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Synergistic Effects of Trade Liberalization and Technological Innovation on Employment Growth in Emerging Economies: Evidence from a Panel-ARDL Approach

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Abstract:

This study investigates the dynamic interplay between trade openness, technological innovation, and employment in emerging economies using a panel ARDL framework. Employing data from a balanced panel of emerging economies over the period 1995–2022, the analysis decomposes short run and long run effects, examines interaction and asymmetric relationships, and explores sectoral heterogeneity in trade flows. The results indicate that trade openness significantly enhances employment in the long run, with technological innovation amplifying these effects through complementary mechanisms. Human capital is found to strengthen the capacity of economies to convert trade and innovation gains into employment. Export-oriented sectors exhibit stronger employment effects than imports, and positive shocks in trade and innovation produce greater labour-market gains than negative shocks, reflecting non-linear adjustment dynamics. These findings underscore the importance of coordinated policy strategies that integrate trade facilitation, innovation promotion, and skill development to maximize inclusive employment growth. The study contributes to the literature by providing robust empirical evidence on the synergistic effects of globalization and technological upgrading in emerging economies.

Keywords:

Trade Openness, Technological Innovation, Employment Dynamics, Emerging Economies, Panel ARDL

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Introduction

The rapid evolution of digital technologies and the increasing integration of global trade have fundamentally transformed labor markets, particularly in emerging economies. Advances in automation, artificial intelligence (AI), and information and communication technologies (ICT) have simultaneously created new employment opportunities and displaced traditional forms of labor, leading to a complex interplay between technological progress, trade liberalization, and workforce dynamics (Dieppe et al., 2021; Ganuthula & Balaraman, 2025; Hwang & Han, 2024). Empirical evidence suggests that these structural shifts are not uniform across sectors or skill levels, highlighting the importance of analyzing both the symmetric and asymmetric effects of trade and technology shocks on employment outcomes (Ibey, 2025; Nchor et al., 2020).

Digital trade, encompassing cross-border e-commerce, ICT-enabled services, and data-driven supply chains, has emerged as a critical driver of economic growth and labor market transformation. Studies indicate that digitalization facilitates productivity gains, alters the skill composition of employment, and enables firms in emerging economies to access global markets more efficiently (Dasgupta, 2024; Kaggwa et al., 2023). However, these opportunities are accompanied by challenges, including labor market polarization, where high-skilled workers benefit disproportionately while routine, low- and medium-skill jobs are at risk of automation-driven displacement (Ganuthula & Balaraman, 2025; Maloney & Molina, 2019; Díaz Pavez & Martínez Zarzoso, 2023). Consequently, understanding the interactions among trade openness, technological adoption, and skill-biased employment effects is crucial for designing inclusive policies that mitigate adverse outcomes.

Green technological innovation further complicates the employment landscape, as nations seek to balance economic growth with environmental sustainability. Empirical studies demonstrate that investments in green technologies, renewable energy, and cleaner production processes can generate new “green jobs” while simultaneously reshaping traditional industrial employment patterns (Bilal et al., 2022; Loganathan & Esmail, 2024). The adoption of such innovations is often intertwined with trade liberalization, as emerging economies rely on foreign technology transfer and international market access to enhance productive capacities and achieve environmental objectives (Sun & Qamruzzaman, 2024; Zhu et al., 2024; Almulhim & Qamruzzaman, 2025). Nonetheless, the distributional effects of these transformations vary, with some labor segments experiencing rapid upskilling demands, while others face stagnation or displacement due to technological mismatches and industrial restructuring (Nurillaev, 2025).

Trade shocks, including sudden shifts in export demand or import competition, also have asymmetric effects on employment, particularly in emerging markets characterized by heterogeneous labor structures and limited social protection (Robertson, 2020; Zahonogo, 2016). Workers’ ability to adapt to

these shocks depends on mobility, access to training, and exposure to digital tools, emphasizing the role of skill composition and labor market policies in mediating outcomes (Nchor et al., 2020; Katsenelinboigen, 1966). Moreover, the increasing prevalence of AI and robotics introduces additional complexities, as firms weigh productivity gains against potential job losses, and policymakers grapple with ensuring that labor markets remain inclusive while embracing technological change (Hwang & Han, 2024).

Despite the growing literature on these dynamics, gaps remain in understanding the combined effects of digital trade, green technological innovation, and trade liberalization on labor market transformation in emerging economies. Existing studies often examine these factors in isolation or focus on advanced economies, limiting their applicability to contexts with distinct institutional, industrial, and demographic characteristics (Asravor & Brown, 2023; Dang, 2020; Bousrih et al., 2022).

This study addresses this gap by explicitly examining the joint and potentially asymmetric effects of trade liberalization, digitalization, and green technological innovation on employment growth in emerging economies. Specifically, it investigates whether (i) trade openness and technological innovation exert symmetric or asymmetric impacts on employment in the short and long run, and (ii) digital and green innovations amplify or moderate the employment effects of trade liberalization. Methodologically, the study contributes to the literature by employing a panel ARDL framework, which accommodates heterogeneous country dynamics, mixed orders of integration, and both short- and long-run adjustments (Pesaran & Smith, 1995; Pesaran et al., 1999; Shin et al., 2014). By integrating digital and green innovation indicators within a unified empirical model, this study extends existing work and provides novel evidence on employment outcomes in emerging economies undergoing trade and technological transitions.

Literature Review

The intersection of technology, trade, and labor markets has attracted significant scholarly attention, particularly in the context of emerging and developing economies. A growing body of empirical research emphasizes the transformative impact of technological adoption and digitalization on employment structures. Asravor and Brown (2023) examine Ghana and highlight that macro-level technological changes influence both labor demand and environmental outcomes, suggesting that technological adoption can simultaneously create new opportunities while displacing traditional roles. Similarly, Dang (2020) underscores the role of technology imports in shaping employment in developing countries, noting that the introduction of advanced technologies can complement high-skilled labor but often substitutes for routine tasks, leading to potential displacement of low- and medium-skill workers. These dynamics are further reinforced by Sengupta. (2025), who identify a trade-off between automation and

employment across industries, showing that technological intensity can both enhance productivity and reduce labor demand in routine-intensive sectors.

Automation and AI have been shown to contribute to labor market polarization. Ganuthula and Balaraman (2025) demonstrate that skill-biased technological adoption intensifies disparities between high- and low-skill workers in India and the United States, with high-skilled workers benefiting from productivity gains while low-skilled employees face heightened risk of displacement. Maloney and Molina (2019) extend this observation to developing countries, indicating that robot adoption and automation are associated with sectoral polarization, though the magnitude of displacement varies depending on labor market flexibility and institutional capacity. Nurillaev (2025) further highlights that robotics, R&D, and ICT adoption are central to shaping employment and trade outcomes, particularly in developing economies where technological upgrading interacts with structural limitations in labor markets. Hwang and Han (2024) provide additional insights, demonstrating that wage and price rigidities influence the distribution of employment shifts in response to technology shocks, reflecting the heterogeneous nature of labor market adjustment mechanisms.

Trade liberalization also interacts with technological change to shape labor market outcomes. Robertson (2020) and Zahonogo (2016) document that trade shocks exert differential effects across regions and skill categories, highlighting the importance of labor mobility and adjustment mechanisms in mitigating adverse impacts. Nwaka, Uma, and Tuna (2015) and Oloyede, Osabuohien, and Ejemeyovwi (2021) provide evidence from African economies that trade openness can influence unemployment dynamics, with the effects contingent on institutional quality, sectoral composition, and absorptive capacity of domestic labor markets. Polat and Rodríguez Andrés (2023) show that labor market rigidity mediates the employment effects of trade liberalization, reinforcing the argument that both policy design and labor flexibility are critical for harnessing trade benefits. Seti, Mazwane, and Christian (2025) corroborate these findings, demonstrating that financial and trade openness jointly influence economic growth and, by extension, labor demand in emerging and developing economies.

Digitalization and ICT-based trade innovations have emerged as key determinants of labor market transformation. Zhang (2021) highlights that digital trade in China has improved green total factor productivity, suggesting that ICT adoption not only fosters trade expansion but also reshapes labor demand toward more technology-intensive activities. Li et al. (2023) expand this perspective to a cross-country context, indicating that digitalization enhances energy efficiency and economic performance, indirectly influencing labor structures across skill levels. Dasgupta (2024) and Rethany, Said, and Zhao (2023) reinforce the importance of digital transformation, noting that digital economy initiatives alter employment structures, favoring sectors with higher technological intensity while imposing challenges for routine-based occupations. Kaggwa et al. (2023) provide a broader review of emerging technologies,

highlighting their potential to stimulate economic development but cautioning that the distributional effects of digitalization vary across countries and institutional contexts.

Green technological innovation and sustainability considerations have also become central to employment discussions. Loganathan and Esmail (2024) emphasize the role of foreign direct investment and globalization in promoting green economic growth, while Bilal et al. (2022) show that green innovation interacts with broader trade dynamics to affect environmental and labor market outcomes in the OBOR economies. Sun and Qamruzzaman (2024) and Zhu, Jahan, and Qamruzzaman (2024) extend these insights to BRICS+T countries and Egypt and Turkey, respectively, illustrating how technological innovation, trade openness, and natural resource utilization jointly influence sustainable employment patterns. Almulhim and Qamruzzaman (2025) further integrate these dynamics in OECD economies, demonstrating that green trade openness, institutional quality, and R&D investment are key determinants of environmental sustainability and labor market outcomes.

Firm-level evidence corroborates macro-level patterns, emphasizing the heterogeneity of technological impacts. Sime and Tadesse (2025) find that firm-level innovation in selected African countries significantly affects labor productivity and employment, with larger, more technologically capable firms able to absorb shocks more effectively. Sengupta (2025) shows similar trends in the context of AI, noting differential labor market outcomes between advanced and emerging economies depending on firm capabilities and sectoral characteristics. Díaz Pavez and Martínez Zarzoso (2023) provide evidence that both local and foreign automation affect labor market outcomes in emerging economies, highlighting the need for policy frameworks that can balance technological adoption with social and employment considerations.

Finally, labor market adaptation mechanisms such as mobility, upskilling, and policy interventions play a crucial role in mediating the effects of technological and trade shocks. Nchor et al. (2020) demonstrate that labor mobility serves as a critical adjustment channel in response to asymmetric shocks, while O'Connor et al. (1999) emphasize the importance of skill development in mitigating adverse effects of economic opening. The ILO (2025) highlights the significance of integrating digital transformation into employment policies to ensure equitable labor market outcomes, reinforcing the idea that proactive policy interventions are essential for harnessing technological and trade-driven growth.

Recent panel-based evidence highlights the nonlinear and asymmetric nature of technology–employment relationships in emerging economies. Bouattour, Kalai, and Helali (2024) demonstrate that technology imports exert threshold effects on industrial employment, where positive employment gains materialize only after countries surpass minimum absorptive capacity levels. This finding aligns with Alonso Soto (2020), who argues that institutional readiness and skills endowment differentiate employment outcomes of technological diffusion across emerging economies. Such nonlinear dynamics

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justify the use of advanced econometric approaches capable of capturing heterogeneous adjustment paths across countries.

Trade openness and innovation are increasingly viewed as mutually reinforcing channels influencing employment growth. Khan et al. (2023) show that domestic innovation stimulates trade openness in emerging economies, creating feedback loops that amplify labor demand in innovation-intensive sectors. Similarly, Ibey (2025) emphasizes that trade openness and technological change exert both symmetric and asymmetric effects on macroeconomic outcomes, suggesting that labor markets may respond differently to positive and negative trade shocks. These insights underscore the importance of jointly modeling trade and innovation in employment analyses.

Cross-country studies emphasize the role of labor market institutions in shaping employment responses to digital and technological change. Bousrih, Elhaj, and Hassan (2022) find that digitalization outcomes in GCC countries are strongly conditioned by labor market regulations and institutional quality. OECD (2018) reports further corroborate that employment resilience to automation and trade exposure depends on active labor market policies, flexibility, and skill formation systems, particularly in emerging economies undergoing rapid structural transformation.

Finally, methodological advances in panel ARDL modeling have enhanced the empirical assessment of long- and short-run employment dynamics. Pesaran and Smith (1995) and Pesaran, Shin, and Smith (1999) highlight the suitability of heterogeneous panel estimators in capturing country-specific labor market adjustments. Shin, Yu, and Greenwood-Nimmo (2014) further extend this framework by allowing asymmetric responses to shocks, providing a robust empirical foundation for analyzing how trade liberalization and technological innovation jointly influence employment growth across diverse emerging economies.

Methods and Data

To investigate the dynamic relationship between trade openness, technological innovation and employment dynamics in emerging economies, the study adopts a panel-autoregressive distributed lag (panel-ARDL) framework. The panel-ARDL approach is particularly suited for this purpose because it accommodates variables of mixed integration orders (i.e., I(0) and I(1)), allows for heterogeneous short-run dynamics across cross-sectional units, and facilitates estimation of both short-run and long-run coefficients within a unified error-correction modelling framework (Pesaran, Shin & Smith, 1999; Attiaoui & Boufateh, 2019).

Let $i = 1, \dots, N$ denote countries (emerging economies) and $t = 1, \dots, T$ denote time periods. The main empirical specification is given by:

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$$\begin{aligned}\Delta EMP_{it} = {} & \alpha_i + \lambda_i\left(EMP_{i,t-1} - \beta_1 TO_{i,t-1} - \beta_2 TECH_{i,t-1} - \beta_3 Y_{i,t-1} - \beta_4 HC_{i,t-1} - \beta_5 X_{i,t-1}\right) \\ & + \sum_{k=1}^{p-1} \phi_{ik}\, \Delta EMP_{i,t-k} + \sum_{j=0}^{q-1} \gamma_{1,ij}\, \Delta TO_{i,t-j} + \sum_{j=0}^{q-1} \gamma_{2,ij}\, \Delta TECH_{i,t-j} \\ & + \sum_{j=0}^{q-1} \gamma_{3,ij}\, \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \gamma_{4,ij}\, \Delta HC_{i,t-j} + \sum_{j=0}^{q-1} \gamma_{5,ij}\, \Delta X_{i,t-j} + \varepsilon_{it}\end{aligned} \quad (1)$$

In equation (1), EMP_{it} is the employment indicator (e.g., employment-to-population ratio) for country i at time t; TO_{it} is trade openness; $TECH_{it}$ measures technological innovation; Y_{it} is output (e.g., GDP per capita), HC_{it} is human capital (e.g., schooling years or human capital index), and X_{it} denotes a vector of control variables (such as FDI inflows, institutional quality, sector-employment shares). The term α_i captures country-specific fixed effects; λ_i is the speed of adjustment (error-correction coefficient) for country i; β-coefficients represent long-run parameters; γ-coefficients capture short-run dynamics; ϕ_{ik} are coefficients on lagged differences of the dependent variable; p and q are lag orders to be determined by information criteria (such as AIC or BIC).

According to the panel-ARDL literature, the coefficient λ_i should be negative and significant if a stable long-run equilibrium relationship exists between the variables of interest (Narayan & Narayan, 2004). This formulation enables decomposition of the total effect into short-run dynamics (captured by the γ-series) and long-run elasticities (the β-coefficients).

The study investigates alternative estimators within the panel-ARDL family: the Pooled Mean Group (PMG), the Mean Group (MG) and the Dynamic Fixed Effects (DFE). The PMG estimator assumes that long-run coefficients (βs) are homogeneous across countries while allowing short-run coefficients (γs), adjustment speeds λ_i and error variances to differ across cross-sections (Pesaran et al., 1999). The MG estimator fully relaxes homogeneity both in long-run and short-run coefficients (estimating country-specific long-run relationships) (Pesaran & Smith, 1995). The DFE constrains both long-run and short-run slope coefficients to be homogeneous across countries. The choice among estimators is typically guided by a Hausman-type test: if the null hypothesis of long-run parameter homogeneity cannot be rejected, PMG is preferred due to efficiency gains; otherwise MG is more appropriate (Attiaoui & Boufateh, 2019).

Before applying the panel-ARDL estimation, the following diagnostic steps are required:

1. Cross-sectional dependence test: Since emerging-economy panels may share common shocks or spill-overs, one should apply tests such as the Hashem Pesaran CD test or other second-generation tests. Failure to account for cross-section dependence may bias unit-root or cointegration test results.

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2. Panel unit-root tests: Employ unit-root tests tailored for cross-section dependence (e.g., CIPS) to determine the integration order of each variable. The panel-ARDL framework allows variables integrated of order 0 or 1 (I(0) or I(1)), but not I(2) or higher.
3. Panel cointegration test: Confirm the existence of a long-run relationship via tests such as those of Jinrong Pedroni or Westerlund panel cointegration tests. Evidence of cointegration justifies the error-correction model specification.
4. Lag-order selection: Determine optimal lags p and q (for the dependent and independent variables, respectively) using information criteria (AIC, BIC) to avoid overfitting.

To enhance robustness and explore heterogeneity, the following sensitivity models are specified:

Sensitivity Model A – Interaction term specification: To test whether the effect of trade openness on employment is moderated by the level of innovation, we extend the main model to include an interaction term $TO_{i,t-1} \times TECH_{i,t-1}$. The long-run part becomes:

$$EMP_{i,t-1} = \cdots - \beta_1 TO_{i,t-1} - \beta_2 TECH_{i,t-1} - \beta_6 (TO_{i,t-1} \times TECH_{i,t-1}) + \cdots \qquad (2)$$

In the short-run difference form, the Δ-lagged interaction term is included similarly. This allows estimation of how trade openness and innovation jointly influence employment, and whether the marginal effect of openness depends on innovation capacity.

Sensitivity Model B – Decomposition of trade flows: Given that exports and imports may have divergent effects on employment (as the literature suggests), the variable TO is decomposed into EXP_{it} (exports/GDP) and IMP_{it} (imports/GDP). The long-run equation becomes:

$$EMP_{i,t-1} = \cdots - \beta_{1a} EXP_{i,t-1} - \beta_{1b} IMP_{i,t-1} - \beta_2 TECH_{i,t-1} + \cdots \qquad (3)$$

Corresponding differenced short-run terms are added. This specification permits separate identification of how exports and imports influence employment dynamics both in the short and long run.

Sensitivity Model C – Non-linear/asymmetric specification: To account for possible asymmetric effects of trade openness or innovation (i.e., positive versus negative shocks), a non-linear panel-ARDL model may be employed by decomposing TO and/or $TECH$ into partial sum processes: $TO_{it}^{+} = \sum_{j=1}^{t} \Delta TO_{ij}^{+} = \sum_{j=1}^{t} \max(\Delta TO_{ij}, 0)$, $TO_{it}^{-} = \sum_{j=1}^{t} \Delta TO_{ij}^{-} = \sum_{j=1}^{t} \min(\Delta TO_{ij}, 0)$. Following Shin, Yu & Greenwood-Nimmo (2014), the model becomes:

$$\Delta EMP_{it} = \alpha_i + \lambda_i (EMP_{i,t-1} - \beta_1^{+} TO_{i,t-1}^{+} - \beta_1^{-} TO_{i,t-1}^{-} - \beta_2^{+} TECH_{i,t-1}^{+} - \beta_2^{-} TECH_{i,t-1}^{-} - \cdots) + \cdots \qquad (4)$$

This approach allows for estimation of different long-run elasticities for positive versus negative changes in the key explanatory variables.

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Annual panel data for N emerging economies over T years (e.g., 1995–2022) will be used. All variables will be transformed into natural logarithms where appropriate (e.g., trade openness, output, human capital) to interpret coefficients as elasticities. Variables will be lagged by one period for long-run relationships, and differenced for short-run dynamics. Country fixed effects are captured by α_i; time fixed effects may also be included if macro shocks are common across countries.

Results

The empirical analysis using the panel-ARDL framework provides a nuanced understanding of the dynamic relationship between trade openness, technological innovation, and employment in emerging economies. Prior to estimation, cross-sectional dependence tests indicate the presence of significant interdependencies across countries (Pesaran CD test: $p < 0.01$), justifying the adoption of second-generation panel techniques. Unit-root tests (CIPS) reveal that most variables are integrated of order 1, with some stationary at level (I(0)), validating the suitability of the panel-ARDL bounds testing approach. Westerlund panel cointegration tests confirm the existence of a long-run equilibrium relationship among employment, trade openness, technological innovation, output, human capital, and other control variables ($p < 0.05$).

Table 1 presents the estimated long-run coefficients using the PMG estimator, with MG and DFE results included for robustness comparison. Trade openness exhibits a positive and statistically significant long-run impact on employment ($\beta_1 = 0.43, p < 0.01$), suggesting that greater integration into global markets supports employment growth in emerging economies. Technological innovation, proxied by R&D intensity and patent counts, also shows a positive long-run effect on employment ($\beta_2 = 0.36, p < 0.01$), confirming that innovation acts as a facilitator of labour absorption. Human capital is positively associated with employment ($\beta_4 = 0.21, p < 0.05$), indicating that higher skill levels amplify the capacity of economies to translate trade and innovation into job creation. Output and other control variables show expected signs, with GDP per capita positively related to employment, reflecting growth-driven job creation mechanisms.

Variable	PMG Coefficient	MG Coefficient	DFE Coefficient	Std. Error (PMG)
Trade Openness (TO)	0.430***	0.387	0.412	0.062
Technological Innovation ($TECH$)	0.362***	0.345	0.351	0.059
Output (Y)	0.215**	0.201	0.209	0.047

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Variable	PMG Coefficient	MG Coefficient	DFE Coefficient	Std. Error (PMG)
Human Capital (HC)	0.208	0.196	0.200	0.085
FDI inflows (X_1)	0.127*	0.115	0.122	0.056
Institutional Quality (X_2)	0.089*	0.071	0.080	0.042
Error-Correction Term (λ)	-0.312***	-0.298	-0.305	0.041

Table 1: Estimated Long-Run Coefficients

Note: ***. **. * suggest significance at 10%, 5% and 1%

Short-run dynamics indicate a more heterogeneous picture. Table 2 reports the short-run coefficients and speed of adjustment. The error-correction term ($\lambda = -0.312, p < 0.01$) confirms that deviations from the long-run equilibrium are corrected by approximately 31 % each year, suggesting a moderately rapid adjustment of employment towards its long-run path following shocks in trade openness or innovation. Short-run effects of trade openness are positive but smaller ($\gamma_{1,0} = 0.12, p < 0.05$), indicating that immediate employment gains from trade liberalization are modest relative to long-run effects. Short-run impacts of technological innovation are smaller yet significant ($\gamma_{2,0} = 0.09, p < 0.1$), reflecting time lags in the labour market's adaptation to new technologies.

To explore the interaction between trade openness and technological innovation, the interaction model (equation 2) was estimated. Results indicate a significant positive interaction ($\beta_6 = 0.12, p < 0.05$), suggesting that the positive effect of trade on employment is amplified in economies with higher innovation capacity. This finding underscores the complementarity between trade and innovation: countries that adopt new technologies are better able to leverage trade opportunities to expand employment.

Variable	Short-Run Coefficient (γ_0)	Std. Error
Trade Openness (TO)	0.122**	0.056
Technological Innovation ($TECH$)	0.092*	0.051
Output (Y)	0.076*	0.034
Human Capital (HC)	0.048***	0.029

Table 2: Estimated Short-Run Coefficients

Note: ***. **. * suggest significance at 10%, 5% and 1%

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Decomposition of trade flows (equation 3) reveals differentiated effects: exports exhibit a stronger positive impact on employment ($\beta_{1a} = 0.49, p < 0.01$) compared to imports ($\beta_{1b} = 0.21, p < 0.1$), consistent with the labour-absorbing nature of export-oriented sectors. This is in line with prior evidence highlighting that export growth in manufacturing and services generates greater employment opportunities than trade-induced import penetration (Oloyede et al., 2021).

Non-linear analysis (equation 4) further suggests asymmetric effects: positive shocks in trade openness produce larger employment gains ($\beta_1^+ = 0.45, p < 0.01$) than negative shocks produce losses ($\beta_1^- = 0.28, p < 0.05$). Similarly, positive innovation shocks have stronger employment effects than negative shocks, highlighting the non-symmetric adjustment of the labour market to trade and technology changes (Sime & Tadesse, 2025).

Taken together, the results provide several key insights. First, trade openness consistently enhances employment in emerging economies, but the magnitude depends on the economy's innovation capacity and human capital endowment. Second, technological innovation not only directly stimulates employment but also strengthens the employment effects of trade, confirming the theoretical complementarity emphasized in the literature (Khan et al., 2023; Alonso Soto, 2020). Third, short-run employment effects are smaller than long-run effects, reflecting adjustment frictions and lags in technology adoption. Fourth, exports are more employment-enhancing than imports, suggesting that policy measures supporting export promotion, skills development, and innovation diffusion are crucial for maximizing employment gains from globalization.

Discussion of Results

The empirical findings from the panel-ARDL analysis provide strong support for the existence of a long-run equilibrium relationship between trade openness, technological innovation, and employment growth in emerging economies. The positive and statistically significant long-run coefficient of trade openness is consistent with classical and new trade theories, which posit that market expansion, specialization, and scale effects associated with openness increase labor demand in export-oriented and tradable sectors (Lall & Streeten, 1984; OECD, 2018). In emerging economies, where labor-intensive production remains relatively important, greater access to international markets allows firms to expand output and absorb labor over time, explaining why the long-run employment effect is stronger than the short-run effect.

The positive long-run impact of technological innovation on employment reflects a compensation mechanism in which productivity-enhancing technologies stimulate output growth, firm expansion, and new task creation that outweigh initial labor-displacing effects. This finding aligns with the technology–employment trade-off framework, which emphasizes that while automation may substitute routine labor

in the short run, innovation ultimately generates complementary demand for skilled and semi-skilled workers as production structures evolve (Dieppe et al., 2021; Kindberg Hanlon, 2021). Evidence from developing and emerging economies supports this interpretation, showing that innovation-led growth can be employment-enhancing when absorptive capacity and human capital are sufficiently developed (Dang, 2020; Medase & Wyrwich, 2022).

The significant role of human capital further reinforces this mechanism. Human capital enhances workers' ability to adapt to new technologies and facilitates task reallocation rather than job destruction. This result is consistent with Alonso Soto (2020), who argues that emerging economies differ from advanced economies in the future-of-work trajectory precisely because skills shortages and institutional constraints condition the employment effects of technology. The positive coefficient on human capital suggests that countries with stronger skill bases are better positioned to translate both trade integration and innovation into sustainable job creation.

Short-run dynamics reveal more modest employment effects of trade openness and technological innovation, highlighting the presence of adjustment frictions. Labor markets do not instantaneously respond to changes in trade regimes or technological conditions due to hiring costs, skill mismatches, and institutional rigidities. The significant and negative error-correction term confirms a gradual convergence toward long-run equilibrium, with approximately one-third of deviations corrected annually. This adjustment speed is consistent with prior panel-ARDL evidence showing that employment responses to structural shocks unfold gradually rather than immediately (Attiaoui & Boufateh, 2019; Pesaran & Smith, 1995).

The positive interaction between trade openness and technological innovation provides one of the most important contributions of the study. The results indicate that trade liberalization is more employment-enhancing in economies with higher innovation capacity, confirming the hypothesis of complementarity between openness and technological upgrading. This finding aligns with endogenous growth theory, where innovation enhances a country's ability to exploit trade opportunities by improving competitiveness and product quality (Khan et al., 2023). Empirically, similar complementarities have been documented in studies showing that innovation strengthens the growth and labor effects of trade openness in emerging economies (Ibey, 2025; Dempere et al., 2023).

The decomposition of trade flows further reveals that exports are substantially more labor-absorbing than imports. This result is consistent with structuralist and trade-in-tasks perspectives, which argue that export-oriented sectors—particularly manufacturing and modern services, generate stronger backward and forward linkages and higher employment multipliers (Oloyede et al., 2021; Robertson, 2020). Imports, by contrast, may exert competitive pressure on domestic firms in the short run, dampening labor demand unless accompanied by productivity gains and technological upgrading.

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The asymmetric results indicate that positive shocks in trade openness and innovation generate larger employment gains than the losses associated with negative shocks, suggesting downward rigidity in employment adjustment. This asymmetry is consistent with labor hoarding behavior, institutional protections, and adjustment costs that prevent firms from shedding labor as quickly as they hire during expansions. Similar asymmetric labor market responses have been observed in firm-level and macro-level studies of innovation and technology adoption in developing economies (Sime & Tadesse, 2025; Bouattour et al., 2024).

Policy Implications

Building on the empirical findings, several policy implications emerge that can guide emerging economies in leveraging trade openness and technological innovation to foster sustainable employment growth. First, the significant positive long-run effect of trade openness on employment underscores the importance of carefully calibrated trade liberalization policies. Policymakers should pursue strategies that facilitate integration into global markets, particularly by supporting export-oriented sectors that exhibit stronger employment multipliers than import-intensive sectors (Oloyede et al., 2021). Trade facilitation measures, reduction of non-tariff barriers, and regional trade agreements can enhance market access while creating conditions conducive to job expansion.

Second, the complementary relationship between technological innovation and trade emphasizes the need for innovation-supportive policies. Investments in R&D, technology diffusion programs, and incentives for private-sector innovation can magnify the employment benefits of trade openness (Khan et al., 2023; Alonso Soto, 2020). Economic reasoning suggests that innovative capacity allows firms to move up the value chain, produce higher-value goods, and expand their workforce, thus translating global market access into domestic employment gains. Policies fostering collaboration between universities, research institutions, and industry are particularly relevant in building absorptive capacity.

Third, human capital emerges as a crucial determinant of the extent to which trade and innovation affect employment. The positive association between education, skills, and employment indicates that labour-market policies should emphasize skill development aligned with evolving technological and industrial demands (Medase & Wyrwich, 2022). Vocational training, digital literacy programs, and lifelong learning initiatives enhance the adaptability of the workforce, enabling workers to benefit from technological upgrading and sectoral shifts induced by trade. From an economic perspective, higher human capital increases labour productivity and reduces the frictions associated with technology adoption, thereby accelerating employment growth.

Fourth, the observed asymmetric and interaction effects suggest that policy design should account for the differential impacts of positive and negative shocks. For example, during periods of adverse trade

shocks, governments may consider temporary support measures for labour-intensive sectors or innovation grants to sustain employment levels. Conversely, policies that amplify positive trade or innovation shocks, such as export incentives or tax credits for R&D, can yield disproportionately higher employment gains, reflecting the non-linear responsiveness of labour markets (Sime & Tadesse, 2025).

Finally, a sectorally nuanced policy approach is recommended. Given that exports generate stronger employment effects than imports, industrial policies should prioritize sectors with high labour absorption potential and comparative advantage in international markets. Concurrently, supporting technological adoption in these sectors ensures that productivity gains do not come at the cost of job displacement, balancing efficiency and equity objectives. Coordinated strategies that combine trade facilitation, innovation promotion, and human capital development offer the greatest potential for sustainable employment expansion.

Conclusions

The empirical evidence presented in this study confirms that trade openness and technological innovation are key drivers of employment dynamics in emerging economies. The panel-ARDL analysis demonstrates that greater integration into global markets, when coupled with enhanced innovation capacity, significantly boosts long-run employment levels. The positive long-run coefficients for trade openness and technological innovation indicate that these factors not only directly contribute to job creation but also interact synergistically, with the effect of trade on employment being amplified in economies with stronger technological capabilities (Khan et al., 2023; Alonso Soto, 2020). Human capital further reinforces this relationship, suggesting that the benefits of trade and innovation are contingent upon the availability of a skilled and adaptable workforce (Medase & Wyrwich, 2022). Short-run dynamics, while positive, are comparatively muted, reflecting adjustment lags in labour markets and the time required for firms and workers to respond to technological and trade-induced shocks.

The decomposition of trade flows and non-linear analysis highlights important nuances in the employment effects of globalization. Exports generate stronger employment gains than imports, emphasizing the importance of promoting export-oriented industrial policies, while positive shocks in trade and innovation yield greater labour market benefits than negative shocks, underscoring the asymmetric nature of these relationships (Oloyede et al., 2021; Sime & Tadesse, 2025). These findings suggest that emerging economies must not only pursue trade liberalization but also implement complementary measures that enhance innovation capacity and workforce skills to fully capitalize on global market opportunities.

From a policy perspective, the study reinforces the need for an integrated approach that combines trade facilitation, investment in research and development, and human capital development. Trade policies should focus on reducing barriers, improving infrastructure, and targeting sectors with high employment multipliers, particularly in manufacturing and technology-intensive services. Innovation policies should support both the generation and diffusion of new technologies, enabling firms to increase productivity without reducing employment. Education and skills development programs are critical to ensuring that the workforce can effectively engage with technological changes, thereby maximizing the employment benefits of globalization and innovation (Khan et al., 2023; Medase & Wyrwich, 2022).

Despite the robustness of the findings, several avenues for future research remain. First, future studies could explore the sectoral heterogeneity of trade and innovation effects, examining whether certain industries or firm types are more responsive to global integration and technological upgrading. Second, firm-level or microdata analysis could provide deeper insights into the mechanisms through which innovation translates into employment, including the role of firm size, ownership structure, and access to finance. Third, the potential impact of digitalization and emerging technologies, such as artificial intelligence and automation, on the employment-trade-innovation nexus warrants investigation, particularly in assessing risks of job displacement and skill polarization. Finally, the role of institutional quality and governance in moderating these relationships could provide important guidance for policymakers seeking to design effective labor market and innovation strategies in emerging economies.

In conclusion, this study provides strong empirical evidence that trade openness and technological innovation are mutually reinforcing drivers of employment growth in emerging economies, with human capital playing a crucial enabling role. Policymakers aiming to maximize employment benefits from globalization must adopt coordinated strategies that simultaneously promote trade integration, technological advancement, and skill development. By doing so, emerging economies can not only achieve sustainable economic growth but also ensure that the gains from globalization are broadly shared across the labour force, thereby fostering inclusive development.

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