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Article

Identifying green skills gaps through labor market intelligence

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Abstract: The aim of this paper is to introduce a research project dedicated to identifying gaps in green skills by using the labor market intelligence. Labor Market Intelligence (LMI). The method is primarily descriptive and conceptual, as the authors of this paper intend to develop a theoretical background and justify the planned research using Natural Language Processing (NLP) techniques. This research highlights the role of LMI as a tool for analysis of the green skills gaps and related imbalances. Due to the growing demand for eco-friendly solutions, there arises a need for the identification of green skills. As societies shift towards eco-friendly economic models, changes lead to emerging skill gaps. This study provides an alternative approach for identification of these gaps based on analysis of online job vacancies and online profiles of job seekers. These gaps are contextualized within roles that businesses find difficult to fill due to a lack of requisite green skills. The idea of skill intelligence is to blend various sources of information in order to overcome the information gap related to the identification of supply side factors, demand side factors and their interactions. The outcomes emphasize the urgency of policy interventions, especially in anticipating roles emerging from the green transition, necessitating educational reforms. As the green movement redefines the economy, proactive strategies to bridge green skill gaps are essential. This research offers a blueprint for policymakers and educators to bolster the workforce in readiness for a sustainable future. This article proposes a solution to the quantitative and qualitative mismatches in the green labor market.

Keywords: green jobs; sustainable development; skills education and training; skills mismatch; labor market imbalances; green human resource management; natural language processing

1. Introduction

Sustainable development impacts all spheres of economic life, but the most significant changes concern the labor market, where green jobs are emerging (Sulich and Sołoducho-Pelc, 2022). The significance of green jobs arises from the synergy of benefits for the natural environment, business, and workers' well-being (Kozar and Sulich, 2023). Green jobs encompass all positions that positively influence the natural environment and reduce the anthropogenic, detrimental effects of human economic activities. Currently, there is a growing body of literature discussing the increase in the number of green jobs and the qualitative changes they bring about (Werna et al., 2023). There is a notable rise in green job opportunities, and businesses are increasingly adopting environmentally friendly practices. The implementation of theoretical principles of sustainable development consequently leads to the creation of green jobs or the greening of existing positions within organizations. As a result, employees acquire new eco-friendly competencies. Unfortunately, such changes in the business sphere are not accompanied by qualitative changes in the labor market (Kozar,

2023). Moreover, green jobs are often associated with subordinate, low-paid, physical labor performed under strenuous conditions, such as landscaping or waste sorting. Less frequently, green jobs are linked to creative intellectual work, involving Environmental, Social, and corporate Governance (ESG) reporting, researching the impact of corporations on the environment, and implementing strategies for sustainable organizational development (EBES, 2016).

Currently, approximately 40% of workers in the European Union impact the green transition (European Commission, 2024a), and in 2019, there were 4.5 million jobs in the environmental economy (Bulgarelli et al., 2010). Simultaneously, labor shortages in key sectors and jobs for the green transitions have doubled. It is important to note that the green transformation brings with it some hopes for creating additional green jobs. Many workers will need to be trained, upskilled, or reskilled to meet the growing demand of the energy sector for new employees (Bulgarelli et al., 2010). The labor market needs presented exceed the number of available candidates with appropriate qualifications, which is why the European Union has allocated 65 billion euros for training and qualification changes in years 2023–2025 (European Commission, 2024a; European Commission, 2024b).

While many employers claim difficulties in finding workers with the required skills, a considerable portion of the active population currently finds themselves marginalized or trapped in low-quality jobs (Tang et al., 2017). Some studies attribute this mismatch to an education system lagging behind business needs, which poses an important research gap and scientific problem (Li et al., 2023; Renwick et al., 2015). In the face of this paradox, the skills challenge involves aligning workers with jobs and providing them opportunities to acquire the required green skills (Martin and Ondřej, 2017; Adjei-Bamfo et al., 2019). This issue can be partially resolved by ensuring a good match between the skills of employees and the needs of employers, or by enhancing the qualifications of job-seeking candidates and current employees through training (Sapanca and Kanbul, 2022). Some enterprises can view green skills as a potential source of promotion, differentiation from competitors, innovation, and social influence (Correia et al., 2022). Therefore, organizations are investing in creating green jobs and influencing various stakeholders (Akomea-Frimpong et al., 2023). They are not only building a positive image of an environmentally engaged business but also developing modern, green skills as part of human capital, encompassing consumer behaviors and employee habits (Macalik, 2021; Sulich, 2021).

There is a consistent discrepancy that has been observed between employer expectations and offered by employee's competencies (Siuta-Tokarska et al., 2022; Springer Nature, 2023). Market changes, driven by crises, ignite a need in candidates to enhance unique and specialized qualifications and green skills that would increase their employability (Nikoloski et al., 2018). The transformation of the labor market towards environmental sustainability heralds the emergence of novel occupational categories, heretofore unknown, and precipitates a marked augmentation in employment opportunities within specific sectors. Notably, this transition is characterized by significant annual employment growth rates in distinct professions, identified as green jobs (Sulich and Zema, 2018), including sustainability managers (30%), wind turbine technicians (24%), solar consultants (23%), ecologists (22%), and environmental health and safety specialists (20%). This evolution underscores the

expanding nexus of opportunities within green careers, reflecting a concerted response to pressing environmental imperatives (European Commission, 2023a). With the aid of green human resource management, new technologies are emerging that enable both innovative methods of education and training, as well as streamline the job search and candidate matching process (Song et al., 2021). Emerging technologies, such as digitalization, Natural Language Processing (NLP), and Machine Learning (ML), profoundly impact all domains of society, including the functioning of labor markets (CEDEFOP, 2021; Sulich et al., 2023). Up to the present, traditional analytical tools based on regular or sporadic surveys of business establishments have been utilized as the primary source of information concerning skills mismatches. Although the continually increasing use of online information considerably reduces the labor market frictions, the problem of skills mismatches, particularly with respect to the emerging green skills remains as a considerable challenge (Kuhn, 2014). In addition, the green transition and associated green skills mismatch problem has not been yet a target of scientific analysis.

The aim of this paper is to introduce a research project dedicated to identifying gaps in green skills by using the Labor Market Intelligence (LMI). This approach underscores the relationship between demand and supply in the labor market, utilizing a ML method to identify gaps in green skills. The paper is primarily descriptive and conceptual, as the authors aim to develop a conceptual framework and justify the planned research using NLP techniques. In result this research will address the issue of green skill gaps from the perspective of their identification and categorization in labor market (AIAI, 2022). Green skill prerequisites have been systematically classified into technical, soft, and specific competencies (Broecke, 2023). The research further dissects the nature and scope of these gaps, categorizing them into green skill shortages, deficits, and obsolescence. In this context, the availability of data thanks to digitalization and spread of labor market related web services enables application of new technical solutions of analyzing green skills gaps based on big data.

This conceptual paper is structured as suggested by Jaakkola (2020). First, the literature review is presented regarding the green skills, their classification and assessment. Next, the research problem is outlined as a framework for identification and analysis of green skills imbalances. Furthermore, in the research design section are elaborated the main steps in the process of identification of green skills gaps by using the LMI. Finally, the last section conveys the concluding remarks and provides plan for future research recommendations. Furthermore, this study offers policy recommendations, emphasizing roles emerging from the green transition and the urgent need for academic reforms tailored to a sustainable future’s demands.

2. Literature review

As the world pivots towards the sustainable, green or circular economy, the professional landscape undergoes significant transformations (Aneesh et al., 2023; Sulich et al., 2023). Transformative forces such as climate change, demographic challenges, energy crisis and other pressing environmental issues are redefining jobs, tasks and occupations as well as the skill profiles the people need in order to be and remain employable (Nikoloski and Pechijareski, 2017). Companies have to promote

the skills acquisition needed to cope with the changes in the labor market, contribute to sustainable growth, increase technological innovation and support business competitiveness (Fernandez and Ganesan, 2022). The business greening requires qualifications and skills related to implementing sustainable development principles, translating its theoretical assumptions into business practice (Gajdzik and Štverková, 2023). In this context, one of the emerging groups of jobs are the green jobs. On the other hand, the skills dimension of green transition is often underemphasized in national and sectoral strategies aiming to achieve effective transformative change (ETF, 2023; Sołoducho-Pelc and Sulich, 2020).

Green jobs can be defined as "jobs in business that produce goods or services that benefit the environment or conserve natural resources" (US Bureau of Labor Statistics Green Jobs Overview). Green jobs combine the principles of sustainable development with fairness and dignity of work. Other established occupations evolve, leading to emergent green skill gaps (AIAI, 2022). Firms face challenges with these gaps when recruiting for roles demanding specific green competencies that are scarce in the market (Napathorn, 2021). Therefore, there are green jobs and their absolute opposites. Such polar understanding of environmental jobs implicates green skills and competences development among employees. However, in business practice the number of green jobs is often presented, while little attention is paid to the organizational quality and effects of the green jobs created (Feng et al., 2022). This disparity between skills supply and demand is well-documented and described both qualitatively and quantitatively (US Bureau of Labor Statistics Green Jobs Overview).

Future green workers should possess competencies and a readiness to become agile learners. It is because, green skills are shaped through continuous education and professional training. The green skills include knowledge, abilities, values, and attitudes, in promoting a sustainable socio-economic framework. Green skills can be divided into: (i) technical proficiencies, facilitating the application of green technologies and processes that emphasize resource conservation and minimal environmental impact, and (ii) transversal skills, paired with inherent knowledge and values that promote eco-conscious decisions in both professional and personal area. The green skills are described in the common internationally adopted skills descriptors such as the Occupational Information Network (O*NET) and the European Classification of Occupation, Skills and Competences (ESCO). The O*NET is based on the US Standard Occupational Classification system. This system contains information on hundreds of standardized and occupation-specific descriptors. On the other hand, ESCO is a multilingual classification system for all European skills, competences, qualifications and occupations. It is worth noting that ESCO follows the structure of the International Standard Classification of Occupations (ISCO-08), which is an important advantage compared to O*NET (Cárdenas Rubio, 2020; Nitschke et al., 2021).

Green skills mismatch occurs when there is a discrepancy between the green skills that individuals possess and those needed by the employers (European Commission, 2013a). Green overskilling, also known as green skill underutilization, refers to a scenario wherein an individual's green skills and competencies are not fully exploited in their present occupational role (Grandi et al., 2023). Conversely, green underskilling, or green skill gap, denotes a circumstance where an individual's

repertoire of green skills and competencies falls short of the requirements needed for competent performance in their current job position (European Commission, 2013b). The are three potential challenges that reflect skills mismatches in green labor market supply and demand relations: green skill shortages, deficits, and obsolescence. A green skill shortage occurs when the demand for a specific type of green skill surpasses its supply at the current wage rate (Hailiang et al., 2023). The shortage is attributed solely to a disparity between demand and supply. A green skill deficit exists when the green skills and abilities of a workforce are below a predetermined benchmark level of green skills (Sołoducho-Pelc and Sulich, 2022). This disparity underscores domains in which existing skill sets fall short of employer expectations. Green skill obsolescence refers to a scenario where green skills previously essential in a job are no longer necessary or have decreased in relevance. This obsolescence arises when certain skills become outdated due to eco-centric industry shifts (Hu et al., 2023). While most measures of skills imbalance focus on the employed population (Sulich and Zema, 2018), certain metrics, such as green skill shortage, may also be empirically evaluated among job seekers (Zhang et al., 2023).

Currently, several megatrends, including climate change and the integration of Artificial Intelligence (AI), are shaping the future demand for modern skills essential in transforming the economy (Yüksel and Dinçer, 2023; Towards Industry 4.0 - Current Challenges in Information Systems, 2020). With the advances in NLP, big data analytics, the labor market community has introduced the emerging field of (LMI) (AIAI, 2022). The LMI utilizes ML algorithms and frameworks to analyze data related to the labor market information for supporting strategies and decision-making (Sus et al., 2023). The AI and ML are not only changing the labor market, but are also providing new tools to analyze the workforce (AIAI, 2022; ETF, 2021). LMI is a set of AI supported algorithms used to recognize crucial skills demanded in certain positions. Data describing the posted online jobs vacancies and online profiles of job seekers can be analyzed exploring the inherent information. These vast data sources are essential for understanding the dynamics and functioning of the modern labor market and employers' recruitment patterns (Broecke, 2023). The concept of labor market information involves integrating diverse information sources to bridge the gap in understanding both supply-side and demand-side factors, as well as their interplay in the labor market. Job advertisement data, offering timely insights into skill demands, are particularly informative (Adjei-Bamfo et al., 2019). However, when examined in isolation, such data may not sufficiently illuminate skill mismatches. Conversely, when combined with other data, it becomes possible to assess whether changes in job vacancy volumes by occupation correlate with broader labor market trends or stem from existing skill mismatch issues (Bennett et al., 2022). Therefore, job vacancy data is instrumental in identifying the specific skills required for various jobs. Further, when this data is merged with information on skill mismatches, it can yield comprehensive insights that are valuable for policymakers in shaping education and training strategies (Zylfijaj et al., 2020).

Recently, big data has been increasingly applied in the analyses of the green transition (OECD, 2023). For instance, in the United Kingdom the Department of Business, Energy and Industrial Strategy applies a big data approach as a way to monitor the development of green jobs and skills. In practice, this approach consists

of an analysis of online job vacancies based on the keyword filtering and ML possess. Furthermore, in a study of online job vacancies in Germany, are defined occupations and sectors that are particularly relevant for the green transition in Germany and identify possible labor shortages that could hinder green transition (Bauer et al., 2022). Namely, they created a catalog of keywords to detect occupations related to the green economy followed by an automated text analysis to detect these relevant keywords in the job postings data. Another example of using web scraping techniques for analyzing the mismatch between supply and demand of green jobs has been applied in the context of the Korean labor market (Song et al., 2021). They obtained information on both the company side and job seekers side as an innovative way to quantify the degree of mismatch between supply and demand for green jobs, in specific country context.

From the presented theoretical background emerges a research gap backed on a lack of comparative studies conducted in relation to the labor market in developing or underdeveloped countries. In the next part of the article, the research problem is introduced along with a skills mismatch context providing a solid foundation for undertaking future scientific studies in developing countries.

3. Research problem formulation

The skills mismatch can be defined according to the European Centre for the Development of Vocational Training (CEDEFOP), which developed this terminology in the context of the European Skills and Jobs Survey (CEDEFOP, 2021). The skills mismatch is a discrepancy between workers' qualifications and skills and labor market needs (CEDEFOP, 2010). Therefore, this mismatch can be vertical or horizontal. A vertical skills mismatch occurs when an individual's level of education or skills is either higher or lower than the required level for a job. On the other hand, a horizontal mismatch arises when the level of education or skills aligns with job requirements, but the specific type or field of education or skills is not suitable for the job (Crowley, 1999). A degree of 'frictional' skill mismatch and skill shortages is to be expected in any dynamic economy (European Commission, 2023b). However, persistently high skill mismatch and skill shortages over the longer term can have adverse economic consequences for individuals, firms and the economy as a whole. At the individual level, skill mismatch has a negative impact on job satisfaction and wages. Therefore, individuals may face difficulties in finding an appropriate job, higher risk of unemployment and possible human capital depreciation in the case of long-term unemployment. Skill mismatches for companies cause hiring difficulties, lower productivity or insufficient product quality, loss of competitiveness and additional costs for investment in retraining. Finally, the society may incur lower national competitiveness, negative impact on public finance and social exclusion and safety (Rani and Mishra, 2014). The relevance to such a broad range of stakeholders calls for the results of skills assessment and anticipation exercises to be widely disseminated in order to maximize their impact on policy making (OECD, 2017).

The research problem of this paper is to introduce a research project framework dedicated to identifying green skills gaps by using the LMI. In order to define the green skills mismatch measures, it is necessary first to adopt an appropriate skills taxonomy. In this context, ESCO is utilized as a foundational reference point, enabling

the effective comparison and analysis of research findings (European Commission, 2023). This comparison can reflect differences between green skills demand and supply in qualitative approach. Those green skills sets and the relationships between them can be compared and explored automatically using AI tools.

The result of this research is a proposition of online platform scheme for services like labor market matching based on the green skills. This tool can be developed with function of suggesting training to people interested in reskilling or upskilling. In addition, this platform might support both employers to find the candidates for their vacancies, and employees to find the position adjusted to their skills. The use of ESCO helps education and training providers to understand what skills in the labor markets are needed. The curricula can be adapted accordingly to prepare students for labor market transition.

The ESCO is a public online platform which provides descriptions of skills and occupations that helps both employees and employers to become more aware of the necessary skills. It is used for describing, identifying and classifying professional occupations and skills relevant for the EU labor market (European Commission, 2023). The aim of ESCO is to support job mobility which in turn supports a more integrated and efficient labor market in Europe. This activity of ESCO is based on the offering a set of occupations and skills that can be used by different stakeholders on employment, education and training topics. The European Commission further distinguishes brown, white and green skills among the ESCO classifications (ESCO Publications, 2022). The EC assumes that brown skills exert negative environmental impact, white skills neither increase nor reduce this impact, while green skills reduce anthropopressure. The green skills are continuously increasing in their number in ESCO, what reflects the trends and changes in the labor market (Kureková et al., 2015). Green qualifications are becoming increasingly important in rapidly developing sectors. There are qualifications related to the green jobs, which include green skills, green knowledge concepts, and transversal skills (ESCO Publications, 2022).

The challenge for this research covering skills assessment and anticipation exercises is to make the results available in a useful and accessible form. In the literature there are several approaches for assessing the skill mismatch that can be classified in three broad categories: objective, subjective and empirical (CEDEFOP, 2010; McGuinness et al., 2017). The objective measure is obtained by systematic job evaluation used to determine the precise level of qualifications required to perform a particular job. The subjective measure is based on individual perception about the level of education required to perform a particular job. According to the empirical method mismatch occurs when the level of education is more than one standard deviation above or below the mean for education within an occupation (Song et al., 2021).

Another challenge for this research is the measurement of skill mismatches, particularly those affecting the employed population, often referred to as ‘internal’ skills mismatches. In contrast, the ‘external’ skill mismatch refers to imbalances between skill needs and supplied skills by the unemployed or by the potential labor force (Stoevska, 2017). While the ‘internal’ skill mismatches are analyzed with respect to the existing jobs, the ‘external’ skills imbalances can only be identified by comparing skills supply and demand, as it is the result of their interaction. However, in empirical analyses direct comparison is difficult because the data on skills supply

and demand often come from different data sources. Therefore, it may be beneficial to calculate distinct indicators for skills supply and demand, and subsequently conduct a qualitative assessment to identify any notable discrepancies between them and existing trends. While some indicators are designed to directly measure mismatches from the data, they can signal the presence of a mismatch but offer limited insights into its underlying structure (ETF, 2019; Řihova, 2016).

In this context, a distinction should be made between general skills mismatch measures, which assess the overall skills level, and green skills mismatch measures, focusing on a specific type of skills. An employed worker may be sufficiently skilled in terms of their overall skills and abilities, yet still underskilled in possessing the necessary green skills (ILO, 2011). In this context, it is particularly relevant to derive a measure of green skill shortages, defined as the estimated number of jobs for which employers encounter difficulties in filling vacancies due to a lack of green skills. These vacancies may also be categorized as hard-to-fill due to green skill shortages (Eurofound, 2023). The proportion of hard-to-fill vacancies attributable to green skill shortages could be further calculated across various occupations, industries, and regions to facilitate comparative analyses.

The application of LMI to analyze both job openings and candidate profiles can contribute to the systematization of qualifications for emerging green jobs. These tools are universal in nature and can be transferred to other countries and different contexts where there is a need to correlate the labor markets of employees and employers. Moreover, it allows for the expansion of the definition of green jobs and their linkage to corporate strategies for sustainable development (Sulich and Zema, 2018). In this way, organizations implementing sustainable strategies will gain skilled workers, specialists who are prepared for such challenges.

4. Research design

This section provides a justification for the research design with detailed steps adopted in the LMI approach, as outlined in the literature review. The novelty of this study lies in the application of existing methodologies of online data analysis to investigate green skills gaps based on reconciliation of both demand and supply side for green skills. The novelty of the proposed solution lies in focusing on the green qualifications sought in the case of green job positions. A significant strength of this research is that the availability of big data allows for larger sample sizes and more frequent analyses compared to traditional surveys. Another advantage is that LMI's reliance on internet-based data sources eliminates the need for field data collection and provides prompt results. Job posting data in the labor market precisely reflect employers' current needs, as companies publish announcements when seeking new hires. Furthermore, big data analytics applied to vacancy data collected from online job advertisement portals can enhance skills anticipation and matching capabilities. This methodological advantage bridges research and business practices and in the future may become a major source of LMI.

Data are collected based on the classification on the websites where employers and job seekers share common terminology with respect to occupation, skills, education level, experience etc. The employers post online job openings with specific

skills requirements to attract workers they need, while the job seekers create online profiles and résumés with skills descriptions to market themselves to potential employers. Alternatively, as a source of data for job seekers can be used the registry of unemployed workers from the Public Employment Service (PES). The advantage of using the registry of unemployed workers as a data source is its well-defined structure and richness of information. Usually, such registers contain information on personal characteristics and data related to gender, age, place of living, education level, previous work experience, unemployment history, participation in active measures etc. The proposed research design has sequential characteristic and consists of three phases: data ingestion, data processing, and data analysis (ETF, 2021). This is presented in **Figure 1**, where the main tools applied are listed for each phase, while the peculiarities related to the analysis of green skills are stated below.

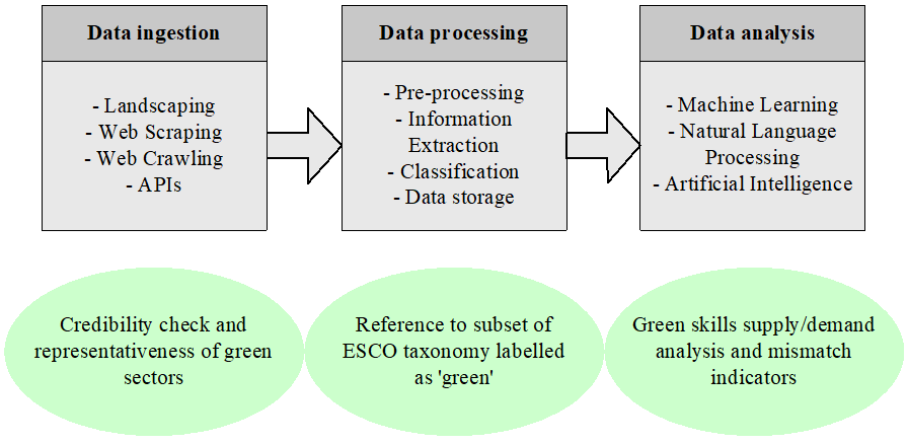

Figure 1. Research design of green skills gaps identification using LMI.
Source: Authors elaboration.

Figure 1 not only illustrates the stages and their technical details in gray boxes, but also the objectives of these stages, which are presented below in green ellipses. The initial phase labeled as data ingestion involves selecting data sources, i.e., data targeting or landscaping to extract job vacancies, followed by downloading raw data from the identified websites. To maximize the quality of the information extracted, websites are ranked and prioritized according to the information they provide and representativeness of green sectors. In this context, it is crucial to evaluate and categorize each source (such as online web vacancies and other online or offline sources) based on the credibility of the information it provides. The set of web portals is not fixed and it can be narrowed or widened depending on the changes in the business environment. Furthermore, this phase involves data collection (by using web scraping, web crawling or via API (Application Programming Interface). The web scraping should be adjusted for each web page having in mind the organization and structure of data is different and may consists of structured and unstructured (text format) data. At the same time the raw data will be stored in the original text format as it appears on the source web page. Some of the challenges involved in this process is providing robustness, good data quality, scalability and governance. Namely, the system needs to deal with potential technical problems when gathering data, to obtain data as clean as possible and to handle a real and complex big data environment.

The data processing phase starts with pre-processing which includes data cleaning in order to eliminate irrelevant information noise and unnecessary information. Namely, the information gathered from the web might encompass various types of non-vacancy content that needs to be discarded. In addition, this phase involves identifying and removing duplicate entries, since vacancies are generally posted on multiple web portals. If they are taken as distinct, then the labor demand for a specific occupation will be overestimated. A similar process of data cleaning and deduplication has to be performed on data gathered from the online profiles of job seekers. Once data has been pre-processed, the process continues with information extraction and classification. In this context, classification algorithms are used to match the content of the downloaded job advertisements to education, experience, skills and labor market ontologies/classifications. For instance, the taxonomy related to green skills and occupations will be provided from the ESCO database that contains 13.890 skills out of which a total of 571 skills and knowledge concepts are labeled as green. Other important classifications are the following: statistical classification of economic activities in the European Community (NACE) for sectors, nomenclature of territorial units for statistics (NUTS) for places of work, International Standard Classification of Education (ISCED) for education levels. Furthermore, custom ontologies can be developed from the information in the job offers (such as contract type, skills, salary). These can be used to develop terms and synonyms which are not yet included in existing ontologies, providing valuable information on emerging technologies, jobs or skills. Once the data classification process is completed, it is possible to store the processed data in a multidimensional database for data navigation and data analysis. This can include developing insights and recommendations into current and emerging technologies, jobs and skills in demand by employers (CEDEFOP, 2021).

The data analysis phase aims to identify patterns of interest in a specific representational format by using suitable ML algorithms (such as classification, clustering, etc.) aligned with the analytical purpose. This phase also includes NLP analysis of the data to extract information from text. The green skills can be classified and organized in different groups and categories. The data hierarchy will follow a tree structure, where green skills can be combined on horizontal and vertical level depending on the particular analytical purpose. In addition, by harnessing AI tools in analyzing the processed data of job vacancies can help to identify patterns and gain a comprehensive understanding of the skills demanded on the labor market. Namely, AI can identify emerging trends, highlight evolving skill requirements and track shifts in the job market over time. Subsequently, the focus of the analysis will be narrowed down to green skills sought in the labor market and green skills offered by the job seekers. The goal is to assess the alignment between the supply and demand for green skills and to define measures/indicators of green skills gaps. Finally, the green skills mismatch indicators will be applied for measuring the discrepancies across different occupation, industries and regions in order to provide the stakeholders with the necessary information.

However, caution needs to be taken with the interpretation and use of big data and online job vacancies as the sample may not be representative of the entire labor market i.e. significant portion of jobs are not advertised online. Namely, skill needs

extracted from online vacancies are likely to suffer from substantial biases in terms of coverage of sectors, occupations as well as geographical coverage (Carnevale et al., 2014; CEDEFOP, 2019). Furthermore, it is important to note that it is difficult in making a one-to-one comparison between job advertisements and a real job vacancy since companies might post more job advertisements than available positions in order to receive more applications (Cárdenas Rubio, 2020). Skills requirements as stated in online job vacancies often reflect firms' effort to attract a desired set of skills among job applicants, rather than to genuinely reflect the required skills profiles in occupations. Job-specific skills may be taken for granted and the emphasis put on transversal skills instead, potentially providing a biased view of the skills needed for the vacancy. Since Internet-based job searching gradually became a more prominent tool for job matching, some challenges related to their representativeness have been already addressed (Kureková et al., 2015).

5. Conclusions

The conceptual framework developed in this paper represents an initial attempt to apply the LMI in the process of identification of green skills gaps. This article proposes a solution to the quantitative and qualitative mismatches in the green labor market. For this purpose, an approach based on separate analyses of demand and supply data gathered from online web sources was proposed. Accordingly, the measures of green skills demand and green skills supply can be produced and presented in the way to reflect the potential green skills mismatches. The use of real time data for green skills analyzes represents an advantage of this method, having in mind the rapid pace of changes in the domain of green transition (European Commission, 2024a). On the other hand, the main criticism is related to its 'external' character, since the focus of the analysis is on the green skills requirements for vacant jobs and the green skills endowments of job seekers. Hence, a comprehensive assessment of the green skills imbalances in a given economy can be obtained by complementing this approach with data gathered from the business establishments.

The results obtained by applying the LMI approach can be useful for a wide range of potential users such as labor market analysts, data scientists, decision makers, business managers etc. The analytical perspective can encompass distributions of green skills with respect to occupation, industry, education as well as the regional and time dimensions. For this purpose, various tools such as interactive dashboard can be developed in order to provide the necessary information that can be customized according to the users' needs. Furthermore, the identified green skills gaps and hard-to-fill vacancies due to the green skills deficits can be used as signals for policy makers, particularly in the domain of education and active labor market policies. Namely, by following the trends of green skills demand, new 'green' subjects might be included in the existing teaching curricula, while for the emerging occupations entirely new curricula can be developed. In addition, the ad-hoc needs for green skills and competences can be satisfied by designing and delivering training courses for unemployed workers within the framework of the active labor market measures.

Furthermore, it is important to emphasize that some sectors, such as renewable energy, face urgent need of workers with green skills and competences (European

Commission, 2024a). In this context, employers may experience reduced productivity due to shortages in green skills and gaps in green skills, which can potentially lead to a loss of competitiveness or even reputation (Macalik, 2021; Macalik and Sulich, 2019). As the unmet demand for green skills continues to rise, companies may respond by promptly equipping the workforce with the necessary skills through the establishment of internal training centers. Furthermore, human resource managers could benefit from utilizing the information from these analyses when planning future investments in industries that require extensive green skills and competencies (European Commission, 2024a).

Employees equipped with strong qualifications are not only ambassadors of specific enterprises, but above all, they are representatives of the idea of sustainable development by influencing consumers' habits (AIAI, 2022). Consequently, in the future, completely new business models will be created based on organizations whose employees are educated and equipped with green skills and competences. In this context, there are three ways of sustainable development: changing people and organizations while adapting them to the needs of the current market, creating green companies that already take advantage of the new labor market and, creating new green professions and concepts that gradually lead to establishing completely new companies. These three aspects are answer to the three types of the mismatches. In order to minimize the mismatch between workers' skills endowments and the needs of the labor market, the education system should equip candidates with green qualifications by teaching three types of thinking: creative, effectual and analytical. Namely, an ordinary reconstructive thinking consisting only in recalling remembered data and information does not provide the instrumentation required for current and future challenges of today which are yet to come.

Having in mind the untapped possibilities of AI in the domain of LMI, there is a wide room for developing various analytical tools. For instance, the skills requirements from the online sources may not be explicit, but implied in description of the workplace. Hence, innovative text analysis is required to extract the relevant information related to workers skills and competences. In this context, the use of ML and NLP techniques are challenging tasks in the process of technical implementation of the above outlined approach. Furthermore, particularly important are the anticipation methods for emerging green skills that have to be appropriately tackled by the policy makers. The future avenue of research has to focus on formulation and empirical calculation of various measures of green skills imbalances based on the developed tools of LMI.

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