Climate Action Law, set national targets for carbon neutrality and climate resilience, and introduced principles for a just transition that align climate action with food security, poverty reduction, and biodiversity protection. Finally, the current National Development Plan 2022–2026 (Congreso de Colombia, 2023) places sustainability at the center of Colombia's development strategy, prioritizing investments in clean energy, reforestation, sustainable mobility, and regional climate adaptation.

Ecuador has established a robust policy framework to advance climate action and a green transition (OCDE et al., 2022). The cornerstone of its climate policy is the National Climate Change Strategy 2012–2025 (ENCC), which outlines goals for both mitigation and adaptation across key sectors such as energy, agriculture, water, and health, while emphasizing principles like citizen participation and the protection of vulnerable ecosystems (Ministerio del Ambiente, 2012). To implement the ENCC, the government introduced the National Climate Change Mitigation Plan (PLANMICC), which sets an ambitious target of reducing greenhouse gas emissions by 70% by 2070 compared to a business-as-usual scenario (Meurer & Soria, 2024). In parallel, National Pact for a Circular Economy, signed in 2019 by more than 330 stakeholders, and the 2021 Organic Law on Inclusive Circular Economy aim to promote sustainable production and consumption, as well as inclusive waste management practices (European Commission, 2023). Moreover, the country has begun developing a green hydrogen roadmap and launched the Master Plan for Electricity 2023–2032, which prioritizes renewable energy expansion and energy efficiency (Ministerio de Energia y Minas, 2023).

Mexico has also developed an institutional framework to guide its transition to sustainable energy sources and more responsible energy use. The Energy Transition Law of 2015 regulates the sustainable use of energy and establishes binding targets for the participation of clean energy in electricity generation (Cámara de Diputados, 2015). The law sets ambitious goals: 25% of electricity from clean sources by 2018, 30% by 2021, and 35% by 2024. To support these objectives, the law mandates the issuance of Clean Energy Certificates and the design of strategic planning instruments, including the National Strategy for Energy Transition and the Special Energy Transition Program 2019–2024. The latter outlines concrete measures to increase the share of renewable sources in the national energy mix (Secretaría de Energía (SENER), 2019). Despite these efforts, Villavicencio & Millán (2020) highlight significant challenges and institutional tensions in the implementation of the country's energy transition agenda.

Similar policies and strategies have been implemented to address energy transition and promote the use of renewable energies in Peru (Sierra, 2024). Legislative Decrete No. 1002 of 2008 is a fundamental instrument that encourages investment in renewable energy projects by providing incentives such as priority in dispatch and long-term contracts through public auctions. It also sets an initial target for renewable energy to contribute at least 5% to the national electricity consumption, excluding large hydroelectric plants over 20 MW (Government of Peru, 2008). Complementing this, the National Energy Policy 2010–2040, aims to diversify the energy matrix by prioritizing renewable sources and energy efficiency (Government of Peru, 2010). The policy seeks to ensure a competitive and affordable energy supply, achieve universal access to energy, and minimize environmental impact.

Despite the progress made in designing and implementing climate and energy transition policies across these four countries, the path toward the creation of green jobs remains less defined. While governments have set clear targets for decarbonization and introduced regulatory frameworks for renewable energy and sustainable production, these strategies do not translate directly into labor market transformations. As a result, the extent to which these policy frameworks are fostering the emergence of green occupations or supporting workers through a just transition remains uncertain. This disconnection raises important questions about how the green transition is shaping labor demand and supply, the quality of new jobs created, and the inclusivity of these opportunities across different sectors and populations.

4 Data and Methodology

4.1 Information Processing

To address the limited information on labour demand, this study relies on online job vacancy postings, which offer rich and structured information on qualifications, required skills, and tasks. Such data allow for a systematic analysis of labour market trends and demands (Kureková et al., 2015; Beblavỳ et al., 2016). The workflow is described in 7.1. First, we selected the job portals based on the availability of information for the countries under study. We took into account the following aspects: the number

of available vacancies for each country, to have enough observations to conduct a more precise analysis; the number of visits, which approximates the number of website users; the frequency of page updates; and the quality of the information. To obtain the data, we implement the web-scraping technique, which allow to extract information available on websites.

Data from vacancies present several advantages over traditional data sources, especially in terms of cost and the ability to create different target samples (Horton & Tambe, 2015). However, there are also limitations due to the potential lack of representativeness for the entire universe of job vacancies (Evans et al., 2023). In addition, job vacancy announcements may often not reflect information about the specific skills required by the employer, making it difficult to accurately assess the demand for skills (Zilian et al., 2021).

In order to obtain an structured database, we proceeded to search for the specific fields of the necessary variables and text analysis using Natural Language Processing to extract information from the description of the job vacancies that are not found in specific fields. The data were collected between February 26, 2023, and August 31, 2023. Table 1 presents the number of vacancies downloaded by country, with a total of 883,548 job vacancies processed. Appendix 7.2 presents the key variables for this research that were identified from the two job portals.

Country	**Vacancy Number**
Colombia	270,631
Ecuador	16,003
México	353,886
Perú	243,828
Total	883,548

Tabla 1: Own elaboration based on vacancy information

Once the job vacancy information is captured, the next step is to clean and homogenize the variables. Initially, duplicate values are removed using a unique identifier for each job vacancy, and duplicates are identified based on the title and description of the job post. Subsequently, the text is standardized by converting it to lowercase, removing accents, and separating variables that are in the same field. Then, stop words are removed to facilitate text analysis.

Two fundamental aspects of the proposed methodological approach are: classifying each job vacancy according to the description into a standardized occupation classification to facilitate statistical analysis and comparability with other studies; and second, inferring the skills required for each vacancy. Both aspects are explored using natural language processing. For the determination of occupation codes, we implement the occupational imputation model proposed by Garcia-Suaza et al. (2025), which adapts the CUOC to the methodology of the R package LabouR, developed by Kouretsis et al. (2020). LabourR library[3] assigns a 4-digit ISCO code to each vacancy. The process begins with the cleaning and tokenization of the input text. These tokens are compared with the occupation vocabulary of ESCO (European Skills, Competences, Qualifications, and Occupations).

[3]The classification process of this package involves a vectorization process, providing high computational performance.

Then, they are combined with the weighted tokens of ESCO occupations, using the TF-IDF[4] score to identify suggested ontologies.

Table 2 shows examples of job vacancies and their assignment to a 4-digit occupational group. In Advertisement 2, it can be observed that a vacancy with the title Automotive Mechanical Technician whose functions are related to vehicle maintenance and repair, is classified in the group of Motor Vehicle Mechanics and Repairers of the ISCO-08. Similarly, a vacancy with the title Internist in the health field is classified within the group of medical specialists.

	Title + Description	ISCO-08 Code	Occupation Title
Ad 1	Automotive mechanical technician. A major company dedicated to the sale, commercialization, and maintenance of vehicles and spare parts for cars, is seeking an automotive technician to carry out maintenance tasks according to the repair manual, aiming to guarantee quality service in vehicle maintenance and repair.	7231	Motor vehicle mechanics and repairers
Ad 2	Internist. A health sector entity is looking to hire an internal medicine physician to work on a fixed weekly and weekend schedule depending on assignment. Permanent contract with full legal benefits.	2212	Medical specialists

Tabla 2: Examples of vacancies and their classification in the ISCO-08 taxonomy

4.2 Identification of Green Jobs

We focus our analysis on a task-oriented approach. This involves considering activities e.g. monitoring and analysing energy consumption, as well as analysing and interpreting energy data using specialized software. These tasks are considered green due to their contribution to the transition towards more sustainable and environmentally friendly technologies. The concept of green potential refers to occupations in which workers already possess the skills, knowledge, and abilities required to perform those green tasks, even if their current roles are not classified as green. This concept is developed by Lobsiger & Rutzer (2021), who propose a continuous index to quantify the degree of greenness at the occupational level. In this study, we adopt their index and, following Bachmann et al. (2024), we refer to it as the Greenness-Of-Jobs Index (GOJI).

Lobsiger & Rutzer (2021) determine the green potential of European labor markets through the information provided by O*NET about the green tasks of an occupation, which is classified based on the Standard Occupational Classification (SOC)[5]. To extrapolate the green potential analysis using other occupational classification systems, Lobsiger & Rutzer (2021) associate a GOJI for each 3-digit ISCO occupation (see Table 3 for some examples).

[4]"Term Frequency-Inverse Document Frequency" (TF-IDF) is a natural language processing metric that highlights important keywords in a document within a larger set of documents.

[5]The SOC is used in both the United States and Europe. In other contexts, such as Latin America, the occupational classification system used is the International Standard Classification of Occupations (ISCO), known as CIUO by its initials in Spanish.

ISCO-08	Title	GOJI
214	Engineering Professionals (excluding Electrotechnology)	1
312	Mining, manufacturing and construction engineering supervisors	0.75
741	Installers and repairers of electrical equipment	0.51
713	Painters, façade cleaners and related	0.32
532	Personal care workers in health care services	0

Tabla 3: Examples of green potential with occupations classified under ISCO at 3 digits
Notes: Autors' elaboration based on Lobsiger & Rutzer (2021).

Once job vacancies have been classified into occupations under the ISCO taxonomy, thresholds are determined to categorize the occupations into three groups of green potential: low (GOJI ≤ 0.3), medium ($0.3 <$ GOJI < 0.7), and high (GOJI ≥ 0.7). The highest proportion of high green potential jobs is found in Ecuador, with 16.10% of the total job vacancies. Following Ecuador is Colombia, with around 12.6% of vacancies having high green potential (Table 4). Ecuador also leads in the proportion of job vacancies with medium green potential (52.18%), followed by Mexico (50.46%), Peru (48.13%), and Colombia (45.42%). Green jobs with low green potential are most frequently found in Peru (43.33%), Colombia (41.97%), and Mexico (40.82%).

Green Potential	Colombia	Ecuador	México	Perú	Total
High	12.61%	16.10%	8.72%	8.54%	10.00%
Medium	45.42%	52.18%	50.46%	48.13%	48.30%
Low	41.97%	31.71%	40.82%	43.33%	41.70%

Tabla 4: Vacancies according to green potential level
Notes: Autors' elaboration based on vacancies. The categories are defined as follows: low green potential (GOJI 0.3), medium green potential ($0.3 <$ GOJI < 0.7), and high green potential (GOJI 0.7).

4.3 Mapping skills

A complementary analysis to the green potential study involves inferring the skills and knowledge that employers demand. To do so, we use the dictionary provided by ESCO classification, which describes, identifies, and classifies professional occupations, skills, and qualifications. This dictionary contains 13,890 terms and phrases related to skills and knowledge[6]. Using ESCO offers several advantages compared to other skills and knowledge dictionaries. Among these are its international standard, availability in multiple languages including Spanish, and clearly defined skills, which facilitate text mining implementation.

Within these skills and knowledge, ESCO provides a collection of 570 so-called green skill. The methodology for identifying skills and knowledge in the job vacancy databases follows the concept used in the occupational classification methodology. Specifically the TF-IDF algorithm, to capture the similarity (distance) between the text of the vacancy titles and descriptions and each of the skills and knowledge in the ESCO dictionary. Table

[6]ESCO defines knowledge as the result of assimilating information through learning. In contrast, a skill is the ability to apply knowledge and use it to complete tasks and solve problems.

5 provides an illustrative example to explain the construction of the skills and knowledge database. In Advertisement 1, two types of knowledge were found: cleaning techniques and chemicals. In Advertisement 2, two types of knowledge and one skill were found: accounting, economics, and teamwork, respectively.

	Description
Job ad 1	brilladora el diamante is seeking general services workers for palmira male high school graduates with experience in cleaning and maintenance in shopping centers, offices, stores, restaurants. minimum experience of 6 months, the worker must carry out the daily cleaning routine following the procedures for specific tasks, comply with the established procedures to carry out the cleaning and disinfection activities, ensure permanent conditions of cleanliness and cleaning techniques in the assigned area, prepare the chemical products according to company procedures, keep cleaning rooms and carts tidy, and use personal protective equipment to complete the task. minimum wage + legal benefits + bonuses.
Job ad 2	— please read before applying — important logistics company is looking for technologists in business administration, accounting, finance or economics to fill the position of portfolio analyst with excellent command of the siigo program. minimum 3 years of experience in similar roles, experience in portfolio collection and client management, accounting and tax knowledge. must have competencies such as: teamwork, customer orientation and results, analytical problem solving, planning and organization.

Tabla 5: Structure of the ESCO Skills and Knowledge Database

Notes: Autors' elaboration based on vacancies.

In this way, after conducting an initial search of the complete dictionary of skills and knowledge in each job offer the identified skills and knowledge were double checked. The result of this cleaning process revealed a pattern of errors, specifically homonymy. This type of error involves a perfect match between a term in the ESCO dictionary and the job offer description, even though the ESCO knowledge or skill does not fit the context used in the offer description. For example, the term "photography" was found in the description of a job vacancy. However, ESCO defines this knowledge as the "art and practice of creating aesthetically pleasing images by capturing light or electromagnetic radiation," while it was found that the reference in the job description referred to the request for a resume with a photograph of the applicant.

5 Results

This section presents the findings of our analysis, organized into four parts. First, we examine the green potential index in job vacancies across the four countries under study, followed by an assessment of the relationship between wages and this index. Additionally, we present results based on the occupational groups defined by O*NET, and finally, we discuss the key skills associated with the demand for green jobs.

5.1 Demand for green jobs

A descriptive and comparative analysis of the countries under study is conducted using the GOJI and the observed characteristics of job vacancies. To analyse the magnitude of the incidence of green jobs, we compute the share of GOJI categories (See Figure 1).It is observed that the proportion of job vacancies with high green potential ranges between 8% and 16%, a significant variation considering the similarity of the analysed countries. In this case, the highest proportion corresponds to Ecuador, while the lowest proportion is recorded in Peru. Additionally, around 45% and 52% correspond to job vacancies with medium green potential. This scenario highlights the potential transformation of the labor market. In particular, OCDE (2023) presents an optimistic outlook, estimating a net cumulative increase in green job creation of around 34% by 2030. These estimates represent a baseline for this potential trend. This result is based on a scenario that assumes the implementation of a high-impact mitigation policy and a steady increase in investment directed towards sectors with high green potential.

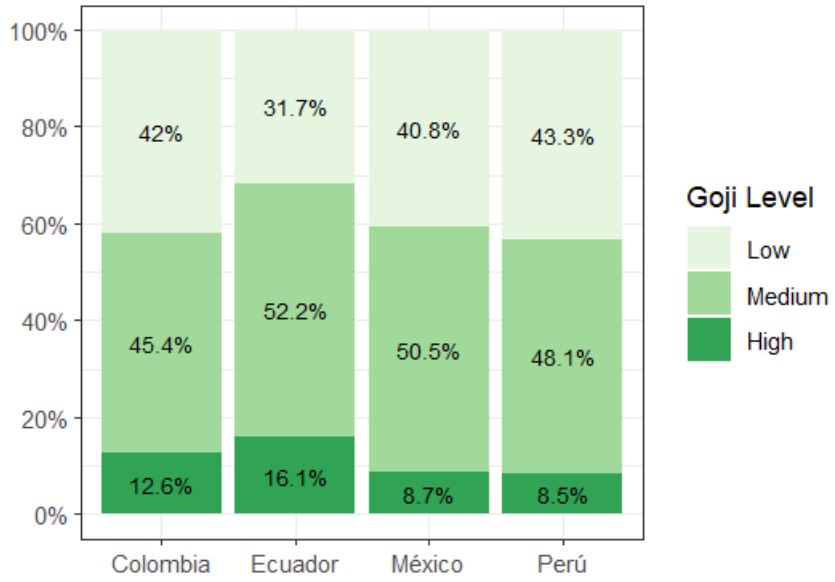


Figure 1: Green potential in vacancies

Notes: Autors' elaboration based on vacancies. The categories are defined as follows: low green potential (GOJI 0.3), medium green potential (0.3 < GOJI < 0.7), and high green potential (GOJI 0.7).

Occupations with green potential have particular characteristics. To identify these features, the composition across ISCO categories is analysed, as shown in Figure 2. The highest green potential index is observed for Managers. This group is responsible for planning, directing, coordinating, and evaluating the general activities of businesses, governments, and other organizations, as well as formulating and reviewing their policies, laws, standards, and regulations. The highest green potential is found in occupations that are associated with higher levels of human capital. Indeed, the second group corresponds to Professionals who are involved in increasing the existing stock of knowledge; applying scientific or artistic concepts and theories; teaching the aforementioned systematically.

In contrast, the lowest levels of green potential is reported by Clerical support workers

who perform functions such as recording, organizing, storing, calculating, and retrieving information. Overall, these findings reveal that countries have similarities in potential composition, showing the greatest differences among professionals. Interestingly, high levels of green potential are also observed for skilled Agricultural and Craft and Related Trades Workers. This raises a scenario where mid-skilled jobs are likely to have a lower level of dynamism in the transition to greener economies.

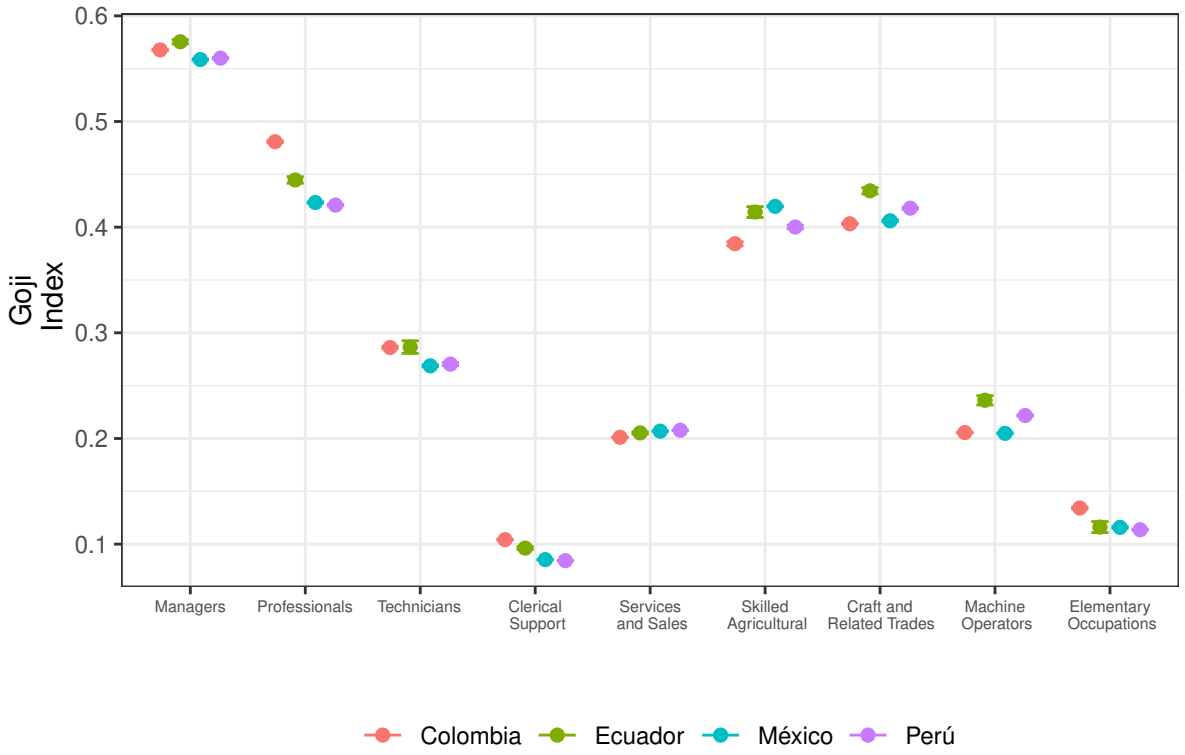


Figure 2: Green potential and main groups of ISCO-08

Notes: Autors' elaboration based on vacancies. The categories are defined as follows: low green potential (GOJI 0.3), medium green potential (0.3 < GOJI < 0.7), and high green potential (GOJI 0.7).

A fundamental element of the green transition is the development of relevant skills. These skills, considered emerging, will be acquired through vocational training but will generally also require higher education levels. Figure 3 shows that, unlike Ecuador, in Colombia, Mexico, and Peru, the proportion of vacancies requiring university education increases with the level of green potential. Similarly, it is observed that in all analysed countries, the proportion of vacancies requiring secondary education decreases with the level of green potential. This may indicate the dynamics of the labour market transformation and the strategies that countries are adopting to accelerate the green transition. For instance, in Colombia, for example, 34% of the job vacancies with low green potential require university education, while 55% of that with high green potential require university education. A similar relationship is observed for Mexico and Peru. This preliminary result is consistent with the findings of Lobsiger & Rutzer (2021), Darendeli et al. (2022), Porto et al. (2022), and Sato et al. (2023), who show that green jobs are more frequently associated with higher levels of education.

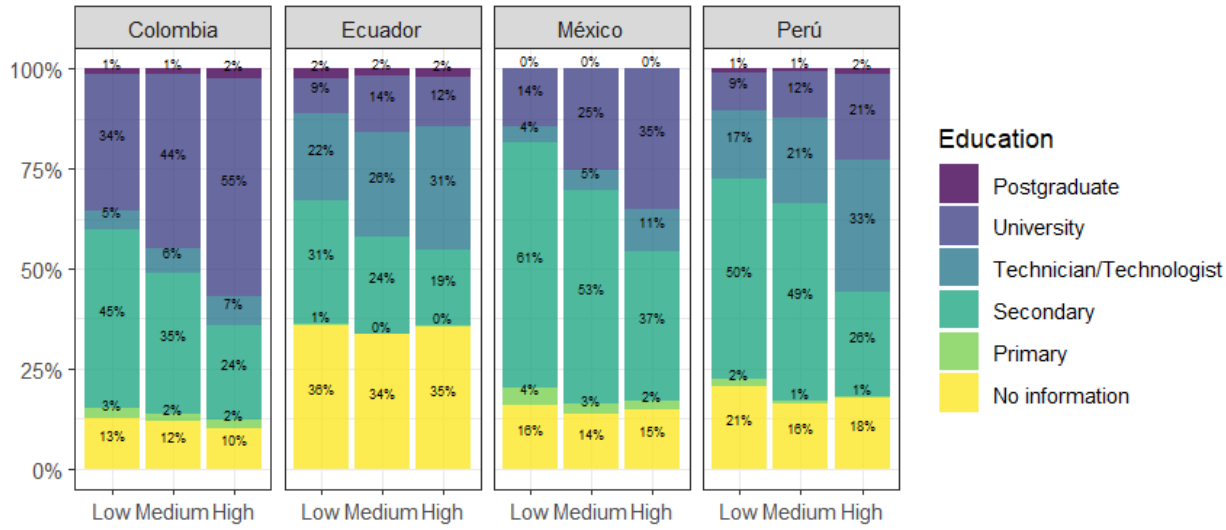


Figure 3: Education level in each green potential category

Notes: Autors' elaboration based on vacancies. The categories are defined as follows: low green potential (GOJI 0.3), medium green potential (0.3 < GOJI < 0.7), and high green potential (GOJI 0.7).

5.2 Salary premium for green jobs

In general, structural transformations of economies are linked to the emergence of highly productive activities. To analyze this aspect in the green transition, we examine the presence of wage returns in green jobs. The previous results suggest that green jobs tend to require higher levels of education, so it is expected to observe a wage premium. However, the composition of jobs with higher potential is diverse, and therefore, it is important to address this question systematically. Usually, salary information is a complex variable to capture; however, our data source facilitates its collection. Therefore, a descriptive analysis of wages, combined with expected experience, according to green potential groups is performed. Findings are also contrasted using regression models.

Table 6 shows both the average salary and the average required experience by green potential categories[7]. These estimates confirm that jobs with high green potential offer a higher salary. In the case of Colombia, jobs with high green potential are 1.09 and 1.15 times higher than the wages of jobs with medium and low green potential, respectively. This salary ratio is 1.15 and 1.23 for Ecuador, 1.17 and 1.36 for Mexico, and 1.23 and 1.43 for Peru. This implies that the green transition can generate high-quality jobs. Noticeable, the required experience does not differ much between high and medium green potential.

[7]Salary values that were above the 95th percentile and below the 5th percentile were removed for each country and green potential level. wages are expressed in dollars and experience is expressed in years.

Country	Green Potential	Wages		Required Experience	
		Average	Standard deviation	Average	Standard deviation
Colombia	High	378.62	148.85	1.99	1.44
	Medium	348.18	122.4	1.7	1.15
	Low	328.01	105.49	1.51	0.97
Ecuador	High	651.88	244.91	2.27	1.58
	Medium	566.85	173.74	2.37	1.54
	Low	528.29	132.07	1.87	1.18
México	High	692.48	282.6	2.04	1.4
	Medium	590.86	225.8	1.72	1.17
	Low	510.1	157.37	1.45	0.94
Perú	High	856.59	897.33	2.08	1.56
	Medium	696.16	740.69	1.64	1.19
	Low	597.22	608.55	1.45	1.03

Tabla 6: Salary and experience required according to green potential and country
Notes: Autors' elaboration based on vacancies. The categories are defined as follows: low green potential (GOJI 0.3), medium green potential (0.3 < GOJI < 0.7), and high green potential (GOJI 0.7).

With the aim of considering the relationship between GOJI and wages beyond the average, Figure 4 presents the dispersion of these two variables. A positive relationship between GOJI and wages is observed, although the slope varies across countries. For instance, Ecuador appears to have a higher greem premium. In general, jobs with higher green potential tend to offer higher wages. This relationship is also found by Porto et al. (2022) who argue that green jobs have higher levels of education, and as they are more qualified, their wages tend to be higher.

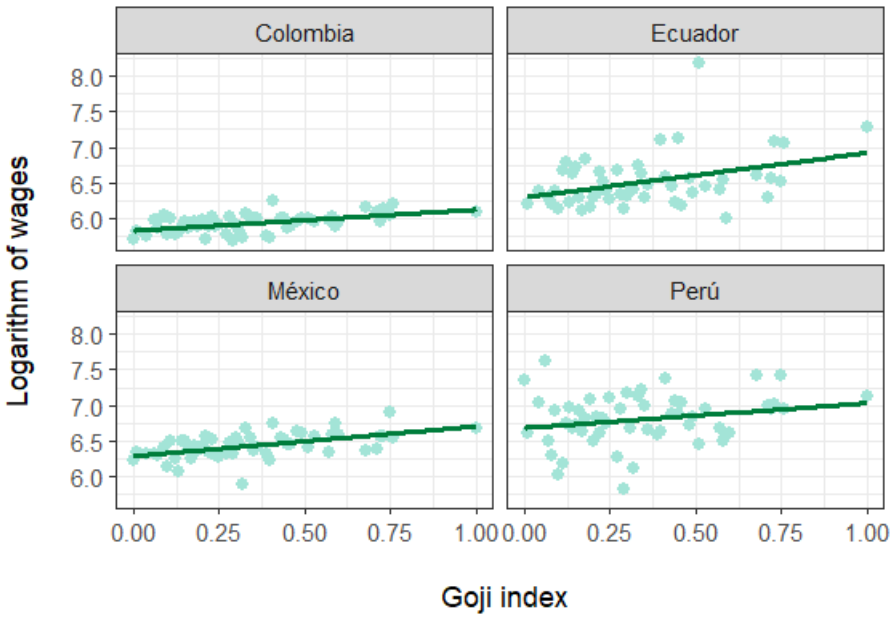


Figure 4: Relationship between green potential and logarithm of salary
Notes: Autors' elaboration based on vacancies.

In order to present systematic evidence on the relationship between wages and green potential, salary equations are estimated following the specification of Equation (1):

$$w_{i,j} = \beta_0 + \beta_1 Goji_{i,j} + \beta_2 Goji^2_{i,j} + \beta_3 Exp_{i,j} + \gamma_j + \beta_4 uni_{i,j} + \beta_5 post_{i,j} + \varepsilon_{i,j} \quad (1)$$

Where $w_{i,j}$ is the logarithm of the offered wages in job vacancy i in country j; $Goji_{i,j}$ is the green potential index of vacancy i in country j; and $Exp_{i,j}$ denotes the required experience in years. The terms $uni_{i,j}$ and $post_{i,j}$ are dummy variables that equal 1 if the vacancy requires university or postgraduate education, respectively. γ_j represents country fixed effects that control for unobserved heterogeneity across countries.

In additional specifications, we introduce interaction terms to explore heterogeneity in the wage premium associated with green jobs. Specifically, we estimate models including the interactions between green potential and education levels, as well as between green potential and country dummies, to examine whether the returns to green potential differ by country or level of education.

Table 7 presents the results of regression models. In column 1, the estimates suggest a positive and statistically significant relationship between the green potential of a job and the offered wage. Specifically, a one-unit increase in the GOJI index is associated with an average increase of 16.1% in wages. To explore potential nonlinearities, a quadratic form of the green potential index is included, but no supporting evidence is found. Other nonlinearities tested include whether the green salary premium varies by education level or across countries. In this case, the results show that Peru has the highest green premium, while the premiums in the other three countries are statistically indistinguishable.

	(1)		**(2)**		**(3)**		**(4)**	
Goji	0.161	***	0.293	***	0.120	***	0.114	***
	(0.029)		(0.090)		(0.041)		(0.026)	
Goji^2			-0.136					
			(0.087)					
Collegue education * Goji					0.087			
					(0.057)			
Postgraduate education * Goji					0.304			
					(0.313)			
Ecuador * Goji							0.052	
							(0.052)	
México * Goji							0.019	
							(0.067)	
Perú * Goji							0.226	**
							(0.098)	
Observations	11.361		11.361		11.361		11.361	
R-square	0.17		0.17		0.17		0.17	

Tabla 7: Wage regressions

Notes: Own elaboration based on vacancy information. The dependent variable is the logarithm of wage offered in the vacancy. Robust standard errors in parentheses. *** p < 0.01; ** p < 0.05; * p < 0.1. The estimates also include variables such as: web portal, experience and country.

5.3 Demand for green jobs according to O*NET categories

While the GOJI provides a continuous measure of the level of green potential of occupations, there are alternative classifications that can be used for analysing the evolution of the labour market. In particular, O*NET proposes a classification of green jobs into three

types: new and emerging green jobs, green jobs with enhanced skills, and green jobs with increased demand. Analyzing these occupational groups can provide valuable insights for policy design, particularly in distinguishing between strategies focused on reallocating trained workers and those aimed at upskilling in emerging green skills.

The incidence of each of these groups is similar across countries. According to Figure 5, the highest participation within each country is attributed to non-green occupations, reaching levels of 54.7% in Mexico. The results show similarities with the groups, i.e., for new and emerging green skills occupations, the highest percentage is observed for Ecuador, although the differences between countries are significantly small. In fact, new and emerging occupations are characterized by requiring higher educational levels (see Figure 10 in Appendix 7.3). This is also consistent with the fact that such occupations are predominantly professional (see Figure 11 in Appendix 7.4). Additionally, Ecuador concentrates the highest proportion of green jobs with enhanced skills (27.7%). Colombia and Peru have a very similar proportion of green jobs with increased demand (16.1% and 15.9%, respectively). Finally, the highest proportion of new and emerging green jobs is found in Ecuador (8.3%).

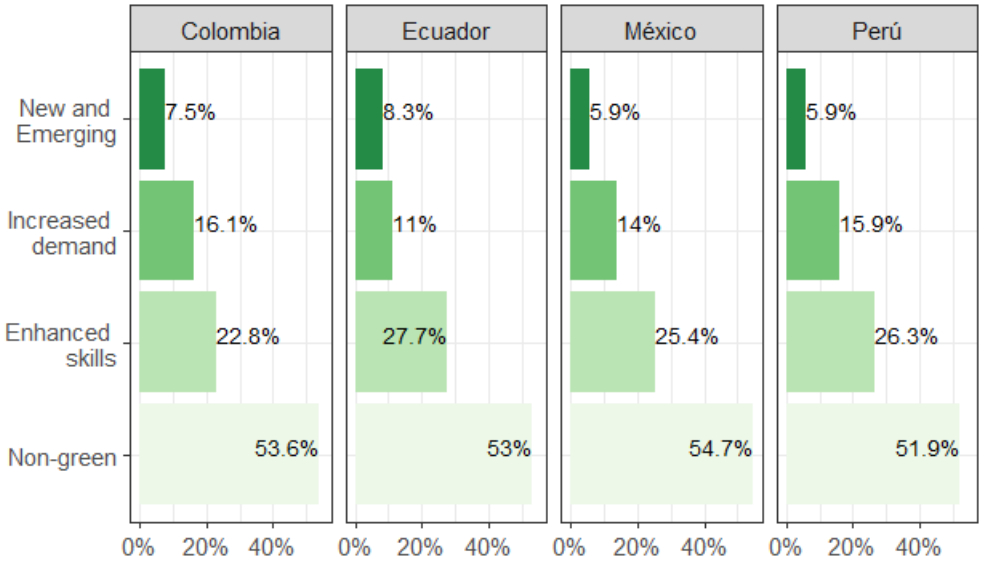


Figure 5: Proportion of jobs according to O*NET categories by country

Notes: Autors' elaboration based on vacancies.

An analysis of the green potential index by O*NET categories reveals a consistent pattern across countries (See Figure 6). Occupations classified as New and Emerging exhibit between 30% and 40% of high green potential occupations in all four countries, reaching up to 46.6% in Ecuador and 41.5% in Colombia. These are followed by Enhanced Skills occupations, which in most countries show a strong presence of medium green potential, more than 90% in Ecuador and the lowest value belongs to Colombia with 86.9%.

In contrast, occupations in the Increased Demand and Non-Green categories tend to

concentrate in the low green potential range. Specifically, the Increased Demand group shows high shares of low potential, exceeding 70% in Peru (73.5%) and Mexico (72%). This pattern aligns with the conceptualization by Dierdorff et al. (2009), who emphasize that such occupations are not inherently green, but rather experience rising demand as a secondary effect of the green transition.

Figure 6: GOJI vs O*NET categories by country

Notes: Autors' elaboration based on vacancies. The categories are defined as follows: low green potential (GOJI 0.3), medium green potential (0.3 < GOJI < 0.7), and high green potential (GOJI 0.7).

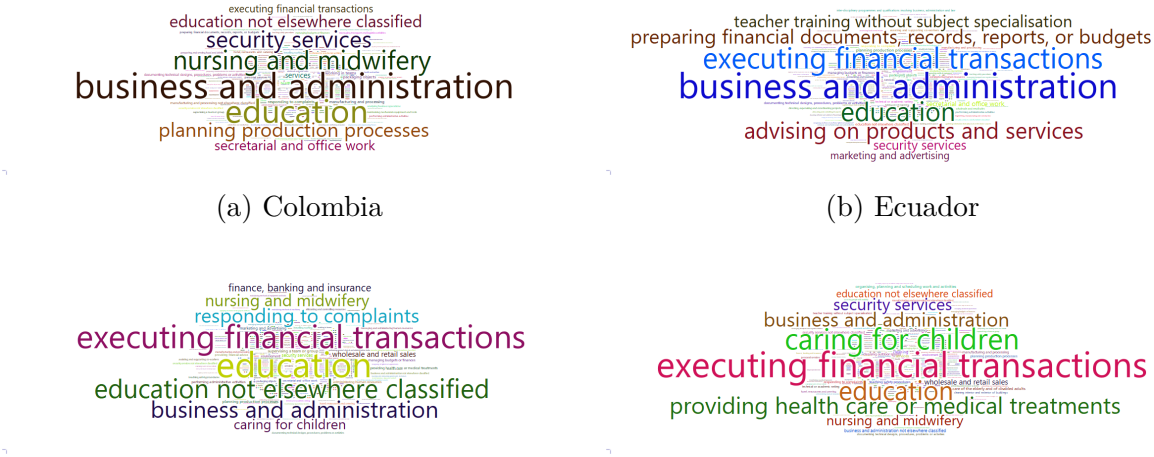
These findings are consistent with the green salary premium. In particular, Table 9 in Appendix 7.5 shows that new and emerging green occupations exhibit the higher average salary. These are occupations linked to the transformation processes with higher innovation. On the other hand, occupations with enhanced skills present the second highest average salary level. Therefore, in the short term, those occupations showing growth could have effects on the quality of employment and levels of inequality, while in the long term, greater impacts in terms of wages can be expected as emerging occupations consolidate. Policies aimed at enabling productive transformation could accelerate these green returns.

5.4 Demand of skills and knowledge

Although the GOJI is homogeneous across job vacancies of the same occupation, the demand for skills is diverse within occupations. In order to provide evidence of this

heterogeneity, we analyze the skills reported in each vacancy. This is informative and helps identify potential areas for training to reduce mismatches in green jobs. Specifically, we identify skills defined by ESCO using natural language processing.

When analyzing the total number of vacancies by country, there are some similarities, but also important differences. In the similarities, skills such as education and executing financial transactions are identified. These skills are often associated with professional and administrative support occupations (see Figure 7). However, there are specific differences in the required job skills. For example, in Colombia, there is a notable need in the areas of security services and operational planning and production processes. In Ecuador, there is a demand for skills related to advising on products and services, and in Mexico, financial management and wholesale and retail sales are particularly relevant. On the other hand, in Peru, healthcare provision and security services occupy prominent positions on the list.



(a) Colombia

(b) Ecuador

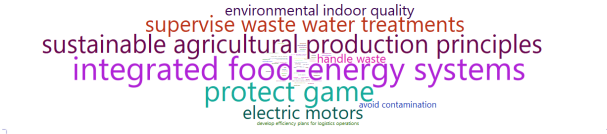
(c) México

(d) Perú

Figure 7: Word clouds of all skills and knowledge by country
Source: Own elaboration based on vacancy information.

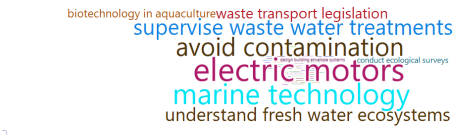
The most interesting aspect of skill identification is the possibility of quantifying the relevance of green skills and knowledge. The demand for green skills exhibits common features among these countries. In particular, there is a notable need for monitoring environmental management systems (see Figure 8). Additionally, specific knowledge areas such as electric motors are observed, a crucial skill for the development of efficient energy supply systems, aligning with regional government initiatives.

Regarding specific aspects of green skills in Colombia, there is a significant demand for integrated food and energy systems, as well as waste management. In Ecuador, emphasis is placed on the planning of water resource development and forest conservation. In Mexico, marine technology and legislation related to waste transportation stand out. In Peru, habitat management and air quality management are highly demanded skills. These skills highlight activities associated with agriculture and ecosystem conservation. These findings are very important as they allow for the differentiation of labor market change approaches. Although there are similar trends in the types of green jobs at an aggregate level, the productive strategies seem to be heading in different directions.



(a) Colombia

(b) Ecuador



(c) México

(d) Perú

Figure 8: Word clouds of green skills and knowledge by country
Source: Own elaboration based on vacancy information.

6 Concluding remarks

Based on the identification of the green potential in job vacancies, we characterize the demand for green jobs in four Latin American countries: Colombia, Ecuador, Mexico, and Peru. Our analysis focuses on assessing the incidence of green jobs and providing evidence of a green salary premium. Results reveal that in Colombia, Ecuador, Mexico, and Peru, the proportion of demand for high-potential green jobs ranges from 8% to 16%, and more than 30% of the job vacancies in all countries have low green potential. These percentages reflect the relevance of occupations with the potential to drive the green transition. Likewise, higher green potential is found in occupations such that managers, while the lowest levels of green potential are in clerical support occupations. This implies that the greener workers would be in occupations responsible for planning, directing, coordinating, and evaluating high-level business activities.

Furthermore, the transition to a green economy would increase the demand for workers with higher levels of education. The proportion of job vacancies requiring university education increases with the level of green potential. In contrast, the proportion of vacancies with secondary education requirements decreases as the level of green potential increases.

We find evidence suporting the existence of a green salary premium. When comparing wages between countries, Colombia is the country where occupations with high green potential have the lowest salary. Regarding the required experience, a positive relationship with green potential was observed, indicating that greener vacancies demand higher levels of experience. These suggest that the growing demand for green jobs could open up opportunities for worker reallocation, particularly if supported by targeted training and reskilling programs.

On the other hand, using the alternative categorization based on O*NET, we observe that the majority of job vacancies are concentrated in the Non-Green category, followed by vacancies in Enhanced Skills, then in Increased Demand, and with a reduced proportion in New and Emerging Occupations. These findings are consistent with previous results, which show that vacancies with low green potential predominate in all countries, while

only a small proportion of jobs have high green potential. Although the green transition is beginning to influence occupational demand, its transformative impact remains limited. The labor market has a modest emergence of entirely new green occupations.

Finally, the comprehensive analysis of skill demand reflects a growing importance of both green and non-green skills in the labour market. While overseeing environmental management systems and managing electric motors stand out as common and essential skills in all countries, significant differences in specific demands are observed in each region. This highlights the need for a strategic adaptation in the training and development of professionals, with an emphasis on flexible programs that meet local and regional needs. The regional commitment to promoting a more sustainable and environmentally friendly economy demands ongoing investment in sustainability-related skills development to drive equitable and sustainable development throughout the region.

There is consensus that the green economy brings long-term benefits where innovation and the development of new technologies will create investment and growth opportunities. In the short term, the creation of new jobs in green sectors is expected; however, due to the limited mobility of the workforce and the time it takes to address and reduce skill gaps in emerging sectors, this economic adjustment can cause structural unemployment. While, in the medium term, the impact of policies will spread throughout the economy, creating and eliminating jobs as behaviours change, and value chains adjust. Workers whose skills do not align with the new dynamics of the green job market may face difficulties in finding employment. Therefore, policies are needed to efficiently manage the just transition that maximizes the benefits for green workers and supports those who would be adversely affected in the short and medium term, namely workers not aligned with the new job requirements.

It will be a priority to strengthen investment to achieve the creation of green jobs, but beyond investments in physical capital, the essential role of adapting human capital in the green transition must be considered. Strengthening mechanisms for monitoring and forecasting the supply and demand for skills in the labour market will be crucial for the design of public policies. In the same vein, the green agenda must be an opportunity to create formal jobs. This is particularly relevant in the region, where there is a high and persistent presence of informal labour.

To minimize the gaps between workers' skills and the new demands associated with the green transition, OCDE (2023) proposes three types of strategies. Firstly, the development of specific studies on the competencies and skills needed to enter the green economy job market, with conclusions guiding the creation and implementation of public policies. Secondly, the coordination of professional training, promoting educational programs that include training in specific skills related to new requirements arising from environmental policies. Thirdly, systematic foresight of new demands for green skills includes renewable energy management, energy efficiency, waste management and recycling, sustainable urban planning, organic agriculture, clean energy technology, and natural resource management.

In addition to designing policies considering the role of the worker, it is necessary to keep in mind the role of companies. Public policy design could lead companies to innovate in green products and services while reducing their environmental footprint and creating

green jobs. Similarly, taxes and exemptions could be alternative tools to expedite a more sustainable business environment in line with a just transition. The transition to a green economy is the urgent and necessary response to protect our planet, guide workers and employers in a new work era, and ensure a fair and sustainable future for all. It is a transformative opportunity that challenges us to forge a world in balance with nature and in harmony with social justice.

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Credit Author Statement

Andres García-Suaza: Conceptualization, Formal analysis, Funding acquisition, Supervision, Investigation, Methodology, Project administration, Validation, Writing - original draft, Writing - review and editing.
Pamela Caiza-Guamán: Formal analysis, Investigation, Visualization, Software, Writing - Original Draft, Writing - review and editing.
Alexander Sarango-Iturralde: Data Curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Writing - original draft.
Catalina Buitrago: Investigation, Writing - Original Draft.
Bernardo Romero-Torres: Investigation, Data Curation, Formal analysis, Writing - Original Draft.

Declaration of Competing Interest

Errors, opinions and omissions are our own and do not represent our institutions. The authors have no relevant interest(s) to disclose.

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7 Appendix

7.1 Workflow

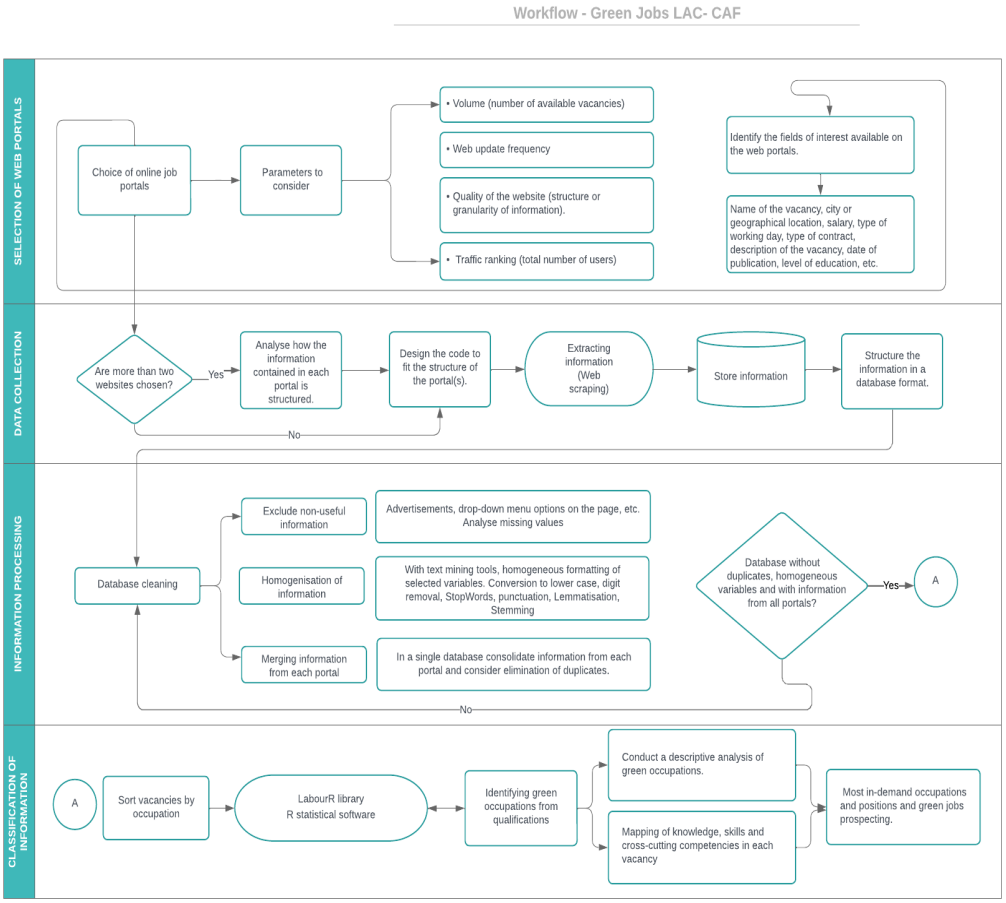

Figure 9: Workflow for the Analysis of Green Job Demand

7.2 Variables and description of the database constructed from vacant positions.

Variable	Description	Type
Vacancy ID	Unique identifier for each vacancy	Alphanumeric
URL	Vacancy link	Text
Date of download	Date when the vacancy was downloaded	Date
Title	Vacancy title	Text
Description	Description showing vacancy details	Text
Company	Company publishing the vacancy	Text
Country	Country where the vacancy is published	Text
City	City where the vacancy is published	Text
Wage	Wage offered in the vacancy	Numeric
Experience	Minimum required experience in years	Numeric
Education	Minimum educational level required	Text
Vacancy number	Number of vacancies offered in the post	Numeric
Journey	Type of work schedule offered in the vacancy	Text
Contract	Type of contract offered in the vacancy	Text

Tabla 8: Description of used variables

7.3 Share of jobs in each O*NET occupation category by country

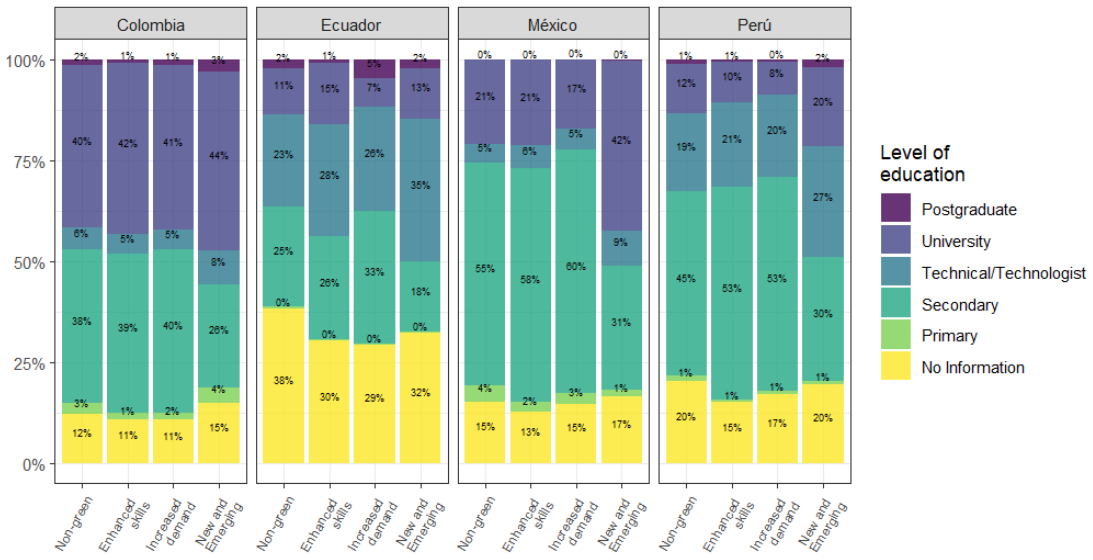

Figure 10: Distribution of O*NET occupational groups by country and education

7.4 Share of jobs according to ISCO major group in each O*NET job category and country

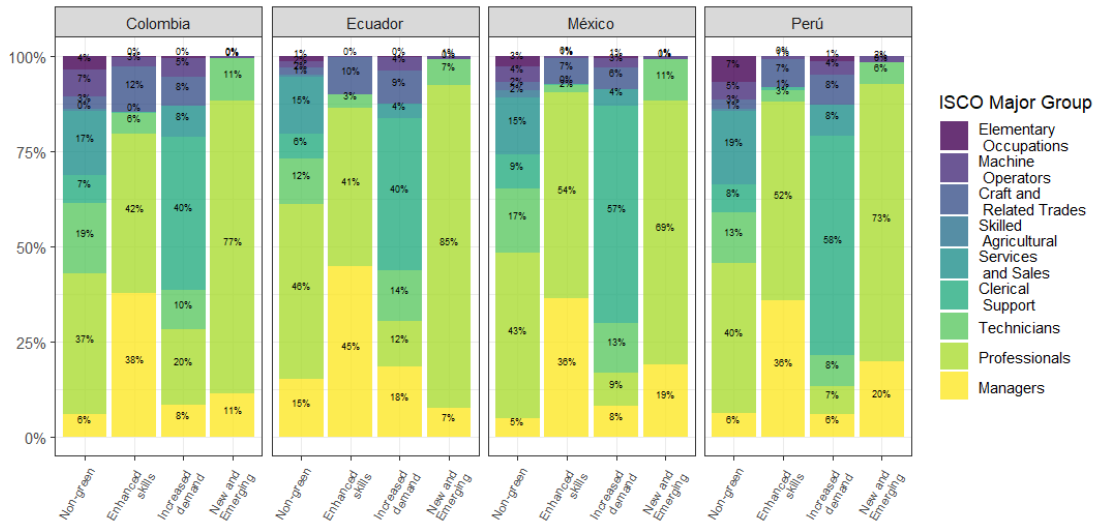

Figure 11: Distribution of O*NET occupational groups by country and Isco group

7.5 Salary and experience required by occupation category O*NET by country

Country	O*NET Occupation Category	wages		Experience	
		Average	Std. Dev.	Average	Std. Dev.
Colombia	New and Emerging Green Occupation	378.16	167.48	2.00	1.51
	Green Occupation with Enhanced Skills	355.15	125.38	1.76	1.20
	Green Occupation with Increased Demand	346.61	114.66	1.64	1.10
	Non-Green Occupation	330.99	107.62	1.59	1.05
Ecuador	New and Emerging Green Occupation	601.21	234.17	2.54	1.64
	Green Occupation with Enhanced Skills	546.98	148.06	2.54	1.59
	Green Occupation with Increased Demand	542.96	156.26	1.99	1.44
	Non-Green Occupation	566.31	176.13	1.99	1.29
Mexico	New and Emerging Green Occupation	719.85	333.13	2.12	1.46
	Green Occupation with Enhanced Skills	594.61	224.88	1.76	1.20
	Green Occupation with Increased Demand	540.58	189.24	1.57	1.09
	Non-Green Occupation	536.50	180.24	1.56	1.04
Peru	New and Emerging Green Occupation	771.92	840.00	2.10	1.61
	Green Occupation with Enhanced Skills	670.83	710.61	1.69	1.24
	Green Occupation with Increased Demand	579.30	593.18	1.56	1.20
	Non-Green Occupation	689.22	727.21	1.53	1.08

Tabla 9: Wages and experience by country under O*NET category