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**Dr Babette Never** is a Senior Researcher in the research department "Transformation of Economic and Social Systems" at the German Institute of Development and Sustainability (IDOS) in Bonn.

Email: babette.never@idos-research.de

**Dr Alexander Stöcker** is a Researcher in the research department "Transformation of Economic and Social Systems" at IDOS.

**Dr Aimé Tsinda** is Associate Professor, College of Science and Technology, at the University of Rwanda.

**Erick Mujanama** is a consultant at Equilibria Ltd., Rwanda.

**Roger Mugisha** is a consultant at Equilibria Ltd., Rwanda.

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# Abstract

Green, circular buildings and their construction are essential for climate change mitigation and resource efficiency. However, the impact of a systematic shift towards green, circular buildings on employment in Sub-Saharan Africa remains unclear. Rwanda, particularly Kigali, is a relevant case due to its high urbanisation rate, pressing housing needs and political commitment to greening the economy. Currently, we do not know what types of green jobs exist in Kigali's construction value chain or what potential they have for economic development. This paper addresses these questions using a sequential mixed-methods approach. We conducted 33 qualitative, semi-structured interviews with local experts and stakeholders. Based on these insights, we ran a survey with 546 firms across five construction value chain segments: planners/architects, material producers, material and equipment suppliers, construction/masonry firms, and firms installing energy, water, and wastewater technologies. Our analysis reveals four key findings: (1) a significant number of green jobs exist in the construction value chain, with varying degrees of greenness based on the number of environmentally-friendly practices performed (about are 5 per cent highly green and 58 per cent are partly green); (2) diverse green and circular practices are developing through both state support and grassroots initiatives; (3) greening is positively and significantly correlated with employment growth for highly green firms; and (4) greening is positively and significantly associated with improved job quality for all firms. For policy-makers, our results suggest that supporting firms in critical transition phases – those that have initiated greening but are not fully engaged – may enhance both job quantity and quality in the short to mid-term. Expanding green and circular, bio-based building practices across the construction sector requires a mix of interventions focused on cost competitiveness, skills and attitudes.



**Keywords:** green jobs, green economy, green buildings, value chain, Sub-Saharan Africa

**JEL Codes:** J21, 018, 025, Q56, L74

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# Abbreviations

| | |
|---|---|
| ILO | International Labour Organization |
| ISCO | International Standard Classification of Occupations |
| LMICs | Low- and Middle-Income Countries |
| OLS | Ordinary least squares |
| O*Net | Occupational Information Network |
| PV | Photovoltaic |
| RWF | Rwandan Franc |
| SME | Small- and medium-sized enterprise |
| VAT | Value added tax |

# 1 Introduction

The buildings and construction sector is responsible for 37 per cent of global greenhouse gas emissions (UNEP, 2023). While the construction phase of buildings contributes to the bulk of emissions through the production, design and deployment of building materials, it has received less attention than operational carbon emissions from heating and cooling during the use of buildings (UNEP, 2023). A shift to green, circular building design and production strategies that prioritises resource efficiency and enables the reuse of materials could reduce emissions in the construction sector by 10-50 per cent (UNEP, 2023).

We define a green, circular building as a dwelling that has been designed and constructed partly or fully in line with principles of resource efficiency (reducing the footprint of energy, water and materials) and circular economy (i.e., with the future dismantling and reuse of building elements and adaptability of the building use in mind) (Ossio et al., 2023). Furthermore, a green, circular building partly or fully uses bio-based and/or second-hand materials, reducing the use of virgin materials (Khadim et al., 2023). The cost competitiveness of (partly) green, circular buildings depends on the type of technologies and materials used, on local transport costs, local utility costs, and the availability of various new and used materials in local markets. Whereas green technologies tend to have higher upfront costs and generate benefits only over time, used and local construction materials can be less expensive than imported virgin materials, such as steel. Total lifecycle costs of green, circular buildings are generally assumed to be lower than conventional buildings, irrespective of the local context (Minunno et al., 2020).

The transition to a green building environment that is in line with such circular economy principles presents a challenge that cities around the globe are facing today. There is, however, a difference in the type of transition pathway between cities that have already experienced a carbon and resource lock-in of most of their infrastructure and buildings and thus face expensive retrofits now, and those that are still evolving and need to construct a substantial number of new dwellings in the coming decades. The latter group of cities has the opportunity to avoid a lock-in and shift to new, greener construction practices and building types straightaway. With its rapid urbanisation, Rwanda and its capital city Kigali belong to the latter category.

In Rwanda, and in Kigali in particular, three pressing issues shape the future of the construction sector. First, the government has set ambitious goals for a green and circular economy while optimising development needs.[1] The city of Kigali is already engaged in green investments and programmes in the construction sector. These include initiatives such as the Bwiza Riverside environmentally-friendly homes and the “Green City Kigali” project which aims to build a new green suburb. Second, the country requires considerably more and better-quality jobs, especially for its growing young population. The underemployment rate (i.e., the underutilisation of workers’ available time or skills) stands at 55 per cent in 2024 (National Institute of Statistics, Rwanda, 2024). Third, with an annual urbanisation rate of 3.2 per cent and rising land and house prices, affordable living space is a key concern for policy-makers and citizens. In Kigali, 310,000 new dwellings are needed by 2028 (Bower et al., 2019). Given Kigali’s rapid urbanisation and the pressing need for affordable housing, this study investigates how a shift towards green construction can address both environmental and employment challenges.

Greening the construction value chain has the potential to turn these three challenges into positive economic development. Job growth rates in the construction sector are expected to continue at 9 per cent annually in the coming years. The shift towards green technologies used in buildings (e.g., rainwater harvesting, solar water heaters) and greener construction with local rather than imported materials can create additional labour demand, including in maintenance

1 E.g., Green Growth and Climate Resilience Strategy 2023, National Circular Economy Action Plan and Roadmap, Kigali City Master Development Plan of 2020.

and services (Nußholz et al., 2020; Sovacool et al., 2023). It also requires a different skill set, possibly upgrading current low-skilled jobs in the construction sector. Moreover, resource efficiency and circular production can increase firms' productivity and performance, for instance via immediate cost savings on production inputs (Darmandieu et al., 2022; Horbach & Rammer, 2019). For energy efficiency investments, case studies have revealed a clear positive effect on labour productivity as well (Kalantzis & Niczyporuk, 2022). These productivity gains can open up opportunities for firm growth over time, potentially including more green jobs meet these demands.

Thus far, it is unclear what exact effect a systematic shift towards green, circular buildings would have on employment in the construction value chain in a sub-Sahara African country (i.e., the number and types of green jobs that would come about). To the best of our knowledge, there is neither any evidence yet on the types of green jobs currently present in Kigali's construction value chain, nor has there been any analysis of their potential contribution to economic development. This paper contributes to answering these questions by way of a sequential mixed methods approach. Qualitative, semi-structured interviews with 33 experts and stakeholders were followed by a survey with 546 firms active in Kigali along five segments of the construction value chain: planners/architects, producers of materials, suppliers of materials and equipment (quincailleries or hardware stores), construction/masonry firms, and firms that install energy, water and wastewater technologies. Qualitative interviews were conducted in Kigali in March 2024. The survey was conducted in April-June 2024 and covers all three districts of Kigali. We employ a bottom-up approach to defining green jobs that examines what firms and employees in the context of Low-and Middle-Income Countries (LMICs), such as Rwanda, are actually doing. We cross-checked these green practices and supplemented them based on the literature by contrasting them to conventional practices (see Appendix A1). There is a comprehensive, ongoing debate in the literature on what green jobs are and how to measure them (see Apostel & Baslund [2024] and Bowen [2012] for an overview). Rather than using input-output models or adapting occupations or tasks based on databases and labour market structures of high-income countries, such as O*net or ISCO codes, as most other studies do (Urban et al., 2023in). In our perspective, an empirically derived definition is more useful to better approximate a variety of green job types and their future potential. Scholz and Fink (2022) have made a similar argument in their working definition of green jobs in cities.

We generally define green jobs in Rwanda's construction sector as roles that advance environmental sustainability or resource efficiency throughout the building lifecycle, from planning and design to demolition or repurposing (green practices). They can emerge at any point of the value chain and vary in green intensity. In our view, a job in which employees use one or two green practices should not per se qualify as a green job. Instead, the qualification as a green job is about the type and frequency of green practices performed, as we will further explain in this study.

To summarise, the novelty of our contribution is three-fold. First, we provide a nuanced, sectoral analysis of green jobs along all major segments of the construction value chain in Kigali. Thus far, most studies provide broad economy-wide estimations and do not capture jobs along specific value-chains (Apostel & Baslund, 2024; Circle Economy et al., 2024). Second, we use primary, rich empirical data collected at the sub-national level, combining qualitative and quantitative data. This enables fine-grained analyses of green job types rather than having to adapt existing datasets or codes that are ill fitting for LMICs (Doan et al., 2023; Granata & Posadas, 2023). Third, we provide a case study of a green city transition in an African city with a focus on buildings and construction, whereas the few available sectoral studies focus on the United States or Europe and/or examine renewable energy only (Cantore et al., 2017; Lehr et al., 2016; Malik & Bertram, 2022; Sovacool et al., 2023).

# 2 Why green jobs in green low- and middle-income economies require a different perspective

After a decade of relative silence, the policy debate about green jobs as opportunities for LMICs has recently picked up again. The nascent circular economy has created hopes for a new green job machine as the International Labour Organization (ILO) estimates that 6 million new jobs could be created globally from recycling and repair activities (Circle Economy, 2024; ILO, 2024). The scientific debate about green jobs still mainly focuses on measurement issues. The potential of green jobs and estimations of current numbers differ depending on the definition and choice of method. For policy-makers, either an under- or overestimation of the actual potential of green jobs may result.

This section summarises the current conceptual debate on defining green jobs, which is currently focused on high-income countries, and presents four arguments for why green jobs in LMICs need a different, more pragmatic conceptualisation and measurement. Two main definitions of green jobs and three measurements prevail in the debate: output vs. process-based concepts and entity-level vs. occupation- and task-based measurements (see Table 1). We briefly explain these below. We then argue that neither of these is suitable for capturing the dynamics of greening labour markets in LMICs. We give four reasons related to the structure of the labour market in LMICs, the definition of a green job, the scope of what mainstream approaches conceptualised for high-income countries capture, and the different dynamics of a green transition in LMIC cities. Finally, we spell out how and why we differ from mainstream approaches, as Apostel and Barslund (2024) suggested to organise the research field.

The debate about output-based vs. process-based definitions of green jobs concerns the relation of the environmental impact of a firm's product or service to the firm's workers and their activities. Output-based approaches define jobs as "green" if they are based on the production of goods or services that are beneficial to the environment or conserve natural resources (i.e., the number of workers in those firms at the entity-level) (Vona & Consoli, 2015). In contrast, process-based definitions target the environmental impact of the job or activity itself, often focusing on workers in the analysis whose explicit jobs are to reduce the environmental impact of firms (Bureau of Labour Statistics [BLS], 2013).

Researchers taking an output-based definition of green jobs usually measure green jobs either at the entity-level, using statistical input-output models and the respective dataset, or based on occupations. Occupation-oriented measurements and related datasets are also used by researchers that take a process-oriented definition, somewhat confusing the field.

Occupation-based measures classify green jobs via entire job roles, tasks and skills, without sub-dividing tasks (see Table 1). The O*Net database, which is based on employment data from the United States, or different occupation classification systems (e.g., International Standard Classification of Occupations (ISCO), Statistical Classification of Economics Activities in the European Community (NACE) or Standard Occupational Classification (SOC) in the United States) are used for many such analyses. Much of the literature combines occupation-specific measures with output-based definitions to some extent (e.g., Janser, 2018; Scholl et al., 2023) or relate both to a systemic perspective (Bohnenberger, 2022).

Researchers taking a process-based definition of green jobs alternatively use a task-based measurement. Task-based methods focus on the specific tasks that make up an occupation. Weighing occupational shares by the greenness of their tasks has produced a more nuanced understanding of green jobs in the European Union (Vona et al., 2019). Adapting this approach to an LMIC requires many crosswalks and assumptions, as the example of India shows (Ham et al., 2025). The taxonomy developed by Bowen and Hancké (2019) combines tasks, skills and the aspect of labour demand. Their conceptual differentiation into Green Increased Demand jobs (high demand due to green, but only indirectly green themselves, e.g., bus drivers), Green Enhanced Skills jobs (existing jobs that require significant skill changes as a results of greening, e.g., electric vehicle technicians) and Green New and Emerging Jobs (unique jobs created to meet the demand of the green economy) is helpful. It provides the grounds for a more fine-grained understanding of green job types and temporal dynamics that match the evolving nature of the green transition.

**Table 1: Differences between common green job measures and applicability to LMICs**

| | Output-based | Occupation-based | Task-based |
|---|---|---|---|
| **Unit of analysis** | Goods or services produced that are beneficial for the environment or conserve resources | Entire occupations | Specific job tasks or practices |
| **Breadth vs. depth** | Sector-specific outputs | Broad and assumes that complete roles are green | Granular, focusing on different practices within jobs |
| **Data sources** | Firm-level data, industry reports | Labour market statistics, e.g., ISCO, NACE and SOC | Job descriptions and surveys, e.g., O*Net |
| **Applicability in LMICs** | Gives good sectoral overviews, lacks nuance and ignores partly and indirect green jobs | Needs adaptation to local labour market conditions and occupations, as well as ignores partly and indirect green jobs | Task descriptions often do not match LMIC contexts and the frequency and environmental impact of the tasks performed need to be added |

Source: Authors

We now present some points of critique to the above available concepts and measurements. Due to the high level of generalisation inherent to both output- and occupation-based approaches, they tend to end up with conservative, rather low counts of green jobs. They often focus on a few, clearly green sectors or occupations that have good data availability. Measurements based on the O*Net database or the occupations classification systems like ISCO work with job titles that either do not exist (yet) in LMICs, cannot account for locally differing tasks under the same occupation or for mixed occupations (e.g., mason-retailer of used materials), and tend to not accurately capture the informal sector. Process-oriented definitions and task-based measures provide a more useful starting point for green job analyses in LMICs. However, The O*net and ISCO databases also provide the information for task-based measures (e.g., Vona et al., 2019 and Bowen & Hancké [2019] mentioned above), so a direct applicability to LMICs is hardly possible.

In our view, the following four aspects make green jobs in the building sector in LMICs different from high-income countries. These aspects are the reasons why we argue for a new, pragmatic approach. First, the structure of the labour markets in LMICs is characterised by more informal and semi-formal firms which often hire on a day-to-day basis. Skill levels of workers are more mixed and less formally acquired or recognised than in high-income countries. Bottom-up green skills, such as the repurposing of materials for other products, are important for greening, but may not be part of the official skill set in a LMIC's labour market. Additionally, people may combine occupations or fulfil tasks which are relevant to a green transition, but do not exist in the same way in a European labour market (e.g., intermediaries for acquisition/sales of used materials). In terms of greening labour markets, these structural characteristics mean that a topdown blueprint for how to foster a green transition may not work. Instead, an appreciation of ongoing, bottom-up skill development that is more flexible may be required.

Second, task-based definitions and respective measures provide the most useful starting point for capturing green jobs in LMICs among the available approaches, but also require adaptation. In other words, a list of tasks defined for the construction sector in the Global North does not necessarily match what is being done on a construction site in a LMIC, and the task label does not accurately describe the real environmental impact of the task. To capture these impacts, it matters how frequently a task is performed and how relevant it is for the environment (weighting). For example, environmental impacts greatly vary based on whether a worker in a firm regularly maintains an energy-intensive motor or just occasionally switches off the lights when not in use, and whether a civil engineer consistently plans a building with clay and stabilised earth bricks or only rarely does so and otherwise uses cement.

For LMICs, pre-defined tasks based on existing, standardised datasets from the United States or European Union may still mean that some green jobs fall through the cracks of measurement (Ham et al., 2025; Mathieu, 2024). Reflecting on the labour market structure and green job identification in Indonesia, Granata and Posadas state correctly that “there is no straightforward way to translate these (green job) concepts into a measurement methodology that suits existing data or cost-effective collectable new data” (Granata & Posadas, 2023, p. 1). Moreover, the frequency and relevance of tasks performed for the environment are often disregarded. These require additional conceptualisation and weighting.

Third, in terms of the scope of green jobs captured, a value chain perspective shifts the analytical perspective towards the journey of the final product or service which may include some indirect or partly green jobs as well. Opinions in the scientific literature and policy circles as to whether indirect green jobs should be counted as green jobs vary widely. Indirect green jobs “do not contribute directly to preserve the environment but might be in-demand as part of the green transformation” (Granata & Posadas 2023, p. 1). They are generally understood to be located in supply chains (Dell’Anna, 2021). A value chain perspective solves the issue of the inclusion or exclusion of such jobs by including only those firms and retailers that are involved in the generation of the green parts of the end-product (in this paper a green building). In a study on Tunisia, Lehr et al. (2016) attempted this by integrating additional industries supplying renewable energy technology. This does not mean that every screw that is sold for use in a green building turns the worker’s position in the screw factory or the hardware store into a green job. Instead, a deeper analysis and weighting of green vs. conventional production or sales amounts is required (see the Methods section below). A value chain perspective can also more adequately capture the variety of nascent green jobs present, including those that would not be counted as fully green due to the occupation name or task description. We agree with Granata and Posadas (2023) who advocate for a continuous measure of greenness rather than the prevalent dichotomies thus far.

Fourth, the dynamics of the green transition in LMICs are different than such a transition in high-income countries. In contrast to the United States and Europe, many green jobs in LMICs are evolving at an earlier stage. They are adapted to local contexts or reflect locally existing real-life practices that were previously not labelled as a green task or practice (e.g., reusing production waste). There are likely to be many mixed or partly green jobs as firms produce some environmentally-friendly outputs or use some environmentally-friendly production processes, yet not completely. Furthermore, green practices may be both consciously and unconsciously performed as such in LMICs. Both of these aspects should feature in a green job assessment as long as the practices save resources or produce environmentally-friendly goods or services – the awareness of being environmentally-friendly or contributing to a concept like circular economy should not make a difference. Green concepts, such as circular economy, have been developed in the Global North and are likely not well-known in the Global South as concepts, yet repairs and reuse, for instance, are already deeply engrained in many LMIC work cultures, albeit not always in a productive or high-quality manner (Preston & Lehne, 2017).

Given these four arguments on why green jobs in LMICs are different at this stage of the green transition, it makes sense to think about a locally suitable definition of green jobs that also incorporates job quality. Castillo (2023) outlines five key criteria for a decent green job: adequate wages, social protection measures, safe working conditions, promotion of workers' rights and social dialogue, and the right to have labour unions. Safe working conditions are also related to the stability of employment (i.e., permanent jobs vs. non-permanent contracts or casual workers) (ILO, 2013). While these ILO criteria are laudable, the application of all of them narrows down the number of jobs in any LMIC, regardless of being green or not. Allowing for some development space with flexible green job standards here enables job recognition and gives firms time to adjust while supporting Rwanda's green economy goals in line with the revised Green Growth and Climate Resilience Strategy of 2023.

As a working definition of green jobs in Rwanda's constructions sector, we thus propose to not use the decent work criterion as a prerequisite for a green job. We define green jobs in Rwanda's construction sector as roles that advance environmental sustainability or resource efficiency throughout the building lifecycle, from planning and design to demolition or repurposing (green practices). These jobs may involve: responsibly sourced and low-impact materials, minimal transportation emissions, and consideration of environmental impacts during a building's use; cost-effective strategies that reduce resource consumption, reuse or recycling of materials; and providing guidance to clients on greener choices. Such roles can be found at any point in the value chain – directly on construction sites or indirectly in administrative and supply functions. They vary in "green intensity", ranging from certified practices to partial improvements that emerge from bottom-up or informal initiatives. For example, while recycling is often formalised in high-income countries, in Rwanda it frequently emerges as an informal but critical component of green practices.

In our definition, green is thus not a unidimensional concept and going from non-green to green is not dichotomous (i.e., there are different shades of green). Our concept is based on identifying a number of practices that are relevant to our context and then measure them on a non-dichotomous scale. Green practices of a firm or worker should be overall more green than brown in terms of their environmental impacts and be exercised with regular frequency (see a list of specific dimensions and criteria for the construction value chain in  appendix A1).This definition allows for flexibility in applying ILO criteria, aiming to include emerging green practices while advancing decent work and social protections in line with national sustainability goals as per the second generation of the National Strategy for Transformation (2024-2029) and the revised Green Growth and Climate Resilience Strategy (2023).

While our case study focuses on the construction value chain in Kigali, this definition can be applied to all urban areas of Rwanda and could provide a basis for other LMICs. We argue for a value chain lens that includes jobs that also supply greener firms, but may not be fully green themselves, as well as argue for continuous measures of greenness that differentiate green job types and enables the identification of pathways to a greener workforce over time.[2]

2 For space reasons, we are not able to provide a deeper analysis and discussion of pathways that lead to a greener workforce in this paper.

# 3 Methods

This section first describes the sample selection and data collection of both qualitative and quantitative data. We then explain our conceptual methods for calculating green jobs based on the measurement of green practices in our quantitative survey. This is the main independent variable for our regression analyses on job growth and job quality, which both serve as dependent variables. We then explain how we capture these dependent variables, followed by the econometric summary of our approach. The section concludes with a discussion of the limitations of our approach, namely its correlative rather than causal nature.

## 3.1 Sample and data collection

We conducted a mixed methods study with two sequential steps. The first step consisted of a qualitative research phase with 35 in-person semi-structured expert interviews and an analysis of relevant policy documents in March 2024. Expert and stakeholder interviews included key government officials, donor organisations, industry associations, firms active in the construction sector and other local experts on the topics of interest. While the qualitative interviews with seven construction firms were more explorative in nature, the 28 interviews with other key experts and actors reached the saturation point required for expert interviews at which no further relevant information could be gained for the purposes of this study (Hennink et al. 2016). Notes and/or recordings were taken, depending on the consent of the interviewee, and analysed following the content analysis method by Mayring (2014). The goals were to understand the current drivers, barriers and dynamics of Kigali's construction value chain and to discuss approaches to identify green jobs. This first phase informed the firm survey. In the second step, we conducted a quantitative firm survey with 546 companies operating along the construction value chain in May-June 2024, covering all three districts of Kigali. Rather than aiming for a representative sample of one segment of the value chain, we opted for an exploratory approach that covered the main segments of Kigali's construction value chain, approximating the relative distribution of firm types in the value chain based on Rwanda's Establishment census of 2023 (see Table 2).

**Table 2: Sampling within value chain segments**

| Value chain segment | Firm types and occupations included | Number in sample |
|---|---|---|
| **Planners** | Architects, civil engineers and urban planners | 63 |
| **Producers** | Manufacturers of bricks, stone and timber | 122 |
| **Suppliers** | Hardware stores (quincailleries) | 54 |
| **Construction** | Masons, bricklayers and roofers, finishers, helpers on site | 172 |
| **Installation** | Electricians, plumbers, solar energy firms and rainwater harvesting service providers. | 135 |
| **Total** | | 546 |

Source: Authors

We employed partly purposeful, partly randomised sampling for both qualitative and quantitative phases. Full randomisation was not feasible due to the absence of a comprehensive sampling frame and the heterogeneity of firms in Kigali's construction sector. The National Institute of Statistics Rwanda does not have this kind of data from its labour force and enterprise surveys at the level of detail required for this study. For the firms, we set a quota of two-thirds formal firms (with the criteria of having a tax registration/TIN number, registration with the Rwanda Development Board, paying contribution to Rwanda Social Security Board and maintaining account books) and one-third informal firms. The Integrated Business Enterprise Survey 2022 and the 2023 Establishment Census show a similarly high share of formal firms in the construction sector and each use some of the criteria mentioned above. Firms were identified primarily through administrative lists collected from relevant industry associations and trade unions, including the Institution of Engineers Rwanda, the Rwanda Association of Professional Environmental Practitioners, and STECOMA. The resulting list included just below 5,000 entries, which served as an approximate sampling frame. Firms were then randomly selected from this pool in line with the formality quota and value chain segment. To complement the selection of informal firms, a snowball sampling approach was also employed. The survey was conducted door-to-door in Kinyarwanda, the local language in Rwanda, with professional enumerators.

The questionnaire included seven modules. Each firm, represented by its owner or the managing director, answered questions for three modules: one general module on firm characteristics and general green practices, one module on green/conventional practices for the respective firm type, and one containing questions on attitudes, regulatory compliance and training needs. The survey and the connected research received ethical approval from the respective committee at IDOS.

**Table 3: Overview of survey questions on green practices**

| **Practice number** | Survey question | Green practice |
|---|---|---|
| **1** | How often, if ever, do you decide for materials/appliances you are using in your work based on where they come from, i.e., whether material is local, imported, from close or far away…? | Transport |
| **2** | How often, if ever, do you plan/build/sell products with the possibilities for dismantling and reuse of building parts at the end of the life of the building in mind? | Lifecycle |
| **3** | How often, if ever, do you discuss with clients what money they could save over time when using recycled/re-used materials, energy-efficient systems or water conservation methods? | Savings |
| **4** | How often, if ever, do you use/plan with/sell waste, scrap and re-used materials in your work? | Reuse |
| **5** | How often, if ever, do you provide advice to clients on using recycled/re-used materials, energy-efficient systems or water conservation methods? | Advice |
| **6** | How often, if ever, do you install/plan with materials/appliances based on their resource-efficiency? You know, those using less raw materials, less energy, less water etc. | Efficiency |

Source: Authors

## 3.2 Green job calculation methods

We calculate the number of green jobs at the firm level based on the frequency of six major green practices or motivations performed in the firm which vary in environmental impact. Based on our qualitative research phase, the survey focused on the following six green practices deemed most relevant to the local construction context: material sourcing and transportation, lifecycle thinking, financial awareness and cost saving, use of waste/recycled materials, client advisory, and resource efficiency (see Table 3). Respondents were asked to report the prevalence or awareness of these practices in their firm using a seven-point Likert scale ranging from ‘never’ (0) to ‘always’ (6). The responses were aggregated into a Green Index which serves as the primary measure of firm-level greenness. This additive index ranges from 0 to 36 and allows for the comparison of green practices across firms.

We validated the composition of the Green Index in multiple ways. First, correlation analysis showed that the six individual measures were significantly positively correlated, with coefficients ranging from a moderate 0.35 to 0.75, suggesting that the measures are not overly redundant. An exploratory factor analysis confirmed the presence of a single dominant factor (eigenvalue = 3.81, proportion = 0.985) underlying the six separate questions, indicating construct homogeneity around our modelling of “greenness”. Furthermore, Cronbach’s alpha for the index was 0.891, demonstrating a high level of internal consistency of the green index scale. Based on this evidence, aggregating the six measures into a simple additive index was deemed appropriate. To facilitate interpretation of the index in the regression analyses aiming to measure employment growth and job quality, the Green Index was further categorised into three quantiles, representing low, medium and high levels of green practices. Besides being more intuitive, this categorisation also ensures a sufficiently high number of observations in each category.[3]

In the regression analyses, we additionally explore tendencies according to a green typology. For the purpose of uncovering more nuanced green types, we generate a typology of green jobs that emphasises the mixed nature of greenness across our sampled firms. As the aggregate green index only provides an average score on the green practices and allows firms to compensate worse scores on some practices with higher scores in other practices, this typology is meant to evaluate firms on each practice separately. To achieve this, we follow three steps.

*Step 1:* Based on the seven-point Likert-scale (0 = never to 6 = always) we capture the respective frequency of performing the six green practices and group them based on the following scores for simplification:

- High frequency = 5, 6
- Medium frequency = 2, 3, 4
- Low frequency = 0, 1

*Step 2:* Attribute firms to six types of firms based on their scores in the six green index dimensions, raking them from highly green to non-green:

- **Highly green (5)**: Score in the high frequency for all 6 green practices;
- **Select green (4)**: Score in the high frequency in at least 1 of the 6 green practices and medium in the others;
- **Moderate green (3)**: Score in the medium frequency for all 6 green practices;
- **Diverse green (2)**: Score in the high frequency in at least 1 green practice, low in at least 1 green practice and medium in the others;
- **Select non-green (1)**: Score in the low frequency in at least 1 of the 6 green practices and medium in the others; and
- **Non-green (0):[4]** Score in the low frequency for all 6 green practices.

3 Certainly this categorisation can be viewed as arbitrary, but as a robustness check, we also conducted the regression analysis with the uncategorised index and with 4 and 5 categories. All results are the same.

4 This categorisation of green types generally follows an ordered ranking, with numerical values assigned accordingly (as indicated in brackets). However, the relative ordering of the middle categories – moderate and diverse green – is less clear-cut. As a robustness check, these two categories were assigned the same numerical value in the regression analysis. The results remain consistent when using the original full ranking described here, suggesting that the findings are not sensitive to the treatment of these intermediate categories.

*Step 3:* Counting the number of firms and jobs in the different categories. For all types, when counting the jobs per firm according to the type, we removed a ratio of non-production jobs based on firm size since we only want to measure direct green jobs. We do this by generating a share of non-production jobs by firm size based on the date of the World Bank Enterprise Survey of 2023 for Rwanda.[5]

**Table 4: Cross-tabulation of firm distribution of Green Index quantiles and Green typology**

| | Non-green | Select non-green | Diverse green | Moderate green | Select green | Highly Green |
|---|---|---|---|---|---|---|
| **Low** | 61 | 110 | 26 | 0 | 0 | 0 |
| **Medium** | 0 | 82 | 41 | 40 | 4 | 0 |
| **High** | 0 | 2 | 12 | 80 | 68 | 20 |

Source: Authors

Table 4 presents the intersection of the two methodologies used to assess firm greenness. As expected, the two measures are highly positively correlated, with a correlation coefficient of 0.89. The rankings are also consistent at the extremes, as all non-green firms are concentrated in the lowest quantile of the green index, while highly green firms only appear in the highest quantile of the green index. However, some differentiation emerges in the middle range, particularly among select non-green and diverse green firms, with observations in all three quantiles of the green index. The distribution of original green index scores within each category further illustrates this variation: green index scores for select non-green firms range from 2 to 20, diverse green from 5 to 27, moderate green from 13 to 24 and select green from 17 to 30. The widest spreads are thus observed among select non-green and diverse green firms, which is why we provide a more focused analysis for these two categories below in Section 4.2.

## 3.3 Dependent variable measurement: quantity and quality of jobs

The data used for the analysis focuses on understanding the effect of various factors on employment outcomes. Our regression analysis employs three distinct dependent variables: job growth, the share of permanent jobs, and average monthly salaries, with the latter two serving as indicators of job quality. Job growth is calculated based on the change in employee numbers between the survey year and two years prior.[6] To meet the linearity assumption of our regression model, we linearise these growth rates using the inverse hyperbolic sine transformation, which accommodates both negative and zero growth rates, unlike traditional logarithmic transformations that are incompatible with such values.

5 We did not add specific weights based on the environmental impacts of each green index dimension because the available literature does not provide enough scientific grounds for weighting all of our dimensions. Conceptually, developing a scoring ourselves seemed to add too much arbitrariness to our own, already new measurement approach. Besides, the different relevance the six dimensions have for firm types further complicates meaningful weighting. For instance, a hardware store is likely to score higher in the client advice dimension, but lower in a lifecycle thinking dimension, whereas a mason may be more likely to score low on client advice due to less client contact, but high on resource-saving on site.

6 We chose this shorter time frame to limit the likely impact of recall bias and the corona pandemic.

The share of permanent jobs is calculated by dividing the number of permanent employees by the total number of current employees. In our survey, permanent employment includes both employees with and without formal contracts, while temporary and casual employment forms the other category. This differentiation allows for a nuanced analysis of employment quality across firms.

For average monthly salaries, our survey collects salary data for permanent employees across seven salary brackets (details are in Appendix A2) and average daily wages for temporary and casual workers. The average monthly salary for permanent employees is computed by assigning the mid-point value to each salary bracket. For the highest, open-ended bracket, the mid-point is adjusted by multiplying the lower bound by 1.5. We then calculate the average salary across all relevant brackets for each firm. Salaries for temporary and casual workers are combined using an arithmetic mean and subsequently converted to a monthly figure by assuming 20 working days per month. Finally, we derive the average monthly salary by weighting permanent and non-permanent salaries according to the respective share of each group within the firm. This measurement framework directly informs policy by linking greening practices with employment stability and quality.

## 3.4 Empirical methodology

To analyse the relationship between our two different measures for green practices and the different employment outcomes, described above, we estimate a simple ordinary least squares (OLS) regression model. The regression equation is specified as follows:

$$Employ_i = \beta_0 + \beta_1 (G_i) + \gamma \boldsymbol{X_i} + \varepsilon_i,$$

where $Employ_i$ represents the different measures for employment in firm i, including total employment growth, the share of permanent employment, and the average monthly salary. $\mathbf{G_i}$ reflects the two main explanatory variables, namely the green job typology measure and the Green Index quantiles, which categorise firms into low, medium and high levels of green practices. $\mathbf{X_i}$ is a vector of firm- and manager-level control variables to account for observable characteristics of firms. These controls include: the value chain segment, specified as a factor variable with planners as the reference category; firm size, based on employment numbers and divided in the usual categories of small, medium and large (World Bank definition); firm age; and a formality index constructed using four variables that indicate the level of formalisation within the firm. Additional firm-level controls include revenue generated in the past year and whether a firm is involved in government projects and the total current number of projects a firm is engaged with. At the manager level, the controls include the education level and gender of the main manager. Furthermore, we control for spatial differences by including district dummies for the three districts of Kigali in which the firms operate. These control variables are supported by the limited empirical literature on African firms (Aterido et al., 2011; Atwine et al., 2023; Page & Söderbom, 2015) and are chosen based on a parsimonious specification that balances data availability with theoretical relevance. Finally, $\boldsymbol{\varepsilon_i}$ represents the random error term.

The primary coefficient of interest in the analysis is $\boldsymbol{\beta_1}$, which captures the relationship between the greenness measures and the various employment measures. This coefficient allows us to examine whether firms with higher levels of green practices or from a certain green typology are linked to better employment outcomes. To further explore how this relationship potentially differs by value chain segment, we estimate the baseline model separately for firms from the respective value chain segments (e.g., only including planning firms, and then report the estimated coefficients for each group). Furthermore, we investigate potential non-linear effects by including the main explanatory variables as factor variable and visualise the results using average marginal effects plots, which illustrate how the relationship between our green variables and employment outcomes varies across the different categories of our green measures.

## 3.5 Limitations

While the OLS regression provides a useful starting point for understanding the relationship between green practices and employment outcomes, it is important to note that the estimates are correlational in nature. A key limitation of OLS regressions is their inability to assess the direction of causality within relationships. In our case, while it is plausible that greener firms tend to have higher job growth or pay higher average wages, it is equally possible that firms with higher growth or paying higher wages are more likely to be green. Thus, the aim of our analysis is not to establish any causal claims. We also need to stress the limited representativeness of our firm sample both at the national and sectoral level, making cautious interpretation of the results necessary.

Since the Green Index relies on self-reported data, the possibility of a social desirability bias must be acknowledged. Some respondents may have over-reported the prevalence of green practices to present a more favourable image of their firms. To mitigate this bias, several measures were implemented during the survey. Respondents were assured that the survey would remain entirely anonymous, and the importance of truthful responses was emphasised. Questions that the green index were comprised of were asked at the end of the general firm characteristics module (first module), before going more deeply into further green topics, to avoiding priming as much as possible. Moreover, respondents were informed that there were no “right” or “wrong” answers and the survey questions were framed using neutral wording to avoid signalling socially desirable responses. Pre-tests with a handful of firms were conducted to identify and address potentially problematic questions before the final survey implementation.

Regarding reported employee numbers, two biases could not be completely countered. The recall of the number of employees two years ago is likely to have produced some incorrect estimations. This recall bias is inherent to almost all firm surveys of a similar nature. Additionally, construction firms hire a part of their employees depending on commissioned projects. During phases of large-sale projects, numbers in employees and turnover increase, while casual workers, in particular, are let go after such projects are finished. We dealt with this by explicitly controlling for the number of projects firms are engaged with at the time of the survey.

Finally, we could not completely control for seasonal effects in production volumes and financial turnover, possibly affecting the size of total effects. Rwanda has two rainy seasons during which fewer bricks are produced and fewer buildings are constructed. As a robustness check, we did the following for a part of the sample: In the module addressing brick producers, we therefore asked about the type of bricks produced, the averages of the main type produced in a month in each of the two seasons, the types and capacity of kiln used, and the excavation and transport methods. These questions were in line with method developed by SKAT (2023), Proecco Programme. Drawing on 10 years of in-depth sector expertise in Rwanda, they developed a comprehensive methodology to capture employment numbers per an average number of bricks, weighted by technology, machinery used and the season. We cross-checked our employment numbers by re-calculating them by applying their approach for the brick producers in the sub-sample (N= 50). The numbers matched roughly, thus increasing the validity and reliability of our questions and approach.

# 4 Descriptives: green job numbers and types

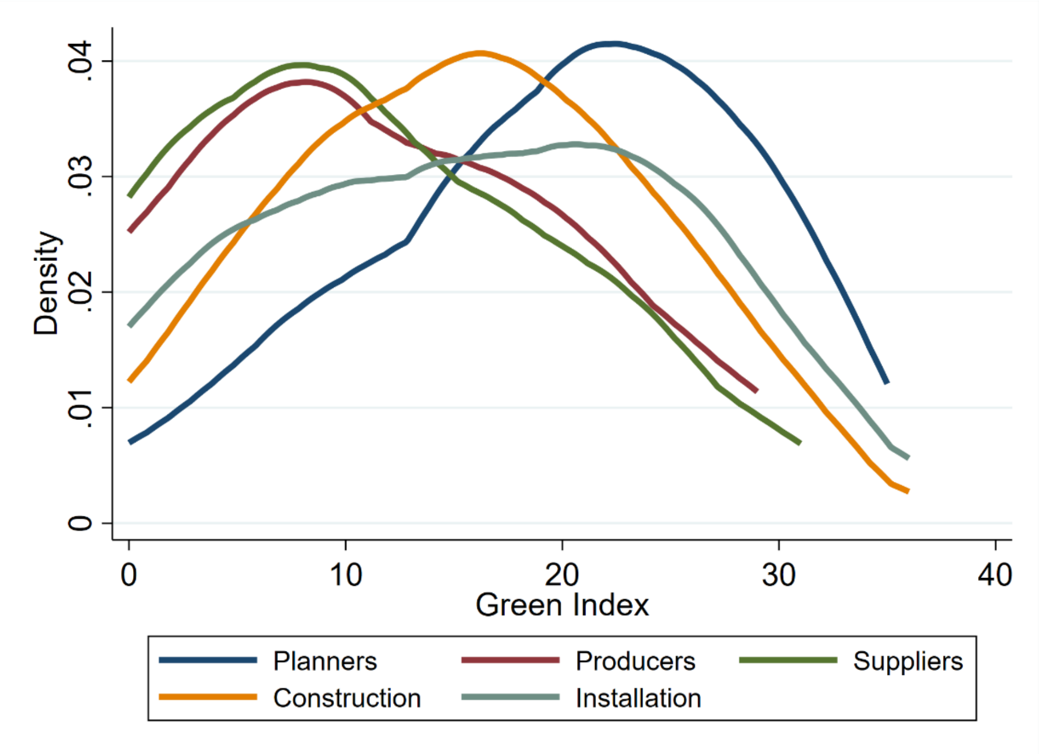
This section provides insights on the green practices and the number and types of green jobs we found. We first present the descriptive results on this based on our quantitative firm survey and discuss them by firm type along Kigali’s construction value chain. We then zoom into job categories that are critical for the green transition, namely those firms that have managed the first steps to greening, but are not fully engaged yet. They represent a big portion of the firms along the value chain. Thus, supporting their continuing green transition could have a substantial impact on greening of the construction value chain. We combine both our quantitative and qualitative data in the analysis of these specific firm categories. Finally, we provide additional highlights of descriptive results on green practices that provide deeper insights into the status of resource efficiency and circular economy within value chain segments.

## 4.1 Green jobs based on the green index of firms' practices

Overall, we find that with our measurement, a substantial number of green jobs already exist along Kigali's construction value chain, albeit with different shades of green. Based on the typology described above, only about 5 per cent of jobs are highly green, but about 58 per cent of jobs are at least partially green jobs (i.e., those defined as select green, moderate green and diverse green, including those that are not always being consciously labelled or executed as green). The density distribution of our additive green index across the five value chain segments already indicates that, on average, the planners (e.g., architects and civil engineers) tend to engage in more green practices, while the majority of material producers and suppliers are mostly located at lower values of the green index (see Figure 1).

Within the value chain segments, firm types also cluster in different green categories according to the typology described above (see Table 3). Most firms fall into the middle spectrum (select green, moderate green, diverse green and select non-green – combined at 88.8 per cent), with a smaller percentage representing the extremes (highly green at 5.1 per cent and non-green at 6.1 per cent). This suggests that while a small minority of firms have adopted robust sustainability measures, an equally small proportion remains almost entirely disconnected from green practices. The plurality of firms (31.2 per cent) is categorised as select non-green, indicating that many remain partially or marginally engaged in sustainable initiatives.

**Figure 1: Density distribution of green index according to firm type**




Source: Authors' calculation based on survey data

**Table 5: Distribution of (production) jobs by firm type and green typology**

| | Highly green | Select green | Moderate green | Diverse green | Select non-green | Non-green |
|---|---|---|---|---|---|---|
| **Planners** | 157 | 252 | 177 | 86 | 287 | 46 |
| **Producers** | 0 | 377 | 223 | 66 | 460 | 190 |
| **Suppliers** | 35 | 135 | 15 | 49 | 141 | 86 |
| **Construction** | 30 | 560 | 658 | 778 | 1,123 | 84 |
| **Installation** | 152 | 152 | 317 | 344 | 259 | 38 |
| **Total** | **374 (5.1%)** | **1,476 (20.3%)** | **1,390 (19.1%)** | **1,323 (18.2%)** | **2,270 (31.2%)** | **444 (6.1%)** |
| **Avg. employees** | 18.7 | 20.5 | 11.6 | 16.7 | 11.7 | 7.3 |

Notes: The number of firms is 546 and the total jobs in these firms is 10,160, of which 7,277 are in production. This table shows the number of employees in production for firms in the different categories. A proportion of non-production employees has been deducted from the total number of employees based on the average shares of non-production workers reported in World Bank Enterprise Survey data for 2023 from Rwanda by firm size.

Source: Authors' calculation based on survey data

More (highly) green jobs can be found among planners and installation firms rather than among material producers or suppliers. This may reflect a stronger emphasis on environmental standards during the design phase, potentially due to greater regulatory oversight (e.g., in large government projects) or specialised client demand. Given the higher average qualifications of workers in the planners segment, managers of these firms are also likely have higher exposure to and knowledge of green practices. As there are only a total of 170 registered architects in Rwanda, their engagement tends to be limited to larger projects commissioned by the government or businesses (interviews 21; 33). One interviewee pointed out that a real environmental sustainability mind-set among planners is not widespread yet (interview 33). Among the installation firms, some are specialised in solar water heaters (N = 22), solar photovoltaic (PV) installation (N = 14) and rainwater harvesting systems (N = 31). In other words, installation firms have greener jobs per se, while other jobs, such as electricians or plumbers, may either act because of client demand or their own motivation.

Green jobs among material producers only partly exist thus far.The value chain segment shows a tendency of polarisation. While a substantial share of jobs is labelled select green (377 or 29 per cent), a large share are select non-sgreen (460 or 35 per cent). This polarisation may reflect both cost pressures for some materials (e.g., stone) and uneven implementation of sustainable sourcing or manufacturing practices. Among suppliers, the distribution of green jobs may to some extent be tied to sales numbers of green hardware and equipment. For half of the quincailleries in our survey, on average, more than 50 per cent of total construction material sales come from green material sales. While these numbers are, of course, estimates based on an interviewee-respondent situation without verification via account books, they underline that there is a substantial demand for green, used and recycled materials.Green jobs in the construction segment are widely distributed across the spectrum, with notable representation in moderate green and diverse green. This underscores that construction firms adopt an assortment of practices – some green, some less so – possibly depending on project-specific requirements. It may also indicate that the planning with greening in mind – done by architects or civil engineers – may not always materialise in actual green construction in the end.

Our survey data on the awareness of the Green Building Standards and Minimum Compliance system indicates a potential knowledge-action gap, as 64 per cent of respondents are partially of fully aware of the Building Code, but their green practises vary a lot and are not clustered among the higher green groups (see Figure A1 in Appendix A2). Furthermore, 34 per cent of respondents also stated that the implementation of the Green Building Standards and Minimum Compliance system is not or only slightly or moderately important for other businesses in their field, while 3.5 per cent chose not to answer this implementation question.[7] According to some of our qualitative interviews, the implementation of the Building Code and Compliance System is challenging for many businesses due to higher costs and lack of knowledge and skills for implementation. From the governmental side, the number of assessors for ensuring compliance is also limited (interviews 11; 25). Previous regulations by the government had temporarily stifled the nascent market for standardised compressed earth block buildings, leading some interviewees to fear a general slow-down of the market for local green materials due to the current Building Code and Compliance System (interview 25). Moreover, some indicators in the Code are believed to be included mainly for political reasons to access international climate funding (interview 27).

Differences in green patterns both across and within value chain segments are more likely to emerge from differences in specific water/wastewater practices and reuse of various materials than from energy saving and energy efficiency. We cross-checked the consistency of answers by firm type for the resource saving question in the green index with more specific questions on energy saving/energy efficiency and water saving in the firm-specific modules (see Appendix A5 and Box 1 in Section 4.2). Overall, the consistency of answers was satisfactory.[8]

In terms of green employee numbers**,** highly green and select green firms tend to be larger, on average (18.7 and 20.5 employees, respectively), potentially indicating that bigger firms have more capacity to invest in and enforce greening, including green building standards. Large and international firms also have higher chances of winning government contracts for large projects which often have stricter environmental requirements than smaller projects or individual projects (interview 18). In contrast, non-green firms remain the smallest (7.3 employees on average), suggesting that resource constraints or limited market demand may hinder the adoption of sustainable practices among micro- and small-enterprises. Interviewees agreed that, overall, the construction sector in Rwanda is dominated by a few large firms and otherwise has many small and micro enterprises which struggle to upgrade their productivity, competitiveness and standards (interviews 9; 28).

Male employees significantly outnumber female employees across all categories, underscoring the persistent gender disparities prevalent in the construction value chain. Gender aspects are analysed further in a separate paper (Stoecker et al., 2025).

## 4.2 Green job types critical for a green transition

The select green and diverse green firms represent critical transition categories for future green economic development, as they make up a large segment of the number of jobs in our sample (20.3 per cent and 18.2 per cent, respectively, as shown in Table 5). The firms and employees in these categories engage in selected green practices – such as energy-efficient materials or selective waste management – without a wholly integrated approach across the other investigated dimensions of green practices. This makes a continued green transition process somewhat easier than for firms starting from scratch, enabling potentially more rapid improvement. However, we also find mixed attitudes to further greening and a range of market and other

7 Asking about implementation by others in the same fields lowers the chances of false positive or socially desired answers.

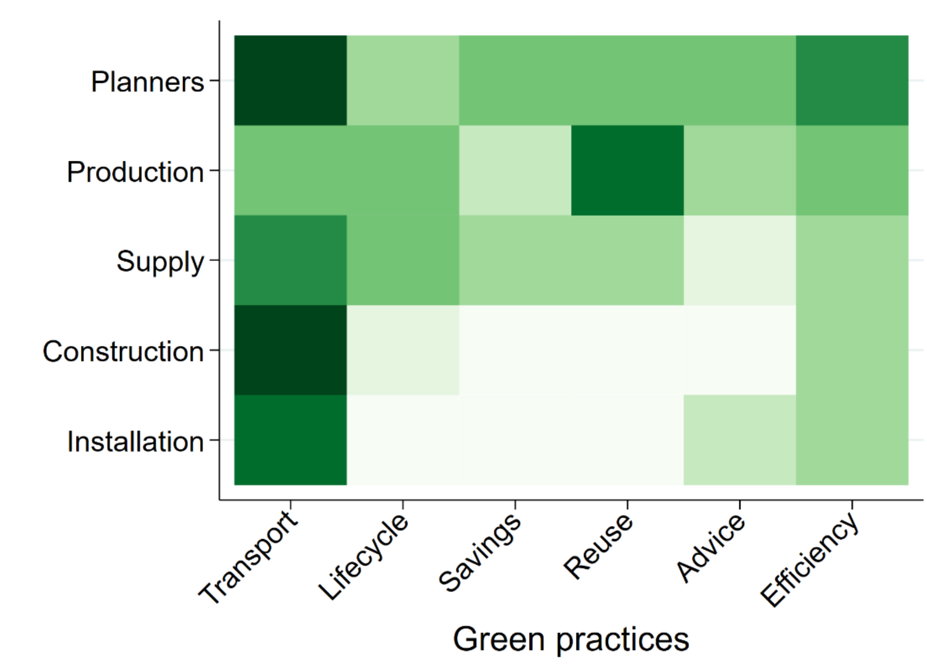
8 We only found potential significant differences for supply firms that could indicate an upward bias in the green index question, but questions that were compared are not identical.

barriers that firms in this critical transition perceive. Further policy support and capacity-building initiatives could stimulate a shift towards higher green performance if they target these barriers.

Firms in the select green and diverse green categories show substantially higher awareness of the national green building code: 81 per cent are at least partially aware of it, compared to only 57 per cent in other firms from our sample. These firms also place greater importance on adhering to these guidelines, with 57 per cent rating them as “very important” – double the share of firms in the comparison group (27 per cent). However, their attitudes towards certain green practices are more mixed, as the median of their attitude score is lower (16 vs. 22), indicating possible reservations or practical barriers in adopting some green measures, which could be based on negative experiences in their implementation.

Among the firms in these critical transition categories, the heatmap (Figure 2) shows that reducing transport distance of materials (Green Practice 1) is a practice that is already much more prevalent in firms across all the value chain segments. This is likely due to a combination of price issues and material availability on the market and – only second to these – green considerations (interviews 9; 14; 33). As a landlocked, hilly country, imports as well as transport by truck over long-distance usually implies substantially higher costs. The government’s import substitution policies (e.g., tax reductions on specific materials and a “Made in Rwanda” label campaign) support local supply. Effects of these policies on the housing market and green jobs are limited due to land prices, high mortgage rates and investors’ desire for high returns on investment (interviews 14; 25). Also, import substitution policies thus far do not manage to close the gap between green materials and less expensive imports from China (interview 32).

**Figure 2: Heat map of select and diverse green firms**




Notes: The heat map shows the mean scores for our six green practices across the different value chain segments. Darker green shades represent higher average values, indicating a higher frequency of green practices. The shading reflects relative differences within the sample, with the darkest green representing the highest observed value – not necessarily the maximum possible score on the scale.

Source: Authors’ calculation based on survey data

For the select and diverse green producers of materials, using and selling scrap and second-hand materials is common. The regression analysis in Section 5 indicates to what extent these “bottom up” and likely unconscious circular economy practices are productive in the way of contributing to firm development and job growth. Similar to installation firms, material producers struggle the most with discussing financial savings from resource saving with clients. This may be due to a lack of own awareness, a lack of direct client contact (selling only to intermediaries in the case of producers) or due to client preferences. Construction firms similarly score low on lifecycle thinking and reuse of materials, indicating a broader challenge in embedding long-term sustainability practices at the implementation stages of the value chain. In our qualitative research, interviewees emphasised a strong price orientation of house owners/renters, but gave contradictory statements on the higher/lower price of sustainable and local materials compared to conventional ones (interviews 4; 13; 11; 23). One expert explained that the perception of high material prices may be due to the overall construction costs that include high land prices and taxation, rather than a higher price of the sustainable material itself (interview 25). Firms may also suggest conventional construction to clients due to a desire for higher profits as green materials are more cost-effective and more durable in the long-run, but often require higher upfront investments (interviews 13; 23). Some firms may also simply assume higher costs and efforts to build with green materials and therefore increase calculations of labour costs upfront (interview 21). We checked prices of some materials, for example, locally made clay bricks (150 Rwandan Franc [RWF]) and lime-based bricks (120 RWF) at the market. Heat-resistant clay (158 RWF/unit including value added tax [VAT]; 0.44 RWF/m2) and heat-resistant cement (630 RWF/unit including VAT; 0.44 RWF/m2) cost the same. A standard 50kg bag of cement costs 9,000- 12,500 RWF, depending on its origin. How many bricks or how much cement is needed for one square meter of wall or flooring depends on the building type and other input materials. We could not do a full price comparison per square meter for various building types with all materials. While it is therefore difficult to provide a full cost comparison based on the numbers we received, experts informed us that the cost of the raw materials alone often do not differ much (interviews 21; 25).

On the one hand, lowering the cost of cement is seen as the most important support measure by firms among both select and diverse green firms in our survey, with 79 per cent of select and diverse green firms and 64 per cent of other firms rating it as “very important”. Providing opportunities for bulk ordering of materials also finds considerably stronger support among select/diverse green firms (73 per cent) compared to the rest (45 per cent), highlighting a 28-percentage point difference. These preferences point to widespread cost-related concerns and the need for targeted material procurement support.

On the other hand, the actual construction costs for a building also arise from high land prices, taxation, monopolies of cement producers in the market, and the perception among construction companies that everything that is environmentally sustainable must be more expensive (interviews 20; 21). The mere assumption that construction with sustainable materials is more complex and labour intensive also results in higher cost calculations by firms in their offers, artificially increasing prices (interviews 21; 25). Still, many interviewees agreed that a building that meets all criteria of the Green Building Code is very likely to be more expensive upfront than a partially green or non-green building.

Attitudes to green and local construction, government support and client preferences from the survey indicate a range of barriers throughout the whole market (see Appendix A3). Beyond the “hard” facts of transport costs and material availability, attitudes of both firms in the value chain and their clients are an issue. The Rwandan government also noted this already in the Circular Economy Action Plan and Roadmap of 2022. Key points to retain on perceptions and attitudes from our survey are:

- Hesitant attitudes to green construction and misperceptions of pricing are still widespread;
- One-third of producers think environmentally-friendly production will not help their business;
- Negative attitudes to bio-based materials are overall more widespread than positive attitudes;
- Planners/architects view prices for local materials as more concerning than producers and builders; and
- Durability perceptions of local materials present a significant challenge, especially for planners.

Interestingly, planners consistently score higher on lifecycle and advisory practices, suggesting that sustainability thinking is more embedded at the design stage than in execution. Bridging this gap could enhance the overall effectiveness of green transitions across the value chain. In line with this, the low scores of the diverse green/select green installation firms in terms of lifecycle thinking/dismantling in mind (Green Practice "Lifecycle") and using/selling scrap or second-hand materials (Green Practice "Reuse") may be largely due to a (perceived) lack of opportunities. The dismantling of a building and installing appliances based on that rationale is mostly beyond an appliance installer who enters the picture when most of the building is finished. However, using screws and bolts rather than adhesives and binders, for example, on roof tiles for solar water heaters or a rainwater harvesting system, is still possible. According to installations firms, the main reasons why clients do not want rainwater harvesting systems, solar water heaters, or solar PV are high price, clients not understanding cost amortisation, and clients preferring grid electricity/piped water. For the solar market to be more cost effective and functional, 80-90 per cent of solar firms stated that import taxes and transport costs for imported parts need to be lower and spare parts need to be more readily available. Interestingly, solar products and equipment parts are already exempt from Rwanda's Value Added Tax. Other issues, such as a mind-set shift among clients or public procurement for solar products, were also seen as key levers by many solar firms. For rainwater harvesting and the use of wastewater, firms rank the same issues, albeit with spare part availability and reliable delivery ranked lower.

When asked about the most helpful mechanisms to improve resource efficiency, firms across the board ranked provision of specific loans to invest in resource-saving technology as the most important (76 per cent in the select/diverse group vs. 58 per cent in the comparison group ranked this as "very important"). Meanwhile, improving the availability of affordable energy-efficient technologies received the lowest overall support, yet this measure shows the largest positive difference in favour of select/diverse green firms – 57 per cent vs. 35 per cent, a 22-percentage point gap – highlighting a growing recognition of the value of energy efficiency, particularly among the important transition category of firms.

In all other fields across various segments of the value chain, the mixed average scores show that some development towards a green transition is both possible and already happening (Figure 2). Supporting these firms rather than non-green firms to transition to highly green is arguably more likely to be successful in the short- to mid-term. Furthermore, circular economy practices such as the re-use of materials are already happening among may firm types (see Box 1), albeit in a very flexible way, often not ensuring quality repairs and re-use yet. Policy-makers should thus focus on providing technical assistance and financial incentives to accelerate the transition of these firms towards higher levels of greenness.

**Box 1: Status of the grassroots circular economy**

Various firms along the value chain already reuse materials – either in a conscious or unconscious pro-environmental way. Given the absence of regulation or best practices by industry regarding green materials, quality and durability, these practices can count as a form of a bottom-up or grassroots circular economy. We can only summarise the most interesting results in selected value chain segments below.

In the *design and planning stage,* the integration of used materials depends on the type of material. Almost half of the planners in our sample stated that they integrate used metal and used bricks for both structural walls and non-load bearing walls and features. Two-thirds stated that they reuse broken bricks for non-load bearing elements, such as wall fillings. This matches reports from construction/masonry firms to some extent. Differences in numbers are likely due to ad hoc changes in client preferences or other situational factors that come in between an initial plan and construction reality.

Among *construction/masonry firms,* about 20 per cent already reuse materials, especially construction waste for either wall fillings or as a base layer for flooring. This could be an example of a bottom-up, unconscious circular economy practice – there are no governmental regulations, incentives, or industry standards on this. Saving costs is more likely the reason than conscious pro-environmental circular economy thinking, as 17 per cent also stated often or very often mixing materials/ingredients to save costs (e.g., mixing cement and adobe for foundations). Reusing materials for insulation purposes is uncommon – only 5 per cent of construction/masonry firms do this. This might be due to the mostly temperate climate in Kigali, requiring neither heating nor cooling throughout most of the year.

Three-quarters of *building material producers* (77 per cent) stated that they either reuse waste internally, for example, putting broken pieces back into production or reuse for something else, or sell or donate waste for reuse/recycling. These high numbers contradict statements from experts we had discussions with during our qualitative phase who noted that firms, such as timber or brick producers, often do not know how to reuse production waste in a productive way (interviews 7; 32). Reusing and selling to scrap dealers compared with reusing materials in a productive way for business development may be two different matters.

Among *installation firms,* roughly half of the firms never work with any used or recycled materials, such as used metals, used screws or used plastic pipes. Some firms install used plastic pipes (20 per cent), while hardly any install used electronics. The sales market for mixed materials or recycled/used materials for construction is also still limited: 17 per cent of quincailleries state that they sometimes, often or very often sell these. The quality and durability of these various used materials is largely unclear. More policy guidance and best practice guidelines by industry associations could be useful to expand nascent circular economy practices in a productive, environmentally friendly and reliable way for both firms and clients.

For all value chain segments, the quality and durability of material reuse as well as effects on firm productivity are not clear from our data, warranting further research.

# 5 Results: relationship between greening and employment outcomes

In this section, we present results on our research question pertaining to what potential greening the construction value chain has for economic development, namely for job growth and job quality in the construction sector. The findings draw on the regression results from our quantitative firm survey. We find that highly green firms are correlated with higher employment growth rates and that greener firms are associated with a greater share of permanent employees and higher average monthly salaries. While correlative in nature, these results provide support to the idea that a green transition in Kigali's building environment can also help meet the challenge of decent job creation.

## 5.1 Job growth

Beyond counting the numbers of jobs across the greenness of firms and our green typology along the construction value chain, we are interested in analysing the relationship between greening and the growth and quality of jobs. These present important components of the economic development potential that a green transition in cities' building environment could bring. We do not find clear correlations between greening and job growth for all firms, but only for highly green firms, irrespective of the measurement. We first present results based on the more straightforward categorisation of firms based on our green index (e.g., low, middle and high quantiles), as described above. We then provide additional tendencies with regressions using our more fine-grained green typology. The results of the regression model introduced above are summarised in Table 6 below.

First, based on the more straightforward green index quantiles, in column 1 we find no statistically significant relationship between the green index and our measure of total employment growth, while the point estimate is positive but small. We then also split the sample into the five value chain segments and run our regression separately for each sub-sample. Table A8 in appendix A2 shows that estimates differ considerably by firm type, but are generally not statistically significant. Still, we find a larger positive estimate for installation firms, which still remains barely insignificant. (p-value = 0.142). While the regressions do not find strong evidence for a linear relationship between the green index and total employment growth, Figure 3 suggests that our model predicts significantly positive employment growth rates among highly green firms, while those for low and especially medium green firms are close to zero and statistically insignificant. There is also a slight drop in the predicted outcome of the employment growth rate between the low and medium green groups may reflect higher upfront investment costs of greening, which only pays off at a later stage.

Second, using our more fine-grained green typology in the regressions, we now find a significant positive link between green typology and total employment growth (Table 6, column 2). Running separate regressions for each firm type again indicate a higher coefficient estimate for installation firms, which is the only significant coefficient (Table A2), suggesting that the overall positive relationship is mostly driven by installation firms. To see how employment growth differs across the different green types, we estimate predicted outcomes for each type separately and plot them in a graph. This marginsplot indicates positive predicted employment growth rates for diverse, select and highly green firms (Figure 4), albeit with relatively large standard deviations, which is not surprising given the small sub-samples in each category. Based on our model, we find the highest predicted employment growth rates in the group of highly green firms, while predicted growth rates in non- and select non-green firms are close to or below zero.

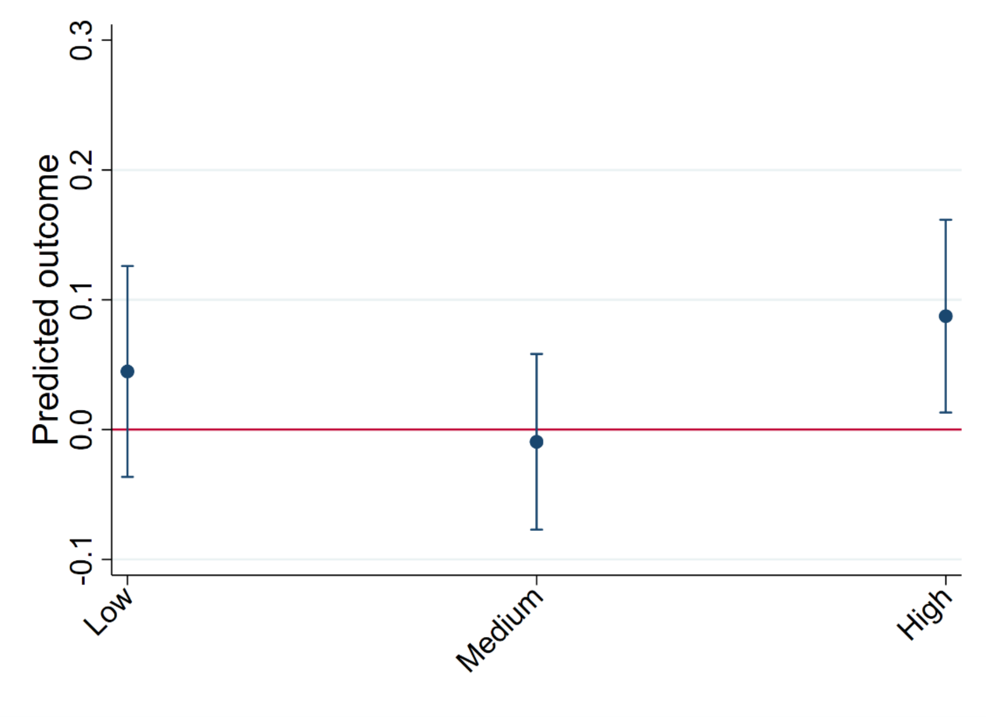
**Table 6: OLS regression results**

| | Linearised employment growth | | Permanent employment share | | Mean monthly salary | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Green Index (quantiles) | 0.017 | | 0.117*** | | 18,141** | |
| | (0.030) | | (0.020) | | (9,155) | |
| Green Typology | | 0.041** | | 0.065*** | | 19,249*** |
| | | (0.019) | | (0.012) | | (5,662) |
| **Firm Type (Planners = 0)** | | | | | | |
| Production | -0.001 | 0.03 | -0.169*** | -0.167*** | -89,087*** | -79,772*** |
| | (0.091) | (0.092) | (0.051) | (0.053) | (25,517) | (25,790) |
| Supply | -0.175** | -.144 | 0.037 | 0.032 | -100,702*** | -92,320*** |
| | (0.088) | (0.088) | (0.052) | (0.053) | (29,180) | (28,918) |
| Construction | -0.170** | -0.161** | -0.284*** | -0.290*** | -53,995 | -51,896 |
| | (0.071) | (0.070) | (0.043) | (0.043) | (32,872) | (32,927) |
| Installation | -0.005 | 0.004 | -0.018 | -0.036 | -48,863*** | -48,363** |
| | (0.072) | (0.071) | (0.043) | (0.044) | (24,329) | (23,779) |
| Firm size | 0.086* | 0.076 | -0.154*** | -0.165*** | 3,540 | -835 |
| | (0.046) | (0.046) | (0.027) | (0.027) | (27,306) | (27,815) |
| Firm age | -0.017*** | -0.017*** | 0.001 | 0.001 | 1,370 | 1,387 |
| | (0.004) | (0.004) | (0.002) | (0.002) | (1,461) | (1,461) |
| Formality index | 0.014 | 0.009 | 0.004 | 0.000 | 13,395* | 11,449* |
| | (0.017) | (0.017) | (0.010) | (0.011) | (7,050) | (6,927) |
| Firm revenue | -0.032** | -0.023* | -0.020** | -0.017* | 18,948*** | 21,987*** |
| | (0.013) | (0.013) | (0.008) | (0.009) | (5,738) | (5,704) |
| Manager education | 0.110** | 0.099** | 0.066** | 0.071*** | 19,121 | 16,657 |
| | (0.046) | (0.045) | (0.026) | (0.026) | (15,103) | (14,839) |
| Manager gender | 0.042 | 0.033 | -0.015 | -0.009 | 21,632 | 19,611 |
| | (0.076) | (0.075) | (0.041) | (0.042) | (24,225) | (23,941) |
| Government projects | 0.202*** | 0.191*** | 0.093*** | 0.103*** | 48,540*** | 46,284*** |
| | (0.059) | (0.059) | (0.03) | (0.031) | (13,365) | (13,324) |
| No. current projects | -0.033** | -0.035** | 0.021 | 0.022 | 9,988 | 9,534 |
| | (0.014) | (0.014) | (0.013) | (0.014) | (10,456) | (10,257) |
| **Districts (Nyarugenge = 0)** | | | | | | |
| Gasabo | 0.426*** | 0.415*** | 0.037 | 0.027 | -22,504 | -27,113* |
| | (0.064) | (0.065) | (0.035) | (0.035) | (15,535) | (15.602) |
| Kicukiro | 0.263*** | 0.236*** | 0.000 | 0.007 | -23,343 | -30.223 |
| | (0.064) | (0.064) | (0.039) | (0.039) | (21,579) | (20,962) |
| N | 545 | 545 | 545 | 545 | 540 | 540 |
| Adj. R-squared | 0.247 | 0.254 | 0.363 | 0.352 | 0.271 | 0.279 |

*Notes:* Robust standard errors (HC3) are shown in parentheses. ***, **, and * denote significance at 0.1, 1, and 5 per cent, respectively.

To summarise, we find evidence that highly green firms, especially in the installation segment, are linked to higher employment growth rates. In addition to the market, skill and awareness/acceptance barriers mentioned in the previous section, investments in labour and especially small- and medium-sized enterprise (SME) upgrading in LMICs depends on a range of entrepreneur and firm characteristics, networks, finance, market and technology factors (Hampel-Milagrosa et al., 2015). In the early stages of greening, changes in the labour force may become visible first in the types of staff that firms employ (e.g., more females) rather than in growing absolute employee numbers. For policy-makers, these results indicate that supporting upgrading from the medium green to highly green firms with measures targeting both greening and other upgrading barriers in a structural change approach would pay off in terms of both supporting the agendas of greening the economy and providing jobs.

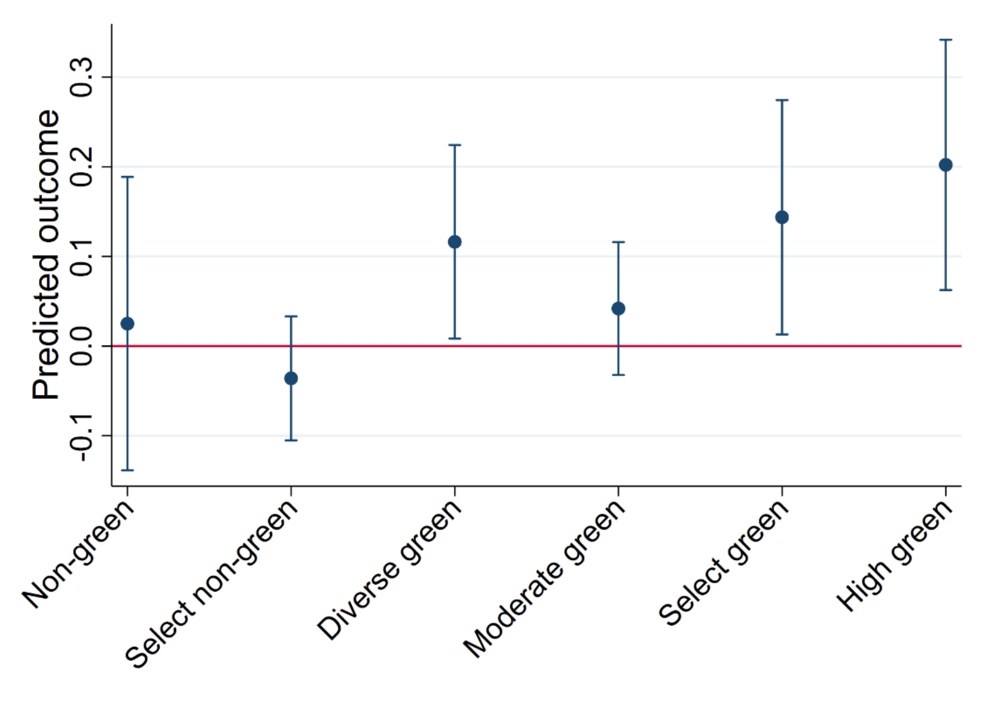
**Figure 3: Marginsplot of employment growth by green index quantiles**




Notes: The graph shows the predicted outcomes of total employment growth across green index quantiles based on the regression model in Table 6, column 1. The red line indicates the zero line.

Source: Authors

**Figure 4: Marginsplot of employment growth by green typology**




Notes: The graph shows the predicted outcomes of total employment growth across green typologies based on the regression model in Table 6, column 2. The red line indicates the zero line.

Source: Authors

## 5.2 Job quality

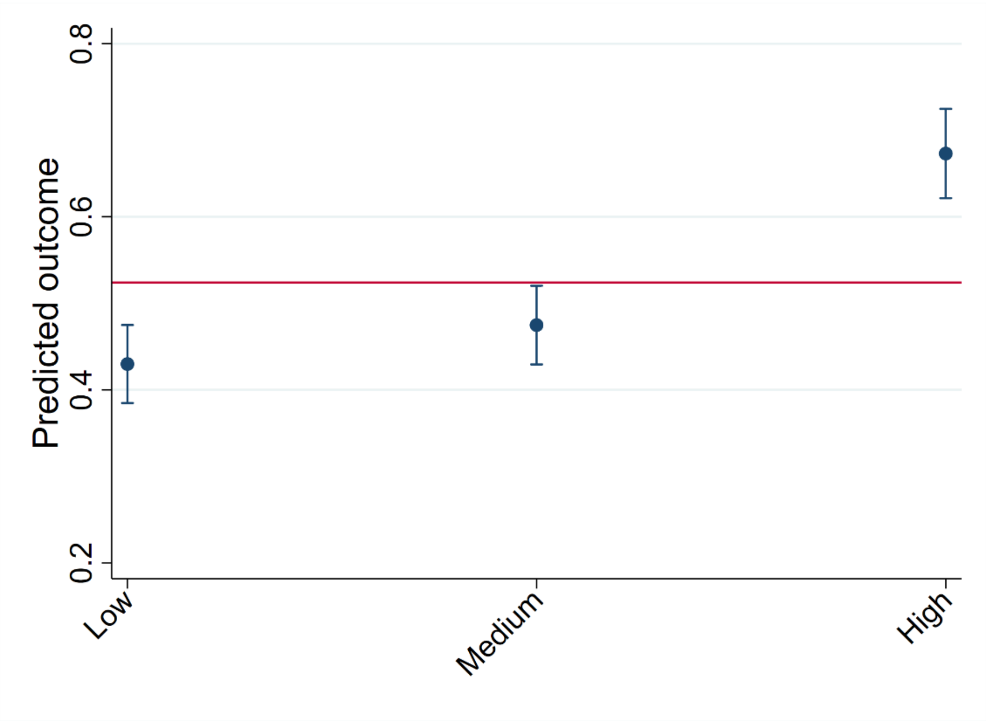
Job quality presents a key concern of policy-makers and job seekers alike. We find that greening is positively associated with two relevant indicators of job quality: the share of permanent employees in a firm and the average monthly salaries that a firm is paying. In this section, we also present results based on our green index (divided into low, middle and high quantiles) and then provide tendencies with regressions using our more fine-grained green typology.

**Permanent employment:** Results can again be found in Table 6 (columns 3 and 4) indicating positive relationships between both the green index and our green typology measure and the share of permanent workers. Separating by firm types again shows particularly large positive coefficient estimates in the construction and supplier segments (for the latter only when using the green index measure, see Table A9 in appendix A2). Looking at the plots of predicted outcomes across the different categories again (Figures 5 and 6) shows some non-linearity in the relationship between greenness and permanent employment share. There appears to be a stronger increase in the predicted outcomes between medium and highly green firms (predicted values of 0.47 and 0.67, respectively), compared to the difference between low and medium green firms (predicted values of 0.43 and 0.47, respectively). Plotting the more fine-grained green typology indicates a similar non-linear pattern, which follows a slight s-shape with larger increases in the middle section, while predicted outcomes are above the sample mean for moderate, select- and highly green firm types. In sum, the indicator “share of permanent employees” shows a consistently positive relationship with greenness regardless of the measurement approach, while revealing some non-linearity in the benefits, suggesting particularly higher shares of permanent employment in highly green firms.

**Salary:** We find strong and consistent evidence of a positive relationship between mean monthly salaries that firms pay for both of our measures of the greenness of firms. Again, using the green index shows a strongly positive link with the weighted mean monthly salary, suggesting a higher salary of about 18,000 RWF/month, on average, when going from one quantile of the index to the next, assuming all other firm characteristics are equal (see Table 6, column 5). In the separate regressions for each firm type, none of the coefficients can be estimated precisely enough to be statistically significant at conventional levels due to the low sample size. Still, we find the largest point estimates among planners and in the installation segment. Looking at the predicted outcomes for each green index quantile again suggests non-linear effects, as the rise in predicted mean salaries can mainly be observed among highly green firms, while the predicted mean salaries for low and medium green firms are practically the same (Figure 7).

Moving to our green typology also shows a positive relationship, indicating that each step up the green typology scale is associated with an increase in the mean monthly salary by about 19,000 RWF (Table 6, column 6). Estimating separately by firm type now shows largers coefficients for construction and installation firms, both of which are statistically significant (Table A10 in Appendix A2). Thus, the overall positive relationship is mainly driven by these two firm types. Plotting the predicted outcomes for each type shows higher predictions for the select and highly green group (Figure 8), while the remaining types have lower predicted values close to the overall sample mean.

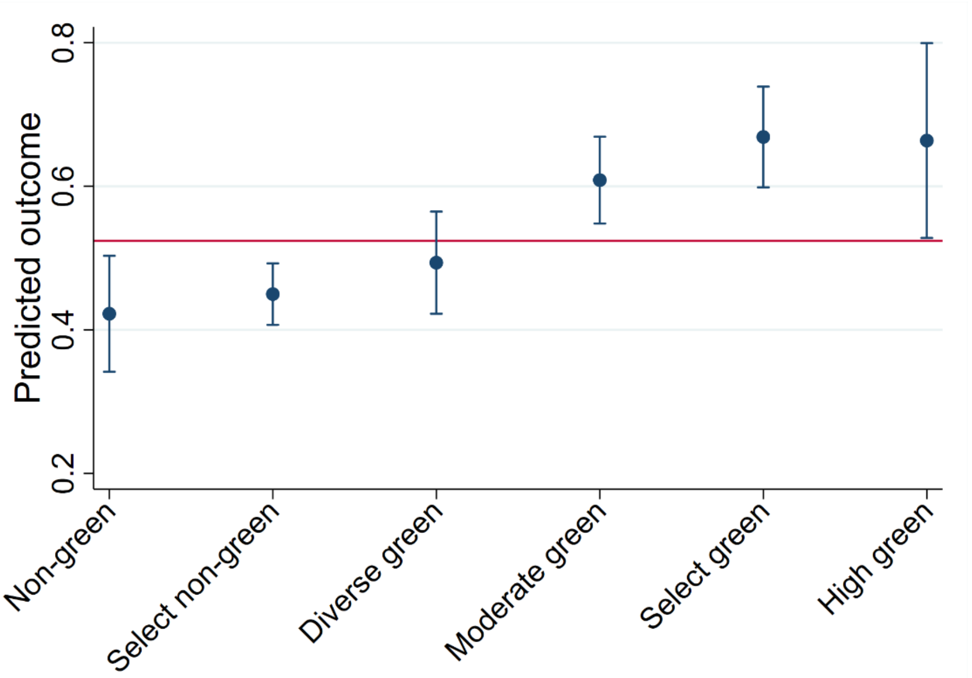
**Figure 5: Marginsplot of permanent employment shares by green index quantiles**




Notes: The graph shows the predicted outcomes of permanent employment shares across green index quantiles based on the regression model in Table 6, column 3. The red line indicates the overall sample mean of the permanent employment share.

Source: Authors

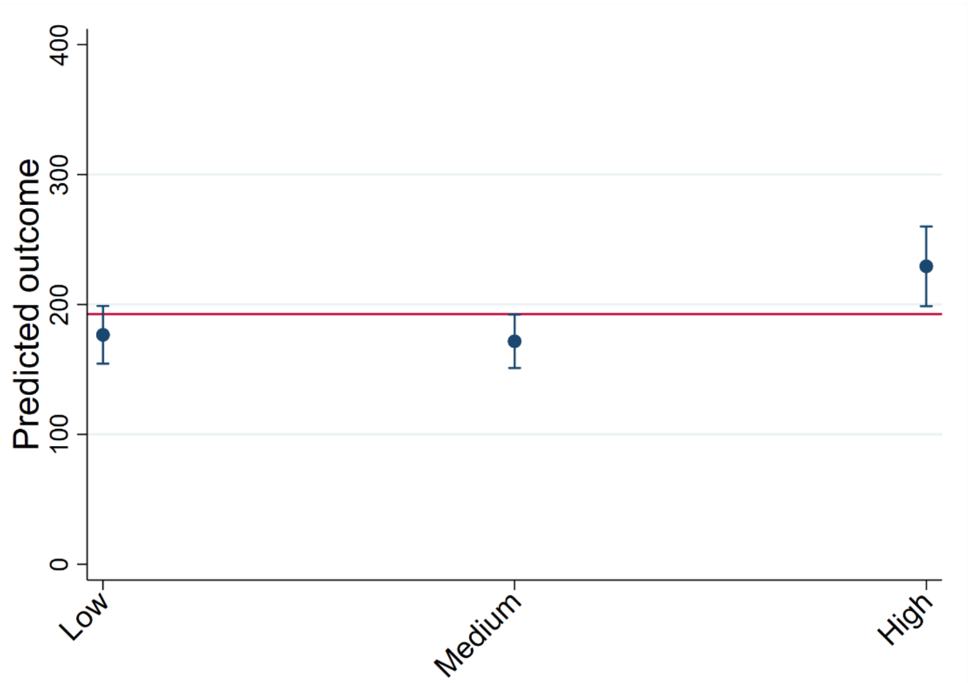
**Figure 6: Marginsplot of permanent employment shares by green typology**




Notes: The graph shows the predicted outcomes of permanent employment shares across green typologies based on the regression model in Table 6, column 4. The red line indicates the overall sample mean of the permanent employment share.

Source: Authors

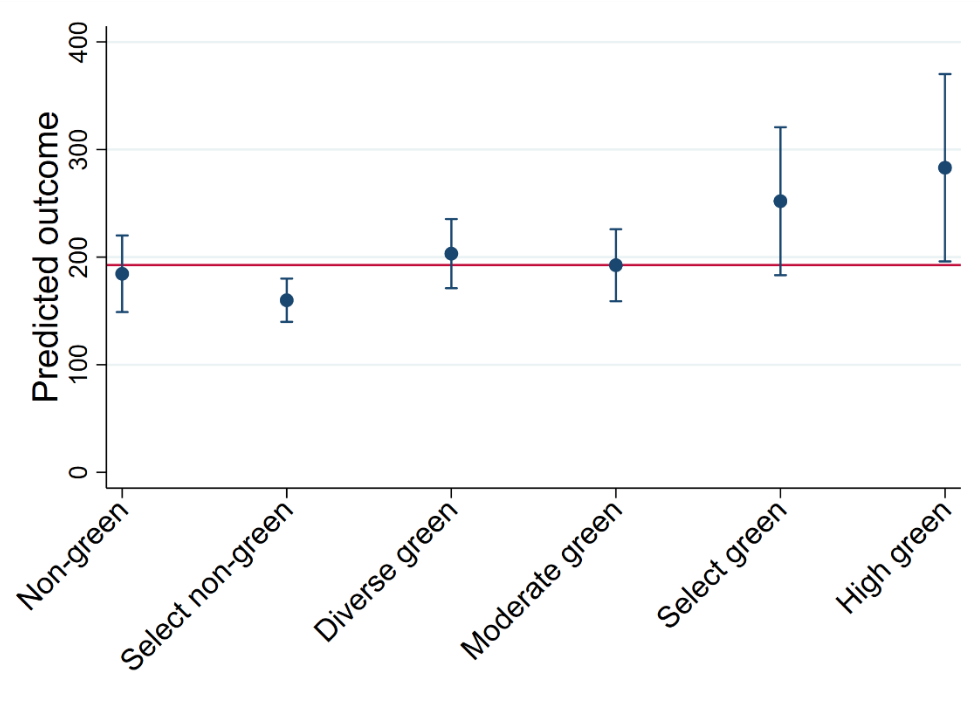
**Figure 7: Marginsplot of mean monthly wage by green index quantiles**




Notes: The graph shows the predicted outcomes of average total monthly wage (reported in thousand RWF) across green index quantiles based on the regression model in Table 6, column 5. The red line indicates the overall sample mean of the average total monthly wage.

Source: Authors

**Figure 8: Marginsplot of mean monthly wage shares by green typology**




Notes: The graph shows the predicted outcomes of average total monthly wage (reported in thousand RWF) across green typologies based on the regression model in Table 6, column 6. The red line indicates the overall sample mean of the average total monthly wage.

Source: Authors

Our data allows for a separate analysis of salaries for permanent and non-permanent workers, as defined above, which suggests that the overall positive link with greenness reported above might be driven by the latter group. However, as some firms do not have permanent workers at all and a few firms only have permanent workers, a thorough comparison is more complex. Thus, this result needs to be interpreted with caution.

Overall, the results on the two investigated dimensions of job quality indicate that firms with higher levels of greenness – measured by both a green index and a green typology – are consistently associated with a greater share of permanent employees and higher average monthly salaries. These relationships appear non-linear, with particularly large increases in both job stability and pay observed among highly green firms, especially in the construction and installation segments of the value chain.

# 6 Outlook: boosting economic development by greening cities' built environment

This study demonstrates that a significant number of green jobs exist along Kigali's construction value chain – though with varying degrees of greenness. Only about 5 per cent of jobs are fully green, but over half are partially green (i.e., engaging in some green practices, but not yet using the full repertoire possible). We could not measure whether firms are actually developing along these categories, indicating a transition towards environmentally-sustainable practices, but it is fairly safe to assume they are, given the clear policy support in this direction. Firms with higher levels of green practices tend to experience better employment outcomes, including increased job quality in terms of permanent contracts and higher wages. The positive association between greening and employment growth is most pronounced among installation firms, although overall job growth effects are complex and vary with the stage of the green transition.

For economic development in growing LMIC cities such as Kigali, these results imply that a lot more potential can be harnessed for job creation and job quality improvement while greening cities' building environment. Resource saving and drawing on grassroots circular economy initiatives can be conducive for cost saving and firm productivity, but barriers such as material availability, durability concerns, client preferences and insufficient skills often prevail. Here, a structural change approach to explicit greening and classic SME upgrading the housing market could be useful. For affordable housing, local and bio-based materials as well as used materials for non-load-bearing walls present viable alternatives. These are not more expensive per se. Instead, challenges are land prices, taxes, perceived production costs and import substitution policies.

We derive the following policy recommendations from our results for advancing the creation of green jobs:

- **Tailored support for transitioning firms:**

  Policy-makers should focus on firms in the "critical transition" phase – those that are partially green – to help them fully integrate sustainable practices. Targeted capacity-building programmes, technical support and financial incentives can accelerate their transition.

- **Adoption of a tiered green job Framework:**

  Implementing a tiered typology that distinguishes between fully green, mixed green and selectively green roles will better capture the nuanced nature of green employment in LMIC contexts. This approach can ensure that policy measures are appropriately scaled to the level of green integration within firms.

- **Flexibility in applying decent work standards:**

  Adjusting ILO's "decent work" criteria to local contexts is crucial. Overly strict standards may exclude emerging green jobs. Policies should allow for flexible green job standards in line with national strategies, such as the revised Green Growth and Climate Resilience Strategy (2023).

Furthermore, our results allow us to derive the following recommendations for the market development of the green building environment in Kigali and possibly other cities in Rwanda:

- **Integrated interventions:**

  A holistic mix of interventions is necessary that address cost competitiveness, skills development and shifts in attitudes. Enhancing local supply chains (e.g., through import substitution policies) and investing in training programmes can stimulate both the quantity and quality of green jobs.

- **Proactively address misperceptions and attitudes on the supply and demand-side in parallel:**

  Misconceptions and negative attitudes to local, bio-based materials and green construction exist on both the supply (firm) and demand (client)-side. Correcting misperceptions on costs and durability of local bio-based materials can increase acceptance by: (a) awareness raising campaigns; (b) establishing material banks and test centres for used, repaired and bio-based materials to ensure quality, durability and flag acceptance; and (c) flexible standard implementation to support market development, including guidelines/standards for used and repaired materials. These measures could help meet ongoing circular economy grassroots practices, as well as support further economic development. Development cooperation could support especially points (b) and (c) with technical insights and lessons learned from other countries.

- **Clearer government "hands-on" guidelines on local and used materials:**

  Pragmatically conveying "which materials to use for what and how" paralleled with a more explicit government push for local and used materials will help counter the perception that government favours only buildings with cement, glass and steel. This is in line with the government's dual strategy to use both concrete and bio-based materials in construction, depending on the purpose. Here, development cooperation could provide support.

- **Address the awareness-action gap on green building code pragmatically:**

  This needs to be done in a way that does not stifle market development. Different strategies may be required for Kigali (where higher compliance is more easily possible) and beyond (where awareness and realistic options for compliance are likely a lot lower).

By adopting the above policy recommendations, Kigali can harness the benefits of green economic development and job quality improvements, contributing to a more sustainable and inclusive urban growth trajectory.

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# Appendix

## A1 Green vs. conventional practices – definitions

**Table A1: General green index (all value chain segments)**

| Green dimension | Conventional counterparts |
|---|---|
| Material sourcing/transport dimension: As close as possible, within Rwanda – origin of materials matters for decision-making | Origin of materials in terms of transport is not a relevant factor in decision-making |
| Design/build with later easy dismantling and potential reuse of elements/materials in mind (lifecycle thinking):<br>- Planning with modular elements/prefabricated elements<br>- Plan with accessibility of materials/elements in mind<br>- Using standardised sizes of building elements and simple open-span systems<br>- Use mechanical bolts, screws and sealants instead of sealants, binders and adhesives<br>- Using durable materials that are worth recovering<br>- Use interlocking bricks, tiles, etc, with less binder/mortar | Dismantling ease and reuse of building elements not catered for:<br>- Disregard of this planning principle (no lifecycle thinking)<br>- High amounts of seals, adhesives, binders and material mixes that are difficult to take apart again<br>- Use of potentially toxic materials<br>- Use of low quality, non-durable materials (e.g., prone to corrosion over time) |
| Client advice monetary savings: Active client advice on what money they could save over time when using recycled/re-used materials, energy-efficient systems or water conservation methods | No advice |
| Design or build with waste, scrap and re-used materials | Designing or building with new materials only |
| Client advice on how to save resources: Active advice to clients on using recycled/re-used materials, energy-efficient systems or water conservation methods with specific examples like solar water heaters or re-using wastewater | No advice |
| Planning/building or installing materials/appliances based on their resource-efficiency | Resource efficiency not a factor in planning, building and installation |

Source: Authors

**Table A2: Planners, architects and engineers**

| **Green planning and design** | **Conventional planning and design**<br>**(criteria/possible answer categories in survey)** |
|---|---|
| Sustainability as a holistic design principle – either to comply with Green Building Standards or beyond/independent of these standards | Sustainability not relevant as a design principle, if at all, then only secondary for parts of the building to comply with minimum requirements |
| Planning with bio-based materials (stone, clay, stabilised earth blocks, up-graded Rukarakara bricks, Rukarakara, timber, etc.) for walls, roofs and floors. | Planning only with cement, iron, steel and aluminium |
| Reduction of the amount of materials/lightweight construction as a design principle for:<br>- Light steel frames<br>- Hollow concrete blocks<br>- Hydraform blocks<br>- Concrete with less clinker<br>- Other lightweight concrete (e.g., with politerm)<br>- Wall strength and material variation according to structural (carrying)/non-structural walls | Standard construction regardless of weight |
| Planning for natural ventilation to reduce heat, such as:<br>- Positioning walls/windows towards or away from the sun<br>- Calculation of air currents<br>- Size of windows<br>- Shading from roofs or trees outside<br>- Plan with roof and wall materials that reduce heat/produce a favourable indoor climate | No conscious planning for maximizing natural ventilation to reduce heat:<br>- No calculation or positioning of walls, windows and shading<br>- No calculation or estimation of air flow |
| Planning for energy efficiency and renewable energy through natural lighting, LED lights and solar energy (as water heaters with PV panels) | Energy efficiency and renewable energy options play no role:<br>- No attention to natural lighting<br>- Use of incandescent light bulbs/Compact Fluorescent Lamps<br>- Conventional grid electricity |
| Planning for water efficiency and water reuse | Water efficiency and reuse play no role |

Source: Authors

**Table A3: Material producers and specific raw material producer-suppliers**

| Green planning and design | Conventional planning and design<br>(criteria/possible answer categories in survey) |
|---|---|
| Transport/selling: Efforts undertaken/possibility to sell close to the source to reduce transport needs of heavy materials (e.g., stones) | Transport: No effort undertaken or no possibility to sell close to the source (transport distance not a factor) |
| Transport/sourcing: Local sourcing of input materials (e.g., sand, pebbles, clay, kaolin, etc.) as much as possible, i.e., within Kigali, at least within Rwanda. Imports only of materials not available in Kigali/Rwanda | Transport:<br>- Input raw materials sourced irrespective of location<br>- Sourcing from within wider Rwanda even though there is availability in Kigali<br>- Importing even though raw materials are available in Rwanda |
| Type of machinery used:<br>- Mostly manual labour (e.g., excavation)<br>- If machines, then the most resource efficient model<br>- Kiln type (Hoffman Kiln, vertical shaft brick kiln) | - Many machines/high degree of automation (higher energy use)<br>- Unclear or old machinery (not the most resource efficient machines)<br>- Kiln type (conventional, such as Clamp Kilns or Bull Trench Kilns) ) |
| Source of energy for production:<br>- Solar energy<br>- Grid electricity (accounting for Rwanda's electricity green/brown mix in the calculation)<br>- Firewood and charcoal (from sustainable forest management)<br>- Wood cuttings or biowaste that is available from other businesses as waste (reuse) | Source of energy production:<br>- Grid electricity (accounting for Rwanda's electricity green/brown mix in the calculation)<br>- Firewood and charcoal (from unsustainable forest management)<br>- Burning of other waste/biomass<br>- Oil/Diesel (generator) |
| Energy saving in production:<br>- Produce continuously (in large bulk) rather than stop and go of machinery<br>- Avoid idle running of machinery<br>- Machinery/kilns are well-maintained (cleaned kilns, motors with complete set of pulleys, dust-free, etc.)<br>- Kiln insulated to avoid heat loss<br>- Kiln size (larger ones with more cooling surface save more energy)<br>- Cold brick production (fired, but at a lower temperature)<br>- Investments in energy efficient machinery | Energy in production:<br>- Batch production rather than continuous<br>- Idle running of machinery<br>- Machines are not well-maintained<br>- Kilns are not insulated<br>- No investment in energy efficiency of machinery |

| **Green planning and design** | **Conventional planning and design (criteria/possible answer categories in survey)** |
|---|---|
| Source of water for production:<br>- Rainwater (harvested)<br>- Wastewater (recycled) | Source of water for production:<br>- Piped water (fresh water)<br>- Tank water (fresh water)<br>- Jerry can water (fresh water) |
| Water saving in production<br>- Well-maintained pipes<br>- Water conserving fixtures<br>- Water only running when necessary | No water saving in production:<br>- Leaking pipes, taps<br>- Conventional water fixtures<br>- Constant running water |
| Use of waste/reuse of pieces that break during production (e.g., brick) for production or other purposes | Disposal of all production waste regardless of reuse potential |
| Timber: Type of trees are local, unprotected species fit for structural construction | Timber: imported trees of unclear sustainability status or protected species |
| Timber:<br>- Sustainable sourcing of trees/timber: Not protected species, from official wood harvesting locations, afforestation included, ideally with sustainability certification<br>- Local trees<br>- Sustainable quality for structural building: fully dried, graded and treated for structural engineering quality | Timber:<br>- Unclear sourcing<br>- Protected species<br>- Uncertified or from protected areas<br>- No afforestation<br>- Low quality that makes sustainable long-term use in structural construction impossible: Not fully dried, graded and untreated for structural engineering |
| Roof materials: Type of material used are:<br>- Clay-based tiles (locally made)<br>- Clay-based tiles (imported tiles are less green, but still count as green in comparison)<br>- Used or recycled components from demolished buildings (aluminium, steel and tiles) | Roof-materials: Type of material used are:<br>- Aluminium sheets (new)<br>- Steel sheets (new)<br>- No recycled or used components in the roofing materials produced |

Source: Authors

**Table A4: Quincailleries (hardware stores)**

| Green planning and design | Conventional planning and design<br>(criteria/possible answer categories in survey) |
|---|---|
| Substantial share of sales are in green products | No/hardly any share of green products |
| Type of products on display. Specific green materials available are clay tiles and Limestone Calcined Clay Cement or other green cement ingredients | No specific green materials available |
| Type of products on display: reused and recycled | Only new products in store |
| Advice on green options/feedback from clients | No advice/no feedback on green materials |
| Reasons for importing materials are environmental reasons (environmentally-friendly materials not available or less durable in Rwanda) | Import of materials unrelated to environmental factors |

Source: Authors

**Table A5: Construction firms (builders and masons)**

| Green construction on building site | Conventional, non-green construction on building site |
|---|---|
| Green building minimum compliance | Conventional construction |
| Building with green raw materials<br>- Clay bricks<br>- Rukarakara bricks<br>- Stabilised compressed earth blocks/upgraded Rukarakara bricks<br>- Sustainably harvested timber<br>- Stone<br>- Low carbon cement | Building with conventional raw materials<br>- Cement/concrete<br>- Steel<br>- Iron |
| Sourcing of materials on-site as much as possible, e.g., earth from the same or neighbouring plot | Conventional sourcing, on-site not considered |
| Build with reused materials/demolition waste and mix materials to reduce input materials | No reuse, or mixing/reuse of toxic materials potentially detrimental to the environment |
| Alternatives to cement-based mortar:<br>- Lime mortar<br>- Calcinated clay<br>- Earth-based mortar | Cement-based mortar (standard) |
| Potential other green material mixes and resource saving that are not known about yet | Standard construction |
| Energy saving (see above for criteria) | No energy saving |
| Water saving (see above for criteria) | No water saving |
| Other de facto green practices that are not known about yet | |

Source: Authors

**Table A6: Installation firms for energy and water (electricians, solar firms, plumbers and water tank firms)**

| Green installations of appliances | Conventional, non-green installations |
|---|---|
| Working with used/waste/recycled materials | Working with new materials only |
| Installation of energy efficient appliances | No/hardly any installation of energy efficient appliances |
| Installation of solar PV | Installation of conventional energy system |
| Installation of solar water heaters | No solar water heaters installed |
| Installation of sub-meters of electricity to help clients save energy | No installation of sub-meters |
| Advice of clients on sub-metering of electricity | No advice on energy efficient appliances |
| Installation of water-saving appliances and systems | No/hardly any installation of water saving systems |
| Installation of appliances for water treatment and reusing wastewater systems | No/hardly any installation of water treatment and reuse of wastewater systems |

Source: Authors.

## A2 Additional tables and figures

**Table A7: Descriptive statistics of variables in the regression model**

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| Employment growth (in per cent) | 546 | .049 | .553 | -.872 | 3.69 |
| Permanent employment share | 546 | .524 | .344 | .012 | 1 |
| Mean monthly salary (in RWF) | 541 | 192,638.71 | 191,587.37 | 10,000 | 2,750,000 |
| Green index (quantiles) | 546 | 1.973 | .833 | 1 | 3 |
| Green typology | 546 | 3.015 | 1.372 | 1 | 6 |
| Firm type | 546 | 3.355 | 1.366 | 1 | 5 |
| Firm size (number of employees) | 546 | 1.35 | .511 | 1 | 3 |
| Firm age (years) | 546 | 9.386 | 6.508 | 0 | 48 |
| Formality index | 546 | 2.592 | 1.613 | 0 | 4 |
| Firm revenue year (in RWF) | 545 | 5.237 | 2.079 | 1 | 9 |
| Manager education | 546 | 3.562 | .65 | 1 | 4 |
| Manager gender (male =1) | 546 | .885 | .32 | 0 | 1 |
| Government projects (yes=1) | 546 | .661 | .474 | 0 | 1 |
| Number projects | 546 | 1.87 | 1.788 | 0 | 20 |
| District | 546 | 2.132 | .74 | 1 | 3 |

Source: Authors

**Table A8: OLS regression results for employment growth by value chain segment**

| Dependent variable: Linearised employment growth | Planners (1) | Production (2) | Supply (3) | Construction (4) | Installation (5) |
|---|---|---|---|---|---|
| Green Index | -0.045 | -0.016 | -0.037 | 0.029 | 0.094 |
| | (0.098) | (0.077) | (0.127) | (0.059) | (0.064) |
| Green typology | 0.044 | 0.017 | 0.018 | 0.048 | 0.112** |
| | (0.034) | (0.044) | (0.077) | (0.034) | (0.049) |
| Full controls | Yes | Yes | Yes | Yes | Yes |
| District dummies | Yes | Yes | Yes | Yes | Yes |
| N | 63 | 121 | 54 | 172 | 135 |
| Adj. R2 (Green Index) | 0.245 | 0.126 | 0.147 | 0.290 | 0.226 |
| Adj. R2 (Green typology) | 0.257 | 0.126 | 0.145 | 0.298 | 0.270 |

Notes: Robust standard errors (HC3) are shown in parentheses. ***, **, and * denote significance at 0.1, 1, and 5 per cent, respectively.

Source: Authors

**Table A9: OLS regression results for permanent employment by value chain segment**

| Dependent variable: Permanent employment share | Planners (1) | Production (2) | Supply (3) | Construction (4) | Installation (5) |
|---|---|---|---|---|---|
| Green Index | 0.114 | 0.096* | 0.143** | 0.164*** | 0.074 |
| | (0.072) | (0.053) | (0.059) | (0.029) | (0.049) |
| Green typology | 0.031 | 0.025 | 0.041 | 0.108*** | 0.058* |
| | (0.038) | (0.035) | (0.043) | (0.019) | (0.032) |
| Full controls | Yes | Yes | Yes | Yes | Yes |
| District dummies | Yes | Yes | Yes | Yes | Yes |
| N | 63 | 121 | 54 | 172 | 135 |
| Adj. R2 (Green Index) | 0.220 | 0.197 | 0.298 | 0.333 | 0.141 |
| Adj. R2 (Green typology) | 0.176 | 0.172 | 0.201 | 0.348 | 0.153 |

Notes: Robust standard errors (HC3) are shown in parentheses. ***, **, and * denote significance at 0.1, 1, and 5 per cent, respectively.

Source: Authors

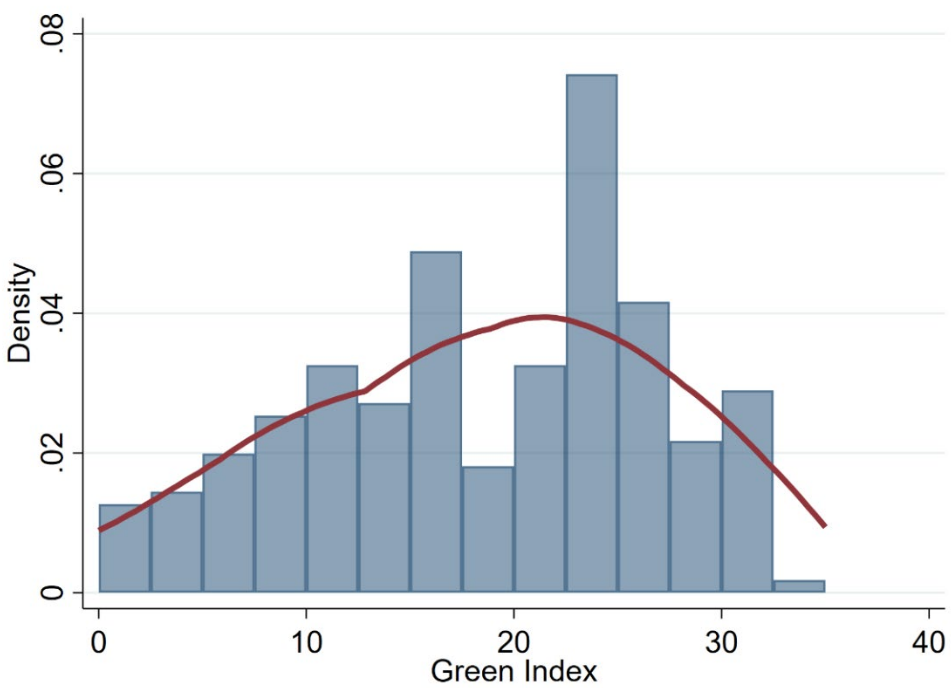
**Table A10: OLS regression results for mean monthly wage by value chain segment**

| Dependent variable: Mean monthly wage (RWF) | Planners (1) | Production (2) | Supply (3) | Construction (4) | Installation (5) |
|---|---|---|---|---|---|
| Green Index | 41,334 | 21,185 | 16,641 | 14,216 | 39,296 |
| | (30,166) | (21,210) | (20,030) | (17,220) | (27,042) |
| Green typology | 27,277 | 6,073 | 8,981 | 27,169*** | 29,797** |
| | (21,073) | (8,847) | (12,126) | (9,364) | (12,633) |
| Full controls | Yes | Yes | Yes | Yes | Yes |
| District dummies | Yes | Yes | Yes | Yes | Yes |
| N | 63 | 121 | 54 | 170 | 132 |
| Adj. R2 (Green Index) | 0.366 | 0.047 | 0.730 | 0.143 | 0.427 |
| Adj. R2 (Green typology) | 0.380 | 0.041 | 0.728 | 0.158 | 0.432 |

Notes: Robust standard errors (HC3) are shown in parentheses. ***, **, and * denote significance at 0.1, 1, and 5 per cent, respectively.

Source: Authors

**Figure A1: Green practices of firms aware of the Green Building Code System (N = 221 firms)**

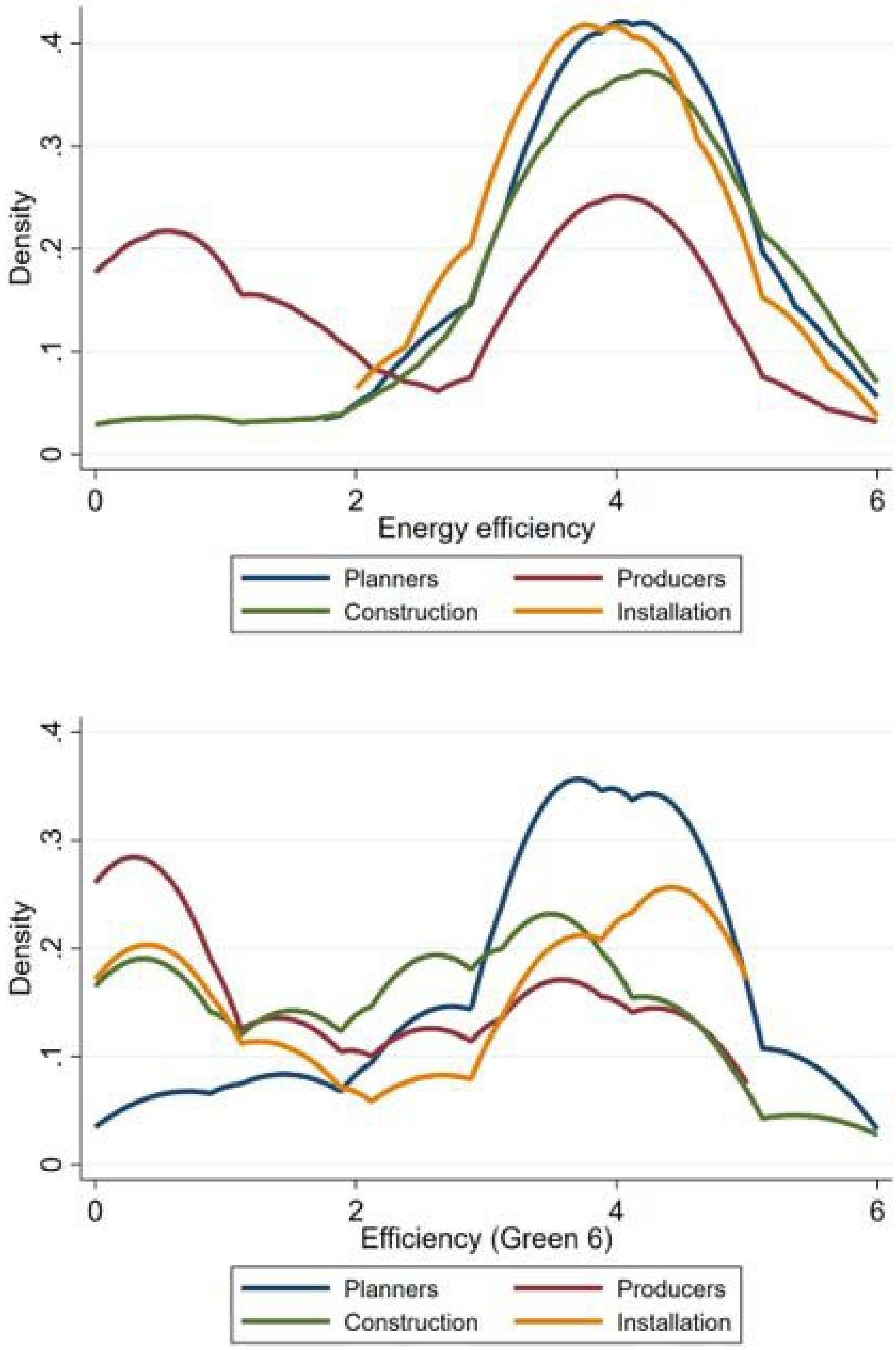



Source: Authors

# A3 Consistency check of the green index

This appendix checks the consistency of responses on the resource saving question in the green index with specific questions on energy efficiency and water saving in questionnaire modules for different firm types (value chain segments).

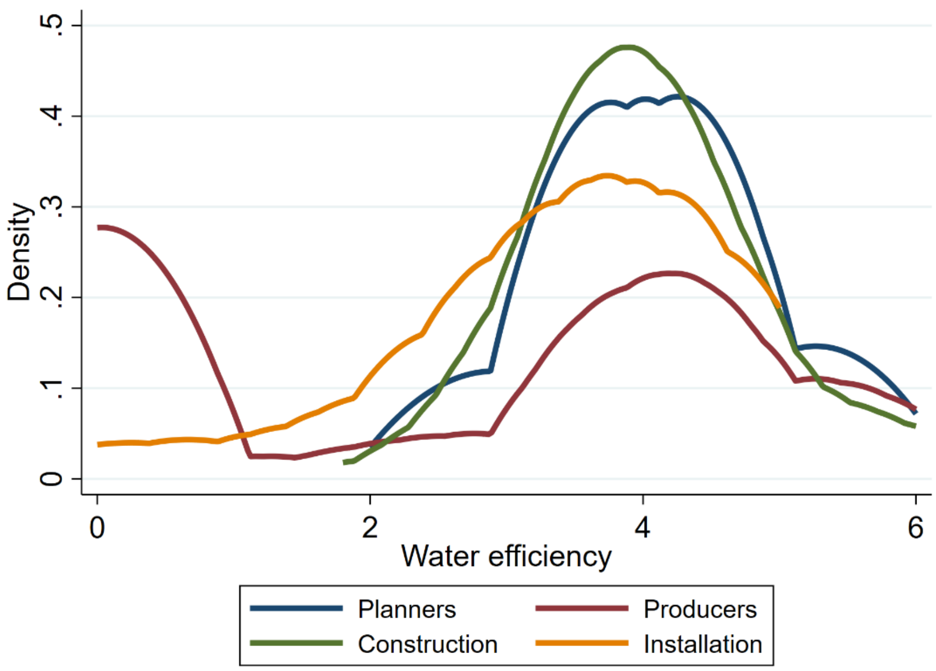
**Figure A2: Energy-efficiency (segment-specific) and general question on resource-efficiency (N = 350 firms)**




Source: Authors

The distribution of responses among planners is very similar across both the general and specific questions. For producers, the patterns are also largely consistent; however, the general question on resource efficiency shows a higher peak at lower values and a slightly lower peak at the higher end compared to the more specific energy efficiency question. This indicates some potential underreporting in responses to the general resource-efficiency question, which is a component of our green index. Similarly, installation and construction firms exhibit a single pronounced peak at higher values in response to the specific energy efficiency question, while their answers to the more general resource-efficiency question are more evenly spread, with an additional peak at lower values, further suggesting underreporting in the general question.

**Figure A3: Water-efficiency (segment-specific) (N = 342 firms)**




Source: Authors

The distribution of responses for planners and construction firms regarding water efficiency closely mirrors the pattern observed in the earlier figure on energy efficiency, indicating a consistent trend across these groups. Among producers, the presence of two distinct peaks – similar to the other distributions – further highlights a notable divide: one segment appears to be actively engaged in promoting resource efficiency, while another remains largely uninvolved. In contrast, the distribution for installation firms shows a slightly lower peak with more responses at the lower end. This trend is drawn from responses by plumbers, as opposed to electricians in the energy efficiency graph, suggesting that water efficiency practices are somewhat less prevalent among plumbers than among electricians.