

Renewable energy consumption and its effects on unemployment: a study of selected middle-income Asian economies

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Abstract

Purpose – This study investigates the short-run and long-run employment effects of renewable energy consumption across twelve middle-income Asian economies from 1995 to 2022.

Design/methodology/approach – The research employs a panel autoregressive distributed lag (ARDL) model using the pooled mean group (PMG) technique. This framework allows for heterogeneous short-run dynamics while identifying a common long-run equilibrium, controlling for economic growth, inflation, FDI, labor participation, and technology exports (as an indirect proxy).

Findings – While renewable energy consumption has no significant short-run effect in most countries, excluding Indonesia and the Philippines, in the long run, increasing the renewable energy share significantly raises unemployment across the region.

Research limitations/implications – By combining long-run and short-run perspectives, this study provides new empirical evidence on the labor market consequences of the energy transition in emerging Asian economies. It highlights the need for tailored, country-specific labor policies to mitigate transitional unemployment and ensure inclusive green growth.

Originality/value – This paper provides one of the first income-group-based assessments of the energy-unemployment nexus in emerging Asia. By reconciling conflicting evidence through a temporal lens, this study demonstrates that the employment trade-offs of the green transition are primarily long-term, necessitating proactive institutional foresight.

Keywords ADRL model, Asian middle-income countries, Renewable energy, Technological advancement, Unemployment

Paper type Research article

1. Introduction

In the contemporary era, as fossil fuel sources become increasingly depleted and environmental pollution becomes a severe concern, countries worldwide are compelled to



accelerate the transition of their energy sectors toward cleaner and more sustainable alternatives.

The shift towards a renewable energy-based economy entails significant changes in the labor market structure. While some regions face the risk of job loss, it also presents opportunities for skilled labor in renewable energy. A recent report by the International Renewable Energy Agency (IRENA), in collaboration with the International Labour Organization (ILO), revealed that in 2023, solar photovoltaic alone generated approximately 7.1–7.2 million jobs, accounting for around 44% of the total global workforce in the renewable energy sector. Conversely, a recent study by the Global Energy Monitor (GEM) predicts that by 2050, approximately 1 million jobs in coal mines, equivalent to 37% of the current workforce in these mines, will cease to exist worldwide.

Beyond the global picture, the urgency of analyzing the labor-market consequences of renewable energy deployment is particularly evident in middle-income Asian economies. According to the joint report by [IRENA and the ILO \(2021\)](#), Asia accounts for the largest share of global renewable energy employment, driven mainly by rapid capacity expansion in emerging and middle-income economies, especially in solar photovoltaic and onshore wind manufacturing, installation, and maintenance activities. In parallel, the International Energy Agency ([IEA, 2025](#)) indicates that most of the future growth in clean-energy investment and employment will be concentrated in emerging and developing Asia, reflecting the region's rapidly increasing electricity demand and ambitious national energy-transition targets.

At the same time, labor-market pressures remain substantial in this group of countries. Middle-income Asian economies continue to exhibit relatively large and growing labor forces, while job creation has not always kept pace with structural changes associated with digitalization and green transformation. The [IEA \(2025\)](#) further highlights that coal-related activities in emerging Asia still account for a significant share of global fossil-fuel employment, implying that many workers in middle-income Asian countries are at risk of displacement during the energy transition. This simultaneous expansion of renewable energy deployment and the persistence of employment vulnerabilities make middle-income Asian countries a particularly critical context for examining whether the increasing share of renewable energy consumption alleviates or exacerbates unemployment. Consequently, providing empirical evidence on the impact of renewable energy use on unemployment in middle-income Asian economies is essential for assessing the real-world social implications of the green transition and for supporting the design of targeted labor-market and energy policies in the region.

In terms of studies, although a substantial body of empirical literature has examined the relationship between renewable energy consumption and unemployment ([Alper and Oguz, 2016](#); [Bhattacharya et al., 2016](#); [Khobai et al., 2020](#); [Yilanci et al., 2020](#)), existing studies largely rely on broad multi-country samples or single-country analyses, with limited attention to middle-income Asian economies as a distinct analytical group. In particular, evidence explicitly structured around income-based country classifications remains scarce. Moreover, the available findings are mixed and largely based on data covering earlier periods, providing limited guidance on the region's recent energy transition. To address these gaps, this study investigates both the short-run and long-run effects of renewable energy consumption on unemployment in a panel of selected middle-income Asian countries using updated data for the period 1995–2022, thereby offering more policy-relevant evidence for labor market and energy transition strategies in Asia.

In addition to the introduction, the article is structured as follows. [Section 2](#) provides an overview of research on the impact of renewable energy on unemployment and theoretical foundations. [Section 3](#) emphasizes the suitability and characteristics of the research model and the PMG estimation method. [Section 4](#) presents the research results and discussion, while [Section 5](#) concludes and offers policy implications based on the research findings.

2. Literature review and theoretical models

2.1 Literature review

The transition to renewable energy necessitates appropriate technology (Østergaard *et al.*, 2020). However, the application of technological advancement does not necessarily bring the better economic outcomes to countries especially the developing countries in Asia (Truong *et al.*, 2024). Consequently, analyzing the technology-unemployment nexus provides critical insights into how renewable energy consumption might similarly affect the labor market.

Numerous studies conducted in middle-income countries outside Asia have examined the relationship between renewable energy consumption and unemployment rates, yet the results remain inconsistent. Specifically, Rafiq *et al.* (2018) argue that the use of renewable energy has led to an increase in unemployment across 41 countries (1980–2014), partly due to rapid technological advancements and the capital-intensive nature of nuclear, wind, and hydroelectric projects. This perspective is echoed in recent analyses by Saussay *et al.* (2023) and reports from the IEA (2025), which warn that while green jobs are being created, the net positive impact in developing regions is often dampened by labor market rigidities and the displacement of workers in traditional fossil fuel sectors. Conversely, several scholars (Bekmez and Ağpak, 2016; Musa and Maijama'a, 2020; El Moummy *et al.*, 2021; Huseynli and Huseynli, 2022) support the view that renewable energy contributes to reducing unemployment. Khodeir (2016) and Khobai *et al.* (2020) further add that in Egypt and South Africa, respectively, renewable energy consumption can significantly reduce unemployment in the long term, despite having negligible short-term impacts. It is also worth noting that some studies find no significant relationship. For instance, regarding technological innovation, a factor closely linked to the energy transition, many researchers (Aguilera and Ramos Barrera, 2016; Matuzeviciute *et al.*, 2017; Lydeka and Karraliute, 2021) found no significant correlation with unemployment rates, even when accounting for time lags and alternative variables. Thus, there is currently insufficient evidence to assert a definitive impact of renewable energy consumption on employment.

In the context of middle-income Asian economies, earlier studies on renewable energy, technological innovation, and unemployment provide diverse results. In the short term, the transition appears to exert pressure on the labor market. Saboori *et al.* (2022) attribute this instability to the mismatch between the demand for specialized green skills and the existing workforce's capabilities. Furthermore, increasing demand for renewable energy may drive up energy prices; Hillebrand *et al.* (2006) argue that persistent increases in energy costs can suppress overall demand and redirect investment toward other sectors, thereby potentially resulting in net job losses. Similarly, Rahman *et al.* (2023) observed a positive short-term relationship between renewable energy consumption and unemployment in South Asian nations (Bangladesh, India, Pakistan, Sri Lanka) during 1990–2019. Jaber and Szép (2021) and Huseynli and Huseynli (2022) identified a unidirectional causality in which renewable energy consumption contributed to unemployment in the short run, reflecting the initial displacement effects of structural change. These findings align with Sumanto *et al.* (2020), who found that in Indonesia, technological advancements, a prerequisite for energy transition, initially drove up unemployment rates, although this effect varied across resource-rich regions like Sumatra and Bali. However, in the long term, the narrative shifts towards job creation. Research by ÇOBAN (2022) on ASEAN-5 countries (Singapore, Indonesia, Malaysia, the Philippines, Thailand) indicates a statistically significant positive impact of renewable energy on employment from 1991 to 2018. This is reinforced by Özsoy and Özpolat (2020), who demonstrated a positive bi-directional causality between renewable energy and employment in Indonesia. Moreover, Khobai *et al.* (2020) highlighted that renewable energy development in developing countries is crucial to achieving sustainable development goals, as it creates jobs for the unemployed and improves social welfare. Despite these positive outlooks, some studies indicate minimal or no significant impact of renewable energy on unemployment. For instance, Zhao and Luo (2017) found that renewable energy has a negligible impact on unemployment in China. Likewise, while Bekmez and Ağpak (2016) identified no causal

relationship in high-income countries (Singapore), a causal link from employment to renewable energy was found in low-to-middle-income countries (Indonesia, Malaysia, Philippines, Thailand). This suggests that the employment benefits of renewable energy may depend heavily on the country's income level and specific economic structure.

In conclusion, the relationship between renewable energy consumption, technological innovation, and unemployment in middle-income countries remains complex and inconclusive. While evidence from non-Asian regions shows mixed effects, the Asian context suggests a temporal divergence, with short-term labor market disruptions but long-term employment gains. Nevertheless, neutral findings in some countries indicate that these effects are not universal and depend on national economic structures and income levels.

2.2 Theoretical basis

Most previous theories do not directly examine the connection between renewable energy consumption and unemployment rates, but often focus on how technological progress affects unemployment. This is because technological advancements significantly lower costs and boost the efficiency of renewable energy sources, thereby accelerating the energy transition (IRENA and ILO, 2020). Renewable energy, which represents scientific and technological progress, is analyzed for its impact on unemployment through both direct and indirect channels, based on theoretical frameworks such as creative destruction, productivity increases, and compensation models. More specifically, renewable energy directly reduces labor demand in conventional fossil fuel sectors. Simultaneously, the adoption of automation limits the number of new jobs, leading to a short-term increase in overall unemployment. In contrast, the development of renewable energy also stimulates labor demand in related industries such as manufacturing, installation, maintenance, and R&D. However, this process requires time to take effect, which can gradually contribute to a decline in the overall unemployment rate.

2.2.1 Creative destruction model. Renewable energy technologies, such as solar photovoltaics and offshore wind turbines, are progressively displacing traditional coal-fired and oil-based power generation. Such transitions reflect the dynamics of the creative destruction model, which explains how markets are consistently influenced by innovation and competition. This model illustrates a continuous innovation loop in which advancements in technology and techniques dismantle obsolete industries, making way for more innovative and efficient sectors.

Based on this theory, Michelacci and Lopez-Salido (2007) consider a version of the Solow growth model in which technological progress can be either investment-specific or investment-neutral. The results indicate that technological advances will displace traditional jobs and create new ones, but the short-term impact may result in a temporary reduction in employment.

Besides, Postel-Vinay (2002) mentions the negative impact of technological change on employment in the long run and emphasizes that the fast (slow) pace of technological change is likely to have a positive (negative) effect, creating many jobs in a short time.

This theory is evidenced by changes in the US, Japan, and Western Europe in the 1980s and China and India in the 1990s. Based on new technologies, the old companies, structures, and specialized workforces were replaced by the emergence of new industrial organizations and labor relations.

2.2.2 Productivity increase model. Renewable energy is often closely associated with automation technologies through applications such as solar panel cleaning robots, drone-based wind turbine inspections, and AI-driven power forecasting, which help improve operational efficiency and reduce costs (IRENA and ILO, 2020; IEA, 2020). As renewable energy expands, the demand for automation technologies in the energy sector and related industries also increases, thereby indirectly exerting a two-fold impact on employment.

The impact of technological advancement on unemployment has been discussed for centuries. The studies by Frey and Osborne (2013), Acemoglu and Restrepo (2018a), and

Brynjolfsson and McAfee (2014) all demonstrate that the displacement effect of automation has significant short-term impacts on the labor market. Frey and Osborne (2013) estimate that approximately 47% of jobs in the United States are at risk of being automated, with professions such as telemarketers and legal clerks being particularly vulnerable. Acemoglu and Restrepo (2018b) further emphasize that automation reduces the demand for low-skilled labor across various industries, thereby exacerbating income inequality. Similarly, Brynjolfsson and McAfee (2014) highlight that automation accelerates the replacement of labor in repetitive tasks, particularly in manufacturing and services, resulting in short-term unemployment before the labor market can adjust.

However, in the long term, the productivity effect becomes more prominent. The author argues that automation increases labor productivity and reduces production costs, which in turn stimulates consumption and creates new jobs in the service and technology sectors. Likewise, Acemoglu and Restrepo (2018c) suggest that while automation displaces low-skilled workers, it generates new opportunities in high-skilled occupations, especially in fields such as artificial intelligence. Brynjolfsson and McAfee (2014) further argue that automation not only drives innovation but also creates entirely new industries, although job polarization may occur as the benefits tend to concentrate on high-skilled labor.

2.2.3 Compensation model. Since the 19th century, economists have proposed a theory of technological development that Marx called “Compensation Theory” (Marx, 1969; Say, 1964; Ricardo, 1951), which posits that economic forces can offset employment declines resulting from technological advances. Compensation theory can identify a general equilibrium between technological innovation and unemployment, as well as a partial equilibrium that can restore long-run stability.

Based on this theory, Vivarelli (2012) presented six compensation mechanisms, including compensation through new machinery, compensation through price reductions, compensation through new investments, compensation through mechanisms of salary reduction, compensation through income, and compensation through new products.

In the context of renewable energy, the widespread deployment of automation and digital technologies is expected to create new types of jobs, such as solar system installation and maintenance, energy data management, smart grid software development, and AI technicians in the energy sector (IRENA and ILO, 2021; Fankhauser *et al.*, 2022).

In conclusion, previous theories show that the impact of renewable energy consumption on the unemployment rate is complex and multidimensional, meaning it cannot be completely determined as positive, negative, or insignificant. In other words, the impact of technological progress on unemployment depends on the institutional, social, and contextual levels of different economies, the mechanism, and the labor-friendly nature of process innovation.

3. Research method

3.1 Model specification

In time-related datasets such as time-series or panel data, it is essential to examine the stationarity properties and cointegration relationships among the variables before selecting an appropriate estimation method. Methods such as Pooled OLS, FEM, REM, and GMM are considered reliable in panel data only when the variables do not exhibit cointegration relationships (Kettaf, 2025). That is, these models do not account for cointegration (long-run effects) among the variables. Conversely, if cointegration relationships or long-run effects exist, the aforementioned methods become inconsistent and unreliable (Kettaf, 2025). In economics, most of the literature has employed the Johansen cointegration approach to estimate long-run relationships among variables (Johansen, 1988). However, recent studies have introduced the ARDL cointegration test as an alternative framework for addressing cointegration issues, offering several advantages over the Johansen method (Nguyen and Dang, 2025). The advantages of ARDL over other methods, such as Engle and Granger (1987) cointegration method, Johansen (1988), VAR, or VECM models, can be highlighted as follows:

Firstly, the ARDL model can examine the relationship between variables that are stationary at $I(0)$ and $I(1)$. Secondly, it can provide accurate estimates with small sample sizes, unlike VAR or VECM models (Duyen, 2023). Given the relatively small cross-section ($N = 12$) and moderate time dimension ($T = 27$), ARDL using panel data like PMG-ARDL provides more reliable long-run estimates than GMM-based approaches, which are prone to instrument proliferation and weak-instrument bias in small- N panels, since it explicitly captures dynamic adjustment through lagged dependent and independent variables and an error-correction term, allowing heterogeneous short-run dynamics while imposing long-run homogeneity across countries.

To estimate the panel ARDL model, there are three different estimation techniques: the mean group (MG) estimation technique by Pesaran and Smith (1995), the pooled mean group (PMG) technique developed by Pesaran *et al.* (1997, 1999), and the two-way dynamic fixed effects (DFE) estimation technique. Among these, the PMG technique is a combination of MG and DFE; hence, it has several advantages over the other two techniques: (i) performing short-term impact analysis for each country or country groups and consistent long-term impact of all countries; (ii) accommodating different lags, regardless of $I(0)$ or $I(1)$ distinction (Pesaran *et al.*, 1999; Ben-Salha *et al.*, 2021).

Based on previous studies (Özmen *et al.*, 2022; Arvanitopoulos and Agnolucci, 2020; Yilanci *et al.*, 2020), theoretical methods, along with Okun's Law, which highlights the relationship between the unemployment rate and economic growth, and the Phillips curve theory, which explains the relationship between the unemployment rate and inflation, a research model applying the PMG model is proposed as follows:

$$\begin{aligned} \Delta \text{UNP}_{it} = & \varphi_i (\text{UNP}_{i,t-1} - \theta_{1i} \text{RE}_{it} - \theta_{2i} \text{GDP}_{it} - \theta_{3i} \text{TECH}_{it} - \theta_{4i} \text{INF}_{it} - \theta_{5i} \text{FDI}_{it} - \theta_{6i} \text{LF}_{it}) \\ & + \sum_{j=1}^{p-1} \gamma_{ij} \Delta \text{UNP}_{i,t-j} + \sum_{j=0}^{q-1} \delta_{1ij} \Delta \text{RE}_{i,t-j} + \sum_{j=0}^{q-1} \delta_{2ij} \Delta \text{GDP}_{i,t-j} + \sum_{j=0}^{q-1} \delta_{3ij} \Delta \text{TECH}_{i,t-j} \\ & + \sum_{j=0}^{q-1} \delta_{4ij} \Delta \text{INF}_{i,t-j} + \sum_{j=0}^{q-1} \delta_{5ij} \Delta \text{FDI}_{i,t-j} + \sum_{j=0}^{q-1} \delta_{6ij} \Delta \text{LF}_{i,t-j} + \tau_i + \varepsilon_{it} \end{aligned} \quad (1)$$

where UNP, RE, GDP, TECH, INF, FDI, and LF represent the unemployment rate, the rate of renewable energy consumption, annual GDP growth, medium and high-tech export ratio, inflation rate, foreign direct investment, and labor force participation rate, respectively.

3.2 Data collection

The research data encompass information from 12 middle-income Asian countries with data available from 1995 to 2022. The countries included are Bangladesh, Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Thailand, Türkiye, Uzbekistan, and Vietnam. All selected countries have been consistently categorized as middle-income economies by the World Bank during the study period, reflecting a stage of development where labor market structures and energy transitions are particularly dynamic and policy relevant. The inclusion of a diverse set of countries allows for a broader and more generalizable understanding of the relationship between renewable energy consumption and unemployment. Among 12 countries included in the study, Turkey is a transcontinental country, with the majority of its territory located in Asia (the Anatolian Peninsula), sharing similar characteristics with others as an upper-middle income economy possessing substantial renewable energy potential and having made notable progress in its energy transition (Gözkün and Orhangazi, 2025). Additionally, given its geographical location, Türkiye is considered a part of West Asia (Naboureh *et al.*, 2023).

Data on the model's variables have been collected annually from the World Bank. In addition to the dependent variable – unemployment rate (UNP), and the independent variable – renewable energy consumption rate (RE), there are also other control variables, including annual GDP growth (GDP), medium and high technology export ratio (TECH), inflation (INF), foreign direct investment as a percentage of GDP (FDI), and labor force participation rate (LF). Based on previous studies, the group selected socio-economic variables as control variables for the unemployment rate. The data for these variables were collected from the WDI to ensure consistency and correlation in calculations ([Supplementary Table 1](#)).

4. Results and discussion

4.1 Results

Before estimating the model, unit root tests are conducted according to the proposal of [Im et al. \(2003\)](#) to check whether the variables are stationary at $I(0)$ or $I(1)$. Subsequently, the author employs the [Pedroni \(1999\)](#) cointegration test to determine whether long-run cointegrating relationships exist among the variables. If their relationships are confirmed, the ARDL model is applied, with the optimal lag length selected based on the Akaike Information Criterion (AIC) proposed by [Akaike \(1973\)](#). As in the previous section, the ARDL model can be estimated using three approaches: Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effects (DFE). To identify the most appropriate estimation method for the model, the author conducts the Hausman test and examines the robustness of the selected model. Finally, the chosen estimation method, along with the optimal lag structure, is used to obtain the final results regarding the impact of renewable energy on unemployment.

To select appropriate testing methods for the model, we conducted [Pesaran's \(2021\)](#) CD test with the null hypothesis (H_0) that there is no cross-dependence to examine cross-dependence among countries' variables. The results indicate a p -value of 0.8204, suggesting no cross-dependence in the model.

With data showing no cross-dependence, the results of the IPS unit root test in [Supplementary Table 2](#) reveal that only three variables, GDP, INF, and FDI, have significant p -values at the 1% level, indicating that these three variables are stationary at the $I(0)$ level. The variables UNP, RE, TECH, and LF are stationary at the first difference $I(1)$.

According to the results in [Supplementary Table 3](#), the cointegration test proposed by Pedroni has 3/3 test criteria with p -values < 0.1 . Therefore, it can be concluded that there is long-term co-integration among the variables in the model.

To select the optimal lag for the model, the group chose the method proposed by [Kripfganz and Schneider \(2023\)](#). Accordingly, the optimal lag was selected using the Akaike Information Criterion (AIC) ([Akaike, 1973](#)), and the model was estimated with an ARDL (1, 0, 0, 0, 0, 0) specification. Finally, the PMG regression method was chosen as the optimal method through the Hausman test ([Pesaran et al., 1999](#)) ([Supplementary Table 4](#)).

The PMG model results reveal how the error correction vector coefficient (ECM) indicates the dynamic adjustment of the model to restore equilibrium states following shocks. [Banerjee et al. \(1998\)](#) argued that a significant ECM coefficient implies a stable long-term relationship between variables. The estimated ECM coefficient has a negative value (-0.11561) and is statistically significant at the 1% level, indicating a cointegrating relationship among the variables.

Similar to the findings of [Khodeir \(2016\)](#) and [Khobai et al. \(2020\)](#), the impact of the renewable energy ratio on unemployment is insignificant in the short term but significant in the long term. In the long term, the renewable energy consumption rate has a positive impact on the unemployment rate, indicating that as the renewable energy consumption increases, the unemployment rate also tends to rise ([Supplementary Table 5](#)). Although this result is contrary to expectations, it is consistent with previous studies ([Rivers, 2013](#); [Apergis and Salim, 2015](#); [Rafiq et al., 2018](#); [ÇOBAN, 2022](#); [Özmen et al., 2022](#)).

Furthermore, in the long term, variables such as GDP growth, inflation, and FDI contribute to reducing the unemployment rate at 10%; only the increase in medium- and high-tech export ratio variables causes the unemployment rate to increase. Meanwhile, in the short term, higher GDP growth tends to reduce the unemployment rate in middle-income Asian countries. Additionally, the lagged effect of the labor force also contributes to a short-term reduction in unemployment.

Regarding the short-run estimation results for each country, the impact of renewable energy on unemployment rates was found only in the Philippines and Indonesia. In these two countries, an increase in the share of renewable energy consumption is associated with a rise in unemployment rates in the short run. Moreover, the use of renewable energy in Indonesia has a stronger impact on unemployment than in the Philippines. For the remaining ten countries, no relationship was found between the share of renewable energy consumption and unemployment rates in the short run ([Supplementary Table 6](#)).

4.2 Discussion

Utilizing the Pooled Mean Group (PMG) technique to examine the impact of renewable energy consumption in 12 middle-income countries in Asia during the period 1995–2022, this study empirically investigates the impact of renewable energy consumption on unemployment in both the short-term and long-term effects at the regional level, followed by a short-term country-level assessment. Based on prior studies such as [Apergis and Salim \(2015\)](#), [Rafiq *et al.* \(2018\)](#), and [ÇOBAN \(2022\)](#), as well as the referenced theoretical framework, the model results indicate that long-run effects are more pronounced than short-run effects at the panel level.

In the short term, renewable energy consumption does not have a significant effect on unemployment, suggesting that the transition to green energy does not immediately influence labor markets in middle-income Asian countries. Other variables also show no statistically significant impact on unemployment in the short-term, suggesting that labor markets in the region respond slowly and require time to adjust during the energy transition. This finding aligns with previous studies by [Khobai *et al.* \(2020\)](#) and [Khodeir \(2016\)](#), which also found an insignificant short-run correlation between renewable energy consumption and unemployment, despite some upward pressure on unemployment.

At the individual country level, the estimated results show that renewable energy consumption affects unemployment only in Indonesia and the Philippines. In both countries, a 1% increase in renewable energy consumption raises unemployment by 0.124% and 0.071%, respectively. These two lower-middle-income countries remain heavily dependent on fossil fuels, especially coal and oil. Indonesia, one of the ASEAN countries with the highest fossil fuel consumption and production, faces significant challenges in achieving its net-zero goals while continuing to rely on fossil fuels, which are expected to remain dominant until at least 2050. The complex nature of the transition to renewables, coupled with dependence on traditional energy sources, has implications for labor restructuring, though these impacts remain limited due to the continued reliance on fossil energy. [Sumanto *et al.* \(2020\)](#) also found that technological development in Indonesia hampers job creation, with 1% increase in tech development leading to a 1.11568% increase in unemployment. In the Philippines, coal and natural gas still play a major role in energy production. The country's dependence on imported fossil fuels is substantial, accounting for approximately 6.1% of GDP in 2022 and representing 50.6% of the total primary energy supply in the same year. Baseline projections suggest that this reliance could increase to 61.1% by 2050, making the economy more vulnerable to global commodity price volatility. The shift to renewable energy may lead to job losses due to the demand for higher-skilled labor and occupational restructuring. The renewable energy sector faces high upfront costs and limited transmission capacity, particularly in remote areas, which delays project implementation and slows early-stage job creation. As an archipelagic country, the Philippines also incurs high logistics, land, and infrastructure costs, especially for offshore wind and large-scale solar, further delaying project operations and limiting short-term

employment gains (Magoncia *et al.*, 2026). Consequently, the employment impact of renewable energy consumption in the Philippines is smaller than in Indonesia, despite the Philippines having a more stable long-term policy framework, supportive financial incentives, a more reliable regulatory environment, a more diversified energy mix, and a less dominant domestic fossil fuel sector. Similar findings were reported by ÇOBAN (2022) and Bekmez and Ağpak (2016), who observed statistically significant effects only in low- and lower-middle-income countries such as Indonesia and the Philippines.

No significant effects of renewable energy consumption on unemployment were found in Vietnam, Thailand, Cambodia, Laos, Malaysia, Uzbekistan, China, Türkiye, and Bangladesh. In reality, the share of renewable energy employment in total employment remains relatively low in these countries, e.g. in 2018, it accounted for 0.7% of total employment in Malaysia, 0.5% in China, and 0.4% in Cambodia, while Vietnam and Thailand recorded approximately 0.3% (ILO, 2019a). In these countries, other variables such as technology, labor force participation rate, and foreign direct investment (FDI) have a stronger influence on unemployment in the short term. Depending on geographical conditions, technological development, income level, and policy, these variables have varying impacts, with most effects aligning with research expectations – except for FDI. An increase in FDI tends to raise unemployment in many middle-income Asian countries, including the Philippines and Indonesia, as FDI usually targets capital-intensive and technology-driven sectors that favor skilled labor, while much of the workforce remains low-skilled. Taking together with the findings on renewable energy, these results suggest that labor markets in developing countries are not yet fully prepared to absorb technological shifts and foreign investment, leading to transitional unemployment. This result is consistent with the regional context. In terms of workforce skill levels across countries, approximately two-thirds of workers are employed in medium-skill occupations (skill level 2), over 20% in high-skill occupations (levels 3 and 4), and nearly 20% in low-skill occupations (ILO, 2019b). Without proper training systems and institutional support, rising FDI may initially displace more jobs than it creates.

In reality, middle-income Asian countries, many of which are still developing and largely dependent on traditional energy sources, face challenges in transitioning to renewable energy. Although the region has significant natural resources potential, the shift to renewables may increase unemployment, as countries need time and appropriate policies to adapt to their own economic conditions. Moreover, the labor supply in the renewable energy sector remains limited due to a lack of skilled workers, as energy transitions often involve structural shifts in labor demand. Therefore, most countries are not yet fully prepared to adopt renewable energy. As a result, in the short term, no clear effects on unemployment have been recorded, except in Indonesia and the Philippines.

In the long term, the study emphasizes long-run results for middle-income countries in the Asian region and does not represent any individual country. Renewable energy consumption is found to increase unemployment. A 1% rise in renewable energy consumption leads to a 0.12% increase in unemployment. This suggests that while the green transition is necessary, it may cause temporary job losses due to a mismatch between labor skills and technological requirements, as well as inadequacies in training systems. Except for the renewable energy variable, which shows an unexpected positive effect, and labor force participation, which is not statistically significant, all other variables show expected signs and significance. In the long term, TECH and FDI have effects at the 10% level, while GDP and INF are significant at the 1% level. During economic downturns, lower GDP and lower FDI tend to increase unemployment, which aligns with general economic theory. However, governments may respond to recessions by increasing public spending, including investments in renewable energy, which can help create more jobs in this sector. This is a positive signal for mitigating unemployment. The results support Schumpeter's theory of creative destruction, where technological innovation replaces old industries with new ones, causing a temporary rise in unemployment. In the long term, renewable energy, which is often associated with technological advancement, may lead to labor displacement, especially among low-skilled

and manual workers, who make up a significant portion of the workforce in middle-income countries. Consequently, these workers are more likely to be excluded from the labor market during the transition.

Overall, renewable energy consumption tends to raise unemployment in the long term in middle-income Asian countries. This reflects the labor market's lack of readiness for the green transition, particularly given the existing skill gaps. Without complementary policies for retraining and job transition, the green shift may worsen unemployment in the path toward sustainable development.

The findings highlight a noticeable difference between short-term and long-term effects of renewable energy consumption on unemployment across middle-income countries in Asia from 1995 to 2022. In the short term, labor markets are slow to respond, and effects are limited. In the long run, however, unemployment increases more clearly and measurably. Most countries do not show significant effects, except for Indonesia and the Philippines, where dependence on fossil fuels and unprepared labor structures have led to rising unemployment even in the early stages of transition. In contrast, in other countries where the transition is slower, short-term effects are not yet evident but may become significant in the long term as renewable energy grows alongside new technologies and skill requirements. These results suggest that the green transition affects countries differently depending on their institutional readiness, technological capacity, and workforce quality.

5. Conclusion and policy implications

In the long term, the consumption of renewable energy is associated with an increase in the unemployment rate. This finding suggests that the green transition, while necessary, may lead to job displacement due to a mismatch between existing labor skills and the requirements of new technologies, as well as inadequacies in current training systems to meet the demands of a modern labor market. Short-term estimates do not show a statistically significant effect; however, a country-specific analysis reveals that higher renewable energy consumption is correlated with rising unemployment in certain countries, such as Indonesia and the Philippines. This can be attributed to the heavy dependence on fossil fuels in these economies, which presents substantial challenges for the deployment of renewable energy. Although renewable energy sectors do generate new employment opportunities, these gains have not yet fully offset the job losses in traditional industries. As the energy transition becomes inevitable, particularly for fossil fuel-reliant nations, proactive adaptation and context-specific policy interventions are essential to ensure a just and sustainable transformation. Furthermore, the empirical results provide new support for the relevance of creative destruction and compensation mechanisms in the context of renewable energy deployment in emerging Asia. The observed long-run increase in unemployment suggests that skill mismatches, technological upgrading, and labor reallocation constraints remain central channels through which renewable energy expansion affects labor markets. These insights help to explain the mixed and sometimes contradictory findings reported in previous studies and provide a more coherent analytical basis for future comparative research on energy transition and employment in developing and emerging economies.

To ensure that the transition to renewable energy does not negatively impact the labor market, countries should adopt integrated strategies that combine green growth with inclusive employment policies. The empirical findings reflect underlying adjustment challenges, including skill mismatches, uneven institutional readiness, and limited labor market adaptability during the transition process. In this context, foreign direct investment (FDI) may contribute to employment generation when aligned with domestic labor market conditions. Attracting FDI into renewable energy sectors can be more effective when accompanied by policies that facilitate technology transfer, promote local job creation, and support workforce skill development. Macroeconomic stability also plays an important role. Maintaining stable inflation helps sustain purchasing power and aggregate demand, thereby

supporting business expansion and labor absorption. Effective coordination between monetary and fiscal policy is therefore important to avoid conditions that may weaken investment during structural transformation. In addition, sustained economic growth enhances the capacity of economies to absorb labor reallocation across sectors. Integrating renewable energy into broader inclusive growth strategies – such as infrastructure development and industrial upgrading – can further strengthen employment resilience. At the same time, technological advancement associated with the energy transition may contribute to labor displacement, particularly among low-skilled workers. Strengthening human capital through reskilling and upskilling programs, especially for workers in traditional energy sectors, is essential to mitigating these transitional effects. Supporting the development of domestic renewable energy industries can also facilitate labor absorption. Overall, the employment effects of renewable energy transition are not predetermined but depend on the extent to which countries can reduce adjustment frictions and enhance labor market adaptability through well-coordinated policy interventions.

While these policy implications are broadly applicable to middle-income economies, their implementation depends on country-specific conditions. For Vietnam, promoting renewable energy is both a strategic necessity and a long-term driver for achieving the net-zero target by 2050. However, as renewable energy has no significant short-term impact on unemployment but may increase it in the long term, policies should prioritize labor market adjustment. This includes maintaining macroeconomic stability, especially controlling inflation, and strengthening workforce training to address skill mismatches. Improving the legal framework to attract high-quality FDI should be accompanied by technology transfer and workforce development measures. Incentive mechanisms for renewable energy developers – such as facilitated land access, transparent bidding schemes, and a well-designed roadmap for adjusting feed-in tariffs (FiTs) - should be implemented flexibly to balance investment promotion with the financial sustainability of the national power system.

Supplementary material

The supplementary material for this article can be found online.

References

- Acemoglu, D. and Restrepo, P. (2018a), “The race between man and machine: implications of technology for growth, factor shares, and employment”, *The American Economic Review*, Vol. 108 No. 6, pp. 1488-1542, doi: [10.1257/aer.20160696](https://doi.org/10.1257/aer.20160696).
- Acemoglu, D. and Restrepo, P. (2018b), “Artificial intelligence, automation, and work”, in Agrawal, A., Gans, J. and Goldfarb, A. (Eds), *The Economics of Artificial Intelligence: an Agenda*, University of Chicago Press, Chicago, IL, pp. 197-236, doi: [10.3386/w24196](https://doi.org/10.3386/w24196).
- Acemoglu, D. and Restrepo, P. (2018c), “Modeling automation”, *AEA Papers and Proceedings*, Vol. 108, pp. 48-53, doi: [10.1257/pandp.20181020](https://doi.org/10.1257/pandp.20181020).
- Aguilera, A. and Ramos Barrera, M.G. (2016), “Technological unemployment: an approximation to the Latin American case”, *AD-Minister*, No. 29, pp. 58-78, available at: http://www.scielo.org.co/scielo.php?pid=S1692-02792016000200003&script=sci_arttext
- Akaike, H. (1973), “Maximum likelihood identification of Gaussian autoregressive moving average models”, *Biometrika*, Vol. 60 No. 2, pp. 255-265, doi: [10.1093/biomet/60.2.255](https://doi.org/10.1093/biomet/60.2.255).
- Alper, A. and Oguz, O. (2016), “The role of renewable energy consumption in economic growth: evidence from asymmetric causality”, *Renewable and Sustainable Energy Reviews*, Vol. 60, pp. 953-959, doi: [10.1016/j.rser.2016.01.123](https://doi.org/10.1016/j.rser.2016.01.123).
- Apergis, N. and Salim, R. (2015), “Renewable energy consumption and unemployment: evidence from a sample of 80 countries and nonlinear estimates”, *Applied Economics*, Vol. 47 No. 52, pp. 5614-5633, doi: [10.1080/00036846.2015.1054071](https://doi.org/10.1080/00036846.2015.1054071).

- Arvanitopoulos, T. and Agnolucci, P. (2020), "The long-term effect of renewable electricity on employment in the United Kingdom", *Renewable and Sustainable Energy Reviews*, Vol. 134, 110322, doi: [10.1016/j.rser.2020.110322](https://doi.org/10.1016/j.rser.2020.110322).
- Banerjee, A., Dolado, J. and Mestre, R. (1998), "Error-correction mechanism tests for cointegration in a single-equation framework", *Journal of Time Series Analysis*, Vol. 19 No. 3, pp. 267-283, doi: [10.1111/1467-9892.00091](https://doi.org/10.1111/1467-9892.00091).
- Bekmez, S. and Ağpak, F. (2016), "Non-hydro renewable energy and employment: a bootstrap panel causality analysis for countries with different income levels", *Journal of Business and Economic Policy*, Vol. 3 No. 1, pp. 32-45, available at: https://jbep.thebrpi.org/journals/Vol_3_No_1_March_2016/4.pdf
- Ben-Salha, O., Dachraoui, H. and Sebri, M. (2021), "Natural resource rents and economic growth in the top resource-abundant countries: a PMG estimation", *Resources Policy*, Vol. 74, pp. 101-229, doi: [10.1016/j.resourpol.2018.07.005](https://doi.org/10.1016/j.resourpol.2018.07.005).
- Bhattacharya, M., Paramati, S.R., Ozturk, I. and Bhattacharya, S. (2016), "The effect of renewable energy consumption on economic growth: evidence from top 38 countries", *Applied Energy*, Vol. 162, pp. 733-741, doi: [10.1016/j.apenergy.2015.10.104](https://doi.org/10.1016/j.apenergy.2015.10.104).
- Brynjolfsson, E. and McAfee, A. (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, W.W. Norton and Company, New York, NY, available at: <https://www.as.utexas.edu/astronomy/education/fall15/wheeler/secure/ExponentialGrowth.pdf>
- Çoban, M.N. (2022), "Yenilenebilir enerji tüketimi ve İşsizlik arasındaki ilişki: ASEAN-5 Ülkeleri İçin Ekonometrik Bir Uygulama", *Uluslararası Ekonomi ve Siyaset Bilimleri Akademik Araştırmalar Dergisi*, Vol. 6 No. 14, pp. 1-10, available at: <https://dergipark.org.tr/en/pub/joecopol/article/1111891>
- Duyen, T.T.M. (2023), "Application of the ARDL model for examining the relationship between foreign loans economic growth in Vietnam", *Journal of Finance-Marketing*, Vol. 44 No. 2, pp. 1-12, doi: [10.52932/jfm.vi2.327](https://doi.org/10.52932/jfm.vi2.327).
- El Moummy, C., Salmi, Y. and Baddih, H. (2021), "The role of renewable energy sector in reducing unemployment: the Moroccan case", *E3S Web of Conferences*, Vol. 234, 00101, doi: [10.1051/e3sconf/202123400101](https://doi.org/10.1051/e3sconf/202123400101).
- Engle, R.F. and Granger, C.W. (1987), "Co-integration and error correction: representation, estimation, and testing", *Econometrica: Journal of the Econometric Society*, Vol. 55 No. 2, pp. 251-276, doi: [10.2307/1913236](https://doi.org/10.2307/1913236).
- Fankhauser, S., Smith, S., Axelsson, K., Hale, T., Hepburn, C., Kendall, J.M., Khosla, R., Lezaun, J., Mitchell-Larson, E., Obersteiner, M., Rajamani, L., Rickaby, R., Seddon, N. and Wetzler, T. (2022), "The meaning of net zero and how to get it right", *Nature Climate Change*, Vol. 12 No. 1, pp. 15-21, doi: [10.1038/s41558-021-01245-w](https://doi.org/10.1038/s41558-021-01245-w).
- Frey, C.B. and Osborne, M.A. (2013), "The future of employment: how susceptible are jobs to computerisation?", *Technological Forecasting and Social Change*, Vol. 114, pp. 254-280, doi: [10.1016/j.techfore.2016.08.019](https://doi.org/10.1016/j.techfore.2016.08.019).
- Gözkün, K.A. and Orhangazi, Ö. (2025), "Green transition for Turkey: growth, employment, and trade deficit effects", *Energy Policy*, Vol. 202, 114577, doi: [10.1016/j.enpol.2025.114577](https://doi.org/10.1016/j.enpol.2025.114577).
- Hillebrand, B., Buttermann, H.G., Behringer, J.M. and Bleuel, M. (2006), "The expansion of renewable energies and employment effects in Germany", *Energy Policy*, Vol. 34 No. 18, pp. 3484-3494, doi: [10.1016/j.enpol.2005.06.017](https://doi.org/10.1016/j.enpol.2005.06.017).
- Huseynli, B. and Huseynli, N. (2022), "Econometric analysis of the relationship between renewable energy production, traditional energy production and unemployment: the case of Azerbaijan", *International Journal of Energy Economics and Policy*, Vol. 12 No. 4, pp. 379-384, doi: [10.32479/ijeeep.13233](https://doi.org/10.32479/ijeeep.13233).
- IEA (2020), *World Energy Outlook 2020*, International Energy Agency, Paris, available at: <https://www.iea.org/reports/world-energy-outlook-2020>
- IEA (2025), *World Energy Employment 2025*, International Energy Agency, Paris, available at: <https://www.iea.org/reports/world-energy-employment-2025>

- ILO (2019a), "ILO: Bangkok, preparing for the future of work: national policy responses in ASEAN+6", available at: https://www.ilo.org/wcmsp5/groups/public/—asia/—ro-bangkok/—sro-bangkok/documents/publication/wcms_717736.pdf
- ILO (2019b), "ILO: geneva, ASEAN and individual country: Employment and environmental sustainability factsheet", available at: https://www.ilo.org/wcmsp5/groups/public/—asia/—ro-bangkok/documents/publication/wcms_646185.pdf
- Im, K.S., Pesaran, M.H. and Shin, Y. (2003), "Testing for unit roots in heterogeneous panels", *Journal of Econometrics*, Vol. 115 No. 1, pp. 53-74, doi: [10.1016/S0304-4076\(03\)00092-7](https://doi.org/10.1016/S0304-4076(03)00092-7).
- IRENA and ILO (2020), *Renewable Energy and Jobs: Annual Review 2020*, International Renewable Energy Agency, Abu Dhabi, International Labour Organization, Geneva, available at: <https://www.irena.org/publications/2020/Sep/Renewable-Energy-and-Jobs-Annual-Review-2020>
- IRENA and ILO (2021), *Renewable Energy and Jobs: Annual Review 2021*, International Renewable Energy Agency, Abu Dhabi, International Labour Organization, Geneva, available at: <https://www.ilo.org/publications/renewable-energy-and-jobs-%E2%80%9393-annual-review-2021>
- Jaber, M. and Szép, T.E.K.L.A. (2021), "Understanding the causality relationship between renewable energy consumption and unemployment rates: the Toda-Yamamoto technique", *Közgazdász Fórum /Forum on Economics and Business*, Vol. 24, pp. 104-115, doi: [10.1007/s12053-024-10197-x](https://doi.org/10.1007/s12053-024-10197-x).
- Johansen, S. (1988), "Statistical analysis of cointegration vectors", *Journal of Economic Dynamics and Control*, Vol. 12 Nos 2-3, pp. 231-254, doi: [10.1016/0165-1889\(88\)90041-3](https://doi.org/10.1016/0165-1889(88)90041-3).
- Kettaf, H. (2025), "An econometric analysis of the impact of real wages on economic growth in OECD countries using the ARDL-PMG model (2002-2022)", *Economic and Regional Studies*, Vol. 18 No. 2, pp. 177-189, doi: [10.2478/ers-2025-0015](https://doi.org/10.2478/ers-2025-0015).
- Khobai, H., Kolisi, N., Moyo, C., Anyikwa, I. and Dingela, S. (2020), "Renewable energy consumption and unemployment in South Africa", *International Journal of Energy Economics and Policy*, Vol. 10 No. 2, pp. 170-178, doi: [10.32479/ijeep.6374](https://doi.org/10.32479/ijeep.6374).
- Khodeir, A.N. (2016), "The relationship between the generation of electricity from renewable resources and unemployment: an empirical study on the Egyptian economy", *Arab Economic and Business Journal*, Vol. 11 No. 1, pp. 16-30, doi: [10.1016/j.aebj.2015.10.003](https://doi.org/10.1016/j.aebj.2015.10.003).
- Kripfganz, S. and Schneider, D.C. (2023), "Ardl: estimating autoregressive distributed lag and equilibrium correction models", *STATA Journal*, Vol. 23 No. 4, pp. 983-1019, doi: [10.1177/1536867X231212434](https://doi.org/10.1177/1536867X231212434).
- Lydeka, Z. and Karaliute, A. (2021), "Assessment of the effect of technological innovations on unemployment in the European Union countries", *Engineering Economics*, Vol. 32 No. 2, pp. 130-139, doi: [10.5755/j01.ee.32.2.24400](https://doi.org/10.5755/j01.ee.32.2.24400).
- Magoncia, G.V., Xernan Lee, D.A. and Torillos, R. (2026), "Renewable energy transition in the Philippines: trends, opportunities, challenges", *Selected Issues Papers*, Vol. 2026 No. 005, pp. 38-54, doi: [10.5089/9798229039468.018](https://doi.org/10.5089/9798229039468.018).
- Marx, K. (1969), *Theories of Surplus Value: Part 1-3*, Progress, Moscow, available at: <https://www.marxists.org/archive/marx/works/subject/tsv/tsv-v1.pdf>
- Matuzeviciute, K., Butkus, M. and Karaliute, A. (2017), "Do technological innovations affect unemployment? Some empirical evidence from European countries", *Economies*, Vol. 5 No. 4, p. 48, doi: [10.3390/economies5040048](https://doi.org/10.3390/economies5040048).
- Michelacci, C. and Lopez-Salido, D. (2007), "Technology shocks and job flows", *The Review of Economic Studies*, Vol. 74 No. 4, pp. 1195-1227, doi: [10.1111/j.1467-937X.2007.00452.x](https://doi.org/10.1111/j.1467-937X.2007.00452.x).
- Musa, K.S. and Maijama'a, R. (2020), "Causal relationship between renewable energy consumption and unemployment in Nigeria: evidence from Toda and Yamamoto causality technique", *Energy Economics Letters*, Vol. 7 No. 1, pp. 46-60, doi: [10.18488/journal.82.2020.71.46.60](https://doi.org/10.18488/journal.82.2020.71.46.60).
- Naboureh, A., Li, A., Bian, J., Lei, G. and Nan, X. (2023), "Land cover dataset of the China Central-Asia West-Asia economic corridor from 1993 to 2018", *Scientific Data*, Vol. 10 No. 728, doi: [10.1038/s41597-023-02623-z](https://doi.org/10.1038/s41597-023-02623-z).

- Nguyen, H.C. and Dang, T.T. (2025), "Mối quan hệ giữa tham nhũng và tăng trưởng kinh tế tại các nước ASEAN: tiếp cận theo mô hình ARDL", *Kinh tế và Dự báo*, available at: <https://kinhhtevadubao.vn/moi-quan-he-giua-tham-nhung-va-tang-truong-kinh-te-tai-cac-nuoc-asean-tiep-can-theo-mo-hinh-ardl-30859.html>
- Østergaard, P.A., Duic, N., Noorollahi, Y., Mikulcic, H. and Kalogirou, S. (2020), "Sustainable development using renewable energy technology", *Renewable Energy*, Vol. 146, pp. 2430-2437, doi: [10.1016/j.renene.2019.08.094](https://doi.org/10.1016/j.renene.2019.08.094).
- Özmen, İ., Gerçekler, M. and Mucuk, M. (2022), "How does increasing renewable energy and decreasing coal-based electricity generation affect the future of unemployment in developed countries: a heterogeneous panel data analysis?", *Boğaziçi Journal*, Vol. 36 No. 1, pp. 18-39, doi: [10.21773/boun.36.1.2](https://doi.org/10.21773/boun.36.1.2).
- Özsoy, F.N. and Özpolat, A. (2020), "The relationship between renewable energy and employment: a bootstrap granger causality analysis", *Uluslararası Ekonomi İşletme ve Politika Dergisi*, Vol. 4 No. 2, pp. 263-280, doi: [10.29216/ueip.751244](https://doi.org/10.29216/ueip.751244).
- Pedroni, P. (1999), "Critical values for cointegration tests in heterogeneous panels with multiple regressors", *Oxford Bulletin of Economics and Statistics*, Vol. 61 No. S1, pp. 653-670, doi: [10.1111/1468-0084.0610s1653](https://doi.org/10.1111/1468-0084.0610s1653).
- Pesaran, M.H. (2021), "General diagnostic tests for cross-sectional dependence in panels", *Empirical Economics*, Vol. 60 No. 1, pp. 13-50, doi: [10.1007/s00181-020-01875-7](https://doi.org/10.1007/s00181-020-01875-7).
- Pesaran, M.H. and Smith, R. (1995), "Estimating long-run relationships from dynamic heterogeneous panels", *Journal of Econometrics*, Vol. 68 No. 1, pp. 79-113, doi: [10.1016/0304-4076\(94\)01644-F](https://doi.org/10.1016/0304-4076(94)01644-F).
- Pesaran, M.H., Shin, Y. and Smith, R.P. (1997), "Pooled estimation of long-run relationships in dynamic heterogeneous panels", available at: https://www.researchgate.net/publication/4800319_Pooled_Estimation_of_Long_Run_Relationships_in_Dynamic_Heterogeneous_Panels
- Pesaran, M.H., Shin, Y. and Smith, R.P. (1999), "Pooled mean group estimation of dynamic heterogeneous panels", *Journal of the American Statistical Association*, Vol. 94 No. 446, pp. 621-634, doi: [10.2307/2670182](https://doi.org/10.2307/2670182).
- Postel-Vinay, F. (2002), "The dynamics of technological unemployment", *International Economic Review*, Vol. 43 No. 3, pp. 737-760, doi: [10.1111/1468-2354.t01-1-00033](https://doi.org/10.1111/1468-2354.t01-1-00033).
- Rafiq, S., Salim, R. and Sgro, P.M. (2018), "Energy, unemployment and trade", *Applied Economics*, Vol. 50 No. 47, pp. 5122-5134, doi: [10.1080/00036846.2018.1472741](https://doi.org/10.1080/00036846.2018.1472741).
- Rahman, Z.U., Cai, H. and Ahmad, M. (2023), "A new look at the remittances-FDI-energy-environment nexus in the case of selected Asian nations", *Singapore Economic Review*, Vol. 68 No. 1, pp. 157-175, doi: [10.1142/S0217590819500176](https://doi.org/10.1142/S0217590819500176).
- Ricardo, D. (1951), *Principles of Political Economy and Taxation*, J.M. Dent & Sons, London, available at: <https://competitionandappropriation.econ.ucla.edu/wp-content/uploads/sites/95/1970/01/Principles-of-Political-Economy-and-Taxation-1817.pdf>
- Rivers, N. (2013), "Renewable energy and unemployment: a general equilibrium analysis", *Resource and Energy Economics*, Vol. 35 No. 4, pp. 467-485, doi: [10.1016/j.reseneeco.2013.04.004](https://doi.org/10.1016/j.reseneeco.2013.04.004).
- Saboori, B., Gholipour, H.F., Rasoulnezhad, E. and Ranjbar, O. (2022), "Renewable energy sources and unemployment rate: evidence from the US states", *Energy Policy*, Vol. 168, pp. 113-155, doi: [10.1016/j.enpol.2022.113155](https://doi.org/10.1016/j.enpol.2022.113155).
- Saussay, A., Dobrotková, Z. and Pargal, S. (2023), "Employment impacts of clean energy investments in emerging market economies", World Bank Policy Research Working Paper, available at: <https://openknowledge.worldbank.org/server/api/core/bitstreams/44e1a4a3-acc2-4d43-9721-05c54d5519ab/content>
- Say, J.B. (1964), "A treatise on political economy: or the production, distribution, and consumption of wealth, Kitchener", available at: <https://historyofeconomicthought.mcmaster.ca/say/treatise.pdf>

- Sumanto, A., Abbas, M.H.I., Rahmawati, F. and Merlinda, S. (2020), "Do technological developments reduce unemployment in Indonesia?", *4th Padang International Conference on Education, Economics, Business and Accounting*, pp. 345-350, doi: [10.2991/aebmr.k.200305.089](https://doi.org/10.2991/aebmr.k.200305.089).
- Truong, P.X., Nhung, N.C. and Ly, N.T.A. (2024), "The impact of innovation and renewable energy on CO₂ emission in Asian developing countries", *Journal of International Economics and Management*, Vol. 24 No. 3, pp. 42-58, doi: [10.38203/jiem.024.3.0093](https://doi.org/10.38203/jiem.024.3.0093).
- Vivarelli, M. (2012), "Innovation, employment and skills in advanced and developing countries: a survey of the literature", available at: <https://nbn-resolving.de/urn:nbn:de:101:1-201203145587>
- Yilanci, V., İslamoğlu, E., Yildirimalp, S. and Candan, G. (2020), "The relationship between unemployment rates and renewable energy consumption: evidence from fourier ADL cointegration test", *Alphanumeric Journal*, Vol. 8 No. 1, pp. 17-28, doi: [10.17093/alphanumeric.669380](https://doi.org/10.17093/alphanumeric.669380).
- Zhao, X. and Luo, D. (2017), "Driving force of rising renewable energy in China: environment, regulation and employment", *Renewable and Sustainable Energy Reviews*, Vol. 68, pp. 48-56, doi: [10.1016/j.rser.2016.09.126](https://doi.org/10.1016/j.rser.2016.09.126).

Further reading

- IRENA and ILO (2023), *Renewable Energy and Jobs: Annual Review 2023*, International Renewable Energy Agency, Abu Dhabi, International Labour Organization, Geneva, available at: https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@dgreports/@dcomm/documents/publication/wcms_895772.pdf
- Phillips, A.W. (1958), "The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861-1957", *Economica*, Vol. 25 No. 100, pp. 283-299, doi: [10.2307/2550759](https://doi.org/10.2307/2550759).
- Schumpeter, J. (1911), *Theorie Der Wirtschaftlichen Entwicklung*, Duncker and Humblot, Leipzig, available at: https://www.duncker-humblot.de/_files_media/leseproben/9783428517466.pdf
- Schumpeter, J.A. (1939), *Business Cycles: a Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, McGraw-Hill, New York, NY, available at: <https://www.mises.at/static/literatur/Buch/schumpeter-business-cycles-a-theoretical-historical-and-statistical-analysis-of-the-capitalist-process.pdf>
- Şener, M.F. (2000), "A Schumpeterian model of equilibrium unemployment and labor turnover", *Journal of Evolutionary Economics*, Vol. 10 No. 5, pp. 557-583, doi: [10.1007/s001910000052](https://doi.org/10.1007/s001910000052).
- Sjöholm, F. and Lundin, N. (2010), "Will science and technology solve China's unemployment problem?", *Asian Economic Papers*, Vol. 9 No. 2, pp. 1-28, doi: [10.1162/asep_a_00013](https://doi.org/10.1162/asep_a_00013).
- Solow, R.M. (1956), "A contribution to the theory of economic growth", *Quarterly Journal of Economics*, Vol. 70 No. 1, pp. 65-94, doi: [10.2307/1884513](https://doi.org/10.2307/1884513).

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