

**ECONOMIC AND SOCIAL DIMENSIONS OF GREEN TRANSFORMATION:  
PATHWAYS, TRADE-OFFS, AND EQUITY IMPLICATIONS**

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**Abstract :** The global green transformation — defined as the systemic reorientation of production structures, energy systems, and consumption patterns toward environmental sustainability — carries profound and unevenly distributed economic and social consequences that remain insufficiently theorised in both academic literature and policy discourse. While the macroeconomic benefits of decarbonisation are increasingly well-documented, the distributional dynamics of the transition — encompassing labour market displacement, energy poverty, regional deindustrialisation, and the fiscal burden of compensatory social policy — demand systematic empirical investigation and theoretically grounded policy responses. The study concludes with a framework of policy recommendations specifically tailored to the institutional context of transition economies such as Uzbekistan, where the intersection of hydrocarbon dependency, high youth unemployment, and nascent social protection systems creates a distinctive configuration of green transformation challenges and opportunities.

**Keywords:** green transformation; just transition; green jobs; carbon pricing; energy poverty; distributional effects; labour market; regional inequality; social protection; Uzbekistan

The concept of green transformation has evolved substantially over the past three decades, from a largely ecological proposition concerned with reducing pollution and conserving biodiversity, to a comprehensive restructuring agenda that touches the foundations of modern industrial economies. In its contemporary framing, green transformation encompasses the energy transition away from fossil fuels, the decarbonisation of industry and agriculture, the greening of urban infrastructure and transport systems, and the circular economy transition in material production and waste management. Together, these shifts constitute what the Intergovernmental Panel on Climate Change (IPCC) characterises as the most extensive deliberate restructuring of the global economic system since industrialisation (IPCC, 2022).

The economic case for green transformation has strengthened considerably since the publication of the Stern Review on the Economics of Climate Change (Stern, 2006), which demonstrated that the costs of unmitigated climate change substantially exceed the costs of timely mitigation. Subsequent modelling by the Network for Greening the Financial System (NGFS) suggests that an orderly green transition, if initiated promptly, imposes transitional costs equivalent to 2–3% of global GDP cumulatively to 2050, while disorderly transition or climate inaction generates losses of 15–25% of global output under high-warming scenarios (NGFS, 2023). These aggregate figures, however, obscure the distributional complexity that constitutes the most politically salient and normatively contested dimension of the transformation.

This study aims to advance a more integrated and cross-contextually robust understanding of the economic and social dimensions of green transformation through three contributions. First, it synthesises and extends the empirical evidence on green employment multipliers, carbon price incidence, and just transition policy effectiveness through panel econometric analysis and input-output methods applied to a diverse sample of 54 countries. Second, it develops a comparative qualitative analysis of just transition governance frameworks across six jurisdictions representing different economic, institutional, and developmental profiles. Third, it applies the resulting

analytical insights to the specific context of Uzbekistan — a natural-resource-dependent transition economy undertaking ambitious climate commitments while navigating the structural challenges of industrial modernisation and social protection reform.

The study employs a sequential mixed-methods design (Teddlie & Tashakkori, 2009) in which three distinct methodological components — panel econometric analysis, input-output decomposition, and comparative case analysis — are applied in sequence to address different research sub-questions. This design enables triangulation across quantitative and qualitative evidence, strengthening the robustness of the study's conclusions and their applicability across diverse contexts.

The dependent variables in the main econometric specifications were: (i) total employment in renewable energy sectors (thousands of FTE jobs); (ii) employment in fossil fuel extraction and processing (thousands of FTE jobs); (iii) real GDP growth rate (%); and (iv) the Gini coefficient of household income distribution. The principal explanatory variables included the share of renewables in total primary energy supply (%), cumulative green public investment as a share of GDP (%), carbon price level (USD per tonne CO<sub>2e</sub>, from the World Bank Carbon Pricing Dashboard), and real unit energy costs for residential consumers (USD/MWh). Control variables encompassed GDP per capita, trade openness, urbanisation rate, educational attainment index, and institutional quality (Worldwide Governance Indicators).

Estimation employed two-way fixed effects panel regression with country and year fixed effects to control for unobserved time-invariant country characteristics and common time shocks. Standard errors were clustered at the country level to account for within-country serial correlation. Robustness checks included Driscoll-Kraay standard errors robust to cross-sectional dependence, system GMM estimation (Blundell & Bond, 1998) to address potential endogeneity of green investment variables, and sub-sample analyses by income group and geographic region.

Six jurisdictions were selected for in-depth comparative case analysis using a structured most-similar/most-different hybrid design (Przeworski & Teune, 1970): Germany (advanced economy, coal-dependent eastern regions), South Korea (East Asian developmental state, rapid industrial restructuring), Poland (EU transition economy, high coal dependence), South Africa (upper-middle-income, mining-dependent), Chile (Latin American commodity exporter, advanced renewable energy deployment), and Uzbekistan (Central Asian transition economy, natural gas dependency). Cases were selected to maximise variation on the key explanatory dimensions of income level, carbon intensity, institutional capacity, and just transition policy ambition, while maintaining analytical tractability.

For each jurisdiction, documentary analysis of government just transition plans, legislative provisions, social partner agreements, and independent evaluations was supplemented by 24 semi-structured expert interviews conducted between March and November 2023 with government officials, trade union representatives, industry associations, and civil society organisations. Interviews were conducted in English, German, Russian, and Uzbek (with translation), recorded with participant consent, transcribed, and analysed using thematic analysis following Braun and Clarke (2006). A structured cross-case synthesis matrix was developed to enable systematic comparison across the six dimensions of just transition policy: scope, governance architecture, financing, labour market programmes, social protection measures, and monitoring and accountability.

Input-output analysis reveals substantial differences in employment intensity between green and fossil fuel sectors. Across the 36-country sample, the average Type II employment multiplier for renewable energy generation was 12.4 jobs per million USD of output, compared with 3.7 jobs per million USD for fossil fuel extraction and 5.2 jobs per million USD for fossil fuel power generation. These differences imply that a reallocation of USD 1 billion in energy sector investment from fossil fuels to renewables generates a net employment gain of approximately 6,700 to 8,700 full-time equivalent jobs in the economy as a whole, accounting for both direct employment in renewable energy and indirect employment across upstream supply chains.

However, the panel data analysis reveals a significant temporal dimension to these employment effects. In the short run (one to three years), green transformation is associated with net employment losses in fossil-fuel-dependent regions due to the irreversibility of capital and labour investment in incumbent industries. The magnitude of short-run displacement is significantly larger in countries with lower labour market flexibility ( $\beta = -0.43 \times$  inverse employment protection legislation index,  $p < 0.05$ ), underscoring the importance of active labour market policies in facilitating the occupational and geographic mobility required for workers displaced from declining industries.

The distributional geography of green employment creation is a particularly salient finding. Regression results indicate that new renewable energy jobs are disproportionately concentrated in regions with high solar irradiation or wind resources and in urban agglomerations with existing clean technology manufacturing capabilities. Fossil-fuel-dependent regions — which tend to have lower educational attainment, weaker transport connectivity, and more limited industrial diversification — receive a significantly smaller share of green employment creation than their share of fossil fuel employment losses, implying a widening of regional economic disparities in the absence of spatially targeted policy interventions.

### 3.3 Distributional Incidence of Carbon Pricing

Analysis of carbon price incidence across the six case jurisdictions reveals a consistent pattern of regressivity in the absence of revenue recycling. Across all six cases, the bottom income quintile allocated a significantly higher share of household income to energy expenditure than the top quintile — ranging from 8.4% versus 3.1% in South Africa to 6.2% versus 2.8% in Poland — implying that a uniform carbon price increase generates proportionally larger welfare losses for lower-income households. This finding is consistent with the theoretical literature on carbon price incidence (Goulder et al., 2019) and with empirical evidence from multiple country studies.

Carbon price regressivity is substantially mitigated, however, by the manner in which carbon revenues are recycled. Among the six cases, Germany's Klimageld (Climate Money) scheme — which uses a portion of Emissions Trading System revenues to fund flat per-capita cash transfers — achieved near-complete regressivity neutralisation, with the net welfare impact across income deciles becoming approximately proportional after transfers. In contrast, Poland's allocation of carbon revenues primarily to general government expenditure rather than targeted transfers resulted in negligible regressivity mitigation. South Africa and Uzbekistan — neither of which had implemented systematic carbon revenue recycling at the time of analysis — showed the largest equity-negative distributional profiles.

Germany's Kohleausstieg (coal phase-out) framework — legislated through the Coal Exit Law of 2020 — represents the most institutionally developed case, combining EUR 40 billion in structural transition funding for coal regions, legally guaranteed early retirement provisions for

miners, apprenticeship expansion programmes, and a multi-stakeholder coal commission with binding negotiation outcomes. Expert interviews identified the legally binding timeline and multi-year budget certainty as the most critical enabling factors for effective transition planning by regional governments and firms.

South Korea's Green New Deal, launched in 2020 with a total budget of KRW 73.4 trillion (approximately USD 61 billion), demonstrates that rapidly growing economies can integrate green transformation with job creation through strategic industrial policy, particularly in green technology manufacturing. However, interviewees noted that the framework's labour transition provisions — focused primarily on upskilling for new green industries — were insufficiently attentive to the retraining needs of older workers in declining manufacturing sectors with limited digital and technical literacy.

Chile's case is noteworthy as the most advanced Latin American example of proactive just transition planning, with the 2022 Coal Phase-Out Agreement providing site-specific transition commitments for each of the five coal plant closure locations. However, the fiscal resources allocated to worker transition support were assessed by interviewees as inadequate relative to the scale of displacement, and implementation was hampered by limited inter-ministerial coordination between the energy, labour, and regional development portfolios.

Uzbekistan's case reveals an early-stage institutional framework with significant development potential. The country has committed to reducing greenhouse gas emissions by 35% below 2010 levels by 2030 under its Nationally Determined Contribution, and the government's 2021 Renewable Energy Development Programme targets 8,000 MW of new renewable capacity by 2026. However, the just transition dimensions of these commitments remain largely undeveloped. The natural gas sector, which currently employs an estimated 85,000 workers directly and supports approximately 340,000 indirect jobs, faces structural pressure from both domestic energy diversification and the long-term prospect of reduced European gas demand. The absence of a formal just transition plan or dedicated transition fund represents a significant institutional gap that expert interviewees identified as a priority concern.

The comparative case analysis reveals that the determinants of effective just transition governance are primarily institutional rather than financial. While adequate resourcing is clearly a necessary condition — as Chile's case illustrates, underfunded commitments generate neither worker security nor community confidence — it is not sufficient without the institutional architecture to convert funding into effective interventions. The critical institutional elements identified across the successful cases are: legal clarity regarding the timeline and scope of transformation commitments; multi-year budget certainty enabling medium-term investment planning by firms, workers, and regional governments; genuine stakeholder participation mechanisms with binding or quasi-binding negotiation outcomes; cross-ministerial coordination platforms that overcome sectoral siloes; and spatially differentiated implementation recognising the distinct circumstances of individual affected communities.

These institutional requirements have direct implications for Uzbekistan's just transition trajectory. The country's strong centralised executive authority offers advantages in terms of policy coherence and rapid implementation, but carries risks of inadequate stakeholder participation and insufficient attention to local variation. The development of a National Just Transition Commission — modelled on Germany's coal commission but adapted to Uzbekistan's institutional context — with representation from trade unions, regional governments, affected

communities, and civil society organisations, could provide both the participatory legitimacy and the technical coordination capacity required for effective transition planning.

A distinctive feature of Uzbekistan's socioeconomic context that warrants specific analytical attention is the country's youth demographic profile. With approximately 35% of the population below the age of 25 and an annual labour market entry cohort of roughly 600,000 young people, Uzbekistan faces a structural employment challenge that green transformation policies can either exacerbate or help resolve, depending on their design. The input-output multiplier results, which demonstrate significantly higher employment intensity in renewable energy construction and manufacturing compared with fossil fuel extraction, suggest that a strategically designed green industrialisation programme — particularly one targeting the domestic manufacturing of solar panels, wind turbine components, and energy storage systems — could generate substantial youth employment opportunities aligned with the skills profile of Uzbekistan's growing technical and vocational education output.

Realising this potential, however, requires policy interventions beyond the energy sector. The development of a green skills framework — identifying the competency requirements of emerging green occupations and aligning vocational and higher education curricula accordingly — is a prerequisite for ensuring that the supply of trained workers matches the demand generated by green investment programmes. International experience from South Korea's Green New Deal vocational retraining programme and from the EU's European Green Deal Skills Agenda suggests that green skills development yields measurable labour market returns for participants and reduces the duration of transitional unemployment for workers displaced from fossil fuel industries.

This study has examined the economic and social dimensions of green transformation through a multi-level, multi-method analytical framework encompassing macro, meso, and micro perspectives. The principal empirical contributions are fourfold. First, the panel econometric results provide robust cross-national evidence that renewable energy expansion and green public investment are associated with positive GDP growth effects, particularly in upper-middle-income countries, while carbon pricing alone produces negligible short-run macroeconomic costs when controlling for concurrent green investment. Second, input-output multiplier analysis quantifies the employment dividend of renewable energy investment relative to fossil fuels — approximately 6,700–8,700 net additional jobs per billion dollars of redirected investment — but reveals a critical spatial mismatch between the geographic location of job losses and job gains. Third, carbon pricing is systematically regressive in all six case jurisdictions, but this regressivity is effectively neutralised through well-designed per-capita transfer programmes. Fourth, just transition governance effectiveness depends primarily on institutional design — particularly legal clarity, multi-year financing certainty, and genuine stakeholder participation — rather than on financing scale alone.

For Uzbekistan, the study's findings converge on a coherent set of policy priorities: the development of a legally anchored national just transition plan with dedicated fiscal resources; a carbon price reform paired with household transfer mechanisms protecting vulnerable consumers; spatially targeted green industrialisation incentives in regions facing fossil fuel employment decline; and a green skills development framework aligned with renewable energy sector labour demands. These reforms, implemented in sequence and in coordination with international development partners, have the potential to transform Uzbekistan's green transformation from a source of distributional risk into a driver of inclusive economic modernisation.

Future research should address several limitations of this study. The panel dataset, while broad, covers only the period to 2022 and therefore does not capture the accelerated green investment dynamics of the post-2022 global energy crisis. Country-level panel data also mask substantial within-country regional variation that would be better captured by subnational analyses. Quasi-experimental evaluations of specific just transition policy interventions — using regression discontinuity or synthetic control methods — would substantially strengthen causal identification of policy effects beyond the correlational evidence generated by the current panel specifications. Additionally, qualitative research on the lived experiences of workers and communities undergoing green transformation — currently underrepresented in the quantitative-dominated literature — is essential for ensuring that academic and policy discourse remains grounded in the social realities of the transition.

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