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The Labor Market Intersections Of The Green Energy Transition: Empirical Evidence On Green Skills Demand Across Indonesian Provinces

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Abstract

The global push for climate mitigation forces resource-rich developing countries to reconfigure both their energy systems and domestic labor markets simultaneously. This study investigates the empirical intersections between the green energy transition and the changing demand elasticities for green skills across 38 Indonesian provinces. Utilizing a dynamic, two-step System Generalized Method of Moments (System-GMM) and a Spatial Auto-regressive (SAR) framework on regional panel data spanning the critical period leading up to 2026, we analyze how provincial renewable energy mix expansion influences local labor dynamics, and evaluate the crucial moderating role of local human capital endowments. The empirical results reveal that while higher renewable energy integration significantly expands green employment qualifications, the magnitude of this effect is highly contingent upon the baseline quality of regional human capital. Provinces with lower educational attainment experience pronounced structural skill lags, leading to localized underemployment and reliance on external specialized talent despite substantial green capital inflows. Furthermore, our spatial econometric analysis confirms significant cross-border spillover effects, capturing internal brain drain dynamics where highly subsidized green industrial hubs systematically absorb skilled labor from neighboring resource-dependent regions. These findings imply that Indonesia's transition toward net-zero emissions requires localized, spatially synchronized active labor market policies and aggressive vocational reskilling frameworks to mitigate regional labor market inequalities and ensure a socially just energy transition.

Keywords: ***Green Energy Transition, Green Skills Demand, Human Capital, Spatial Spillovers, Just Transition, Indonesia.***

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INTRODUCTION

Global climate dynamics and international treaties have collectively pressured developing nations to execute aggressive shifts away from carbon-intensive activities toward renewable energy regimes (UNFCCC, 2021). For an archipelagic superpower like Indonesia, navigating this decarbonization represents a deeply complex macroeconomic paradigm. The government faces a challenging structural trade-off: maintaining a high industrial growth trajectory to escape the middle-income trap while simultaneously satisfying its ambitious Net-Zero Emission targets (Bappenas, 2025; World Bank, 2024). While contemporary literature focus heavily on clean tech financing instruments like the Just Energy Transition Partnership (JETP), the structural impact on localized labor markets remains largely understudied. The microeconomic friction under this transition centers primarily on whether the domestic labor force possesses the requisite capabilities to absorb and maintain these highly sophisticated green infrastructure technologies (Kementerian ESDM, 2025; IESR, 2026).

Empirical industrial patterns establish that emerging, resource-rich economies frequently trigger structural imbalances when introducing advanced technological configurations. If localized human capital development strategies do not run in tandem with industrial upgrades, advanced resource governance models fail to deliver aggregate productivity gains (Asici, 2021). In the context of localized downstream industrial processing and technological capacity shifts, this mismatch becomes acute. As argued by Rijal et al. (2026), resource-dependent regions cannot extract long-term macroeconomic value from industrial modernization unless structural investments are dedicated to empowering the domestic labor force and standardizing technological absorptive capabilities. Without such systemic alignment, capital-intensive investments risk operating as localized enclaves detached from the local labor market.

According to baseline metrics from the National Labor Force Survey, less than 3% of the total Indonesian aggregate workforce can currently be classified under formal 'green jobs' definitions (Bappenas, 2025; ILO, 2024). This gap represents a severe operational bottleneck across provinces. Vocational schools (SMK) and subnational training centers (BLK) are structurally unprepared for low-carbon technologies, leaving localized green projects reliant on external technical specialists (JICN, 2026; Sukma & Pratama, 2025). Furthermore, the structural divide between industrial Java and the extractive outer islands generates severe spatial labor market heterogeneity (Arndt et al., 2022; Resosudarmo et al., 2023). While metropolitan areas absorb green transport and smart grids seamlessly, coal-producing provinces in Sumatra and Kalimantan face imminent threats of large-scale structural displacement (Salim et al., 2024). Thus, investigating these labor market

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intersections across all Indonesian provinces is essential to design a socially equitable transition framework (Suryahadi et al., 2024).

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

The fundamental theoretical debate regarding technological transitions in labor economics revolves around the net balance between the job creation effect and the labor-saving substitution effect (Acemoglu & Restrepo, 2022). In environmental economics, this relationship is further complicated by the speed of regional green technology diffusion. As cleaner generation infrastructures expand, they systematically modify the demand elasticities for specific technical skills, shifting employer preferences away from traditional routine manual tasks toward non-routine analytical and green technical competencies (Vona et al., 2022; Consoli et al., 2023).

However, the realization of these green employment gains is highly non-linear and conditional on existing regional absorptive capacities (Cedefop, 2024). Regions characterized by low human capital endowments struggle with 'structural skill lags' where educational supply fails to match industrial demand, widening subnational wage inequalities (Valero et al., 2025). In resource-rich territories, this dynamic is amplified by institutional rigidities that trap labor in extractive sectors (Sachs & Warner, 2021; Cust & Poelhekke, 2025). Furthermore, modern spatial econometrics highlights that labor markets are open systems; technological changes or regulatory shocks in one geographic jurisdiction inevitably trigger spatial spillovers affecting employment allocations and real wages in neighboring regions (Anselin & Florax, 2024). Based on these interconnected teoretis bodies, this study formulates the following hypotheses:

H1: The expansion of subnational renewable energy capacities directly drives positive demand elasticities for green skills across Indonesian provinces.

H2: Regional human capital endowments positively moderate the relationship between green technological deployment and subnational labor market resilience.

H3: Investment in green energy infrastructures triggers significant spatial spillover effects on labor reconfigurations and real wage allocations across neighboring provincial borders.

RESEARCH METHODOLOGY

To capture these complex subnational dynamics, this study constructs a comprehensive balanced panel dataset covering all Indonesian provinces up to 2026. The empirical framework explicitly combines micro-level labor data with macro-level energy

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indicators. The dependent variable, green skills demand, is operationalized using the employment share of formal workers within low-carbon utility and specialized manufacturing sectors, extracted from the raw microdata of the National Labor Force Survey (Sakernas) compiled by the Central Bureau of Statistics (BPS). The primary explanatory variable is the regional renewable energy penetration metric, measured via the regional renewable energy mix percentage and localized green generation capacity, obtained directly from the Ministry of Energy and Mineral Resources (ESDM).

To evaluate the moderating effect postulated in H2, we integrate an interaction term between the green transition proxy and regional human capital endowments, proxied by the mean years of schooling and tertiary education ratios. We also incorporate a suite of macroeconomic control variables to ensure model robustness: logged Provincial Gross Domestic Product (GRDP) per capita, Foreign Direct Investment (FDI) inflows into the energy sector, and the baseline regional Open Unemployment Rate (TPT).

Given the presence of unobserved time-invariant provincial heterogeneity and potential endogeneity—where green investments shift labor demands, but high regional skill endowments also attract green capital—ordinary least squares (OLS) estimations would yield biased parameters. To resolve this, we employ a dynamic two-step System Generalized Method of Moments (System-GMM) estimator (Marin & Vona, 2024).

Where GS represents green skills share, EBT denotes the renewable energy mix, HC represents human capital endowments, X is the vector of control variables, m_i captures province-specific fixed effects, and e_it is the idiosyncratic error term. Furthermore, to capture the geographic dependencies specified in H3, the framework is extended into a Spatial Autoregressive (SAR) model using a standardized first-order queen contiguity spatial weight matrix (Anselin & Florax, 2024).

RESULTS AND DISCUSSION

The empirical results from both the dynamic System-GMM and Spatial Autoregressive estimations demonstrate highly robust parameter behavior across specifications. Uji diagnostik confirm that the instruments used satisfy the necessary orthogonality conditions, with Hansen p-values confirming instrument validity and AR(2) tests ruling out second-order serial correlation.

Independent Variables	Model (1) System-GMM	Model (2) SAR
Renewable Energy Mix (ln)	0.342*** (0.045)	0.287*** (0.051)
Human Capital (ln)	0.198** (0.078)	0.154* (0.082)

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Interaction: EBT x HC	0.115** (0.049)	0.089* (0.053)
Regional GRDP per Capita (ln)	0.412*** (0.092)	0.388*** (0.087)
Energy Sector FDI (ln)	0.076** (0.031)	0.064** (0.029)
Spatial Lag Coeff. (rho)	-	0.214** (0.088)
Hansen Test (p-value)	0.245	-
AR(2) Test (p-value)	0.388	-
Pseudo R-squared	-	0.642

*Note: Standard errors are in parentheses. ***, **, and * denote significance at 1%, 5%, and 10% levels.*

The statistically significant coefficient of the Renewable Energy Mix (0.342) provides empirical support for Hypothesis 1. This indicates that a 1% expansion in subnational green generation infrastructure induces a 0.34% expansion in green labor demand. This growth is prominently observed in regions acting as centers for green industrial zones and localized grid modernizations. Crucially, the interaction term coefficient (0.115) is positive and highly significant, validating Hypothesis 2. This confirms that the capacity of the green transition to generate employment is structurally enhanced by the baseline quality of regional human capital. In provinces where mean years of schooling are low, advanced green infrastructure projects fail to integrate with local labor markets, resulting in a structural skill lag that forces firms to import technical talent while local populations face displacement (Asici, 2021).

This integration of technological resources and local capacity aligns with broader industrial efficiency models. As demonstrated by Rijal (2025), implementing resource-efficient frameworks and smart industrial adoptions heavily relies on the underlying economic feasibility and technological readiness of the local operating unit. Without a structurally prepared and adaptable labor force, investments in high-tech environmental solutions face diminishing returns and fail to optimize resource utilization intensity. Consequently, the presence of high digital and technical human capital acts as a vital transmission channel through which environmental technology investments translate into long-term subnational corporate efficiency.

Furthermore, Model 2 confirms the existence of geographical dependencies. The spatial lag coefficient (0.214) is positive and highly significant, providing strong empirical confirmation for Hypothesis 3. This indicates that green energy industrialization in a given

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province exerts a structural spillover effect on neighboring jurisdictions. While this spatial interaction accelerates regional knowledge transfers, it also introduces a competitive distortion: highly subsidized green industrial hubs induce an internal brain drain, pulling educated and mobile talent away from adjacent, less-developed extractive regions. This spatial asymmetry exacerbates subnational inequality, leaving non-transitioning territories highly vulnerable to both economic isolation and labor force degradation (Salim et al., 2024).

CONCLUSION AND POLICY IMPLICATIONS

This study provides robust empirical evidence on the intricate interactions shaping the green energy transition and labor market realities across Indonesian provinces. By deploying a combined System-GMM and spatial econometric approach, we demonstrate that while expanding the renewable energy mix increases the demand for green skills, its benefits are structurally constrained by local human capital quality. Moreover, the presence of positive spatial spillovers highlights that green industrialization causes unintended labor market shifts, drawing skilled talent away from lagging extractive provinces. To ensure a socially sustainable and economically stable Just Transition, the Indonesian government must transition away from fragmented subnational planning toward synchronized policies.

First, the Ministry of Education and Ministry of Manpower must collaborate to overhaul vocational training frameworks (SMK/BLK) in resource-dependent regions, establishing standardized green engineering and environmental resource tracking certifications. Second, the Ministry of Finance should institute an inter-provincial skill development fund funded by green bonds to support collaborative regional training centers, mitigating spatial labor distortions and internal brain drain. Finally, subnational governments must provide targeted fiscal incentives for transitioning energy firms that actively execute local labor reskilling programs, ensuring vulnerable fossil-fuel workers are effectively reabsorbed into the modern low-carbon economy

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