

Economic Cycle Fluctuations and Informal Employment in Countries along the “Belt and Road Initiative” — An Empirical Analysis Based on Three-Dimensional Panel Data of 64 Countries from 2010 to 2021

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ABSTRACT Understanding the interaction between economic cycle fluctuations and labor market dynamics is increasingly important for the sustainable development of digital infrastructure and communication systems supported by advanced electromagnetic technologies. This paper systematically investigates the heterogeneous impacts of economic cycle fluctuations on informal employment across 64 countries participating in the Belt and Road Initiative (BRI) from 2010 to 2021, with particular attention to sectoral labor absorption and infrastructure-driven development. An econometric framework based on Okun's Law is established to examine the dynamic responses of informal employment from sectoral, gender, and age perspectives. The results show that the agricultural sector retains an important role in absorbing informal employment but faces structural transformation pressures. The industrial sector exhibits a distinctive counter-cyclical employment effect, whereas the service sector demonstrates the strongest employment elasticity, especially among youth and female workers. Infrastructure investment under the BRI significantly promotes employment and enhances the service sector's capacity to absorb female labor. Furthermore, economic cycle fluctuations display nonlinear transmission characteristics: service industries dominate employment creation during expansion periods, while industrial sectors provide counter-cyclical labor absorption during downturns. These findings enrich the theoretical understanding of informal employment dynamics and provide empirical evidence for optimizing infrastructure coordination, including communication and electromagnetic-enabled connectivity systems, to improve regional economic resilience and sustainable development.

INDEX TERMS economic cycle fluctuations, informal employment, Okun's Law, communication infrastructure, electromagnetic-enabled connectivity

I. INTRODUCTION

IN 2013, President Xi Jinping proposed the joint construction of the Silk Road Economic Belt and the 21st Century Maritime Silk Road. The Belt and Road Initiative (BRI) serves as an open, inclusive international platform that deepens economic connectivity and common development, specifically by fostering multidimensional cooperation within the manufacturing sector to enhance industrial synergy among participating countries. This collaborative framework transforms regional resource advantages into high-quality growth, ensuring that the modernization of industrial clusters contributes significantly to the building of a shared global future. However, this period coincided with

severe global economic volatility, which exerted profound impacts on global economic growth and recovery, and posed severe employment challenges especially for developing countries. Against this backdrop, informal employment has become a critical channel for alleviating employment pressure and enhancing economic resilience.

Informal employment generally refers to employment forms lacking labor law protection, social security coverage, and formal labor contracts, including self-employment, gig economy work, and micro-business activities. As a key adjustment mechanism in labor markets, moderate informal employment enhances market flexibility and eases employment pressure, while avoiding institutional rigidity and

rising labor costs caused by excessive formalization. The International Labour Organization (ILO) stated in the World Employment and Social Outlook 2022 that informal employment occupies a pivotal position globally, particularly in developing countries, where it serves as a vital buffer for labor markets and a core pillar sustaining economic resilience. Most BRI countries are developing economies, where informal employment not only provides a buffer for the transfer of rural surplus labor and re-employment of urban unemployed groups, but also forms a multi-dimensional employment ecosystem through cross-border labor services, micro-entrepreneurship, and temporary positions. Notably, informal employment in these countries features pronounced heterogeneity: it covers seasonal labor in traditional agriculture, street vending in urban informal sectors, survival-oriented employment for cross-border migrants, and new flexible employment models driven by the digital economy. Existing theoretical research is largely confined to the relationship between formal employment and economic cycles, with a predominant focus on developed economies, leaving insufficient exploration of developing countries. BRI countries, as typical developing economies with unique economic structures and policy practice needs, are ideal samples for studying the impacts of economic cycles on informal employment. On the one hand, these countries feature a dual-track labor market: formal and informal sectors coexist long-term during industrialization, and the informal sector is far more sensitive to economic fluctuations than in advanced economies. For instance, capital flows to formal sectors during economic expansion may squeeze informal employment space, while informal employment acts as a “safety net” absorbing laid-off workers during recessions. On the other hand, the BRI reshapes regional economic cycle synchronization through infrastructure connectivity and trade liberalization, turning the cross-border spillover effect of informal employment into a key variable affecting regional economic resilience. Accounting for over 50% of total employment in BRI countries, informal employment acts as a “shock absorber” in labor markets, and its response path presents unique complexity under the interaction of industrial structure, demographic characteristics, and policy environments.

This study addresses the following core questions: What impacts do economic cycle fluctuations exert on informal employment in BRI countries? Do such impacts differ significantly across sectors, genders, and age groups? Can infrastructure investment under the BRI moderate informal employment, and if so, through what mechanisms? Addressing these questions not only improves employment stability across industrial clusters in BRI countries via deepened cooperation, but also promotes the standardized development of informal employment and inclusive growth through enhanced policy coordination. This integration of manufacturing labor dynamics with multilateral strategy bears great theoretical and practical significance for advancing the building of a community with a shared future for mankind.

II. LITERATURE REVIEW

A. ECONOMIC GROWTH AND EMPLOYMENT ELASTICITY

The relationship between economic growth and employment is a core topic in labor economics. Proposed in 1962, Okun's Law laid the foundation for this field by depicting the negative correlation between GDP growth and unemployment. Subsequent studies found that the applicability of Okun's Law is constrained by economic development stages, labor market structures, and economic cycles. For developed economies, Owyang and Sekhposyan (2012) identified asymmetric employment elasticity between economic expansion and recession, revealing the limitations of linear models. Based on Chinese data, Zhang et al. (2002) detected a fluctuating decline in employment elasticity amid economic structural transformation, with the secondary sector showing significantly lower elasticity than the tertiary sector, further verifying the non-linear relationship. Nevertheless, these studies focus primarily on formal employment and pay insufficient attention to the elasticity characteristics of informal employment. In developing countries, Bosch and Maloney (2010) found that informal employment responds more rapidly and sensitively to economic fluctuations, yet lacks a systematic analytical framework. Cazes et al. (2013) noted that income elasticity of informal workers drops faster during economic recessions, but ignored heterogeneity across sectors and demographic groups. Domestic studies such as Qu et al. (2020) found that the digital economy accelerates structural differentiation in labor markets, and economic restructuring (e.g., automation substitution) may exacerbate volatility in informal employment, but did not analyze the impacts of economic cycle fluctuations.

B. HETEROGENEOUS RESPONSE MECHANISMS OF INFORMAL EMPLOYMENT

Existing literature has recognized differences in employment elasticity across groups and sectors, but most fail to integrate multi-dimensional interactive effects. International studies by Kapsos (2005) found that female employment elasticity is generally higher than that of males, and Anderson and Braunstein (2013) further highlighted stronger female employment responses in the service sector. However, these conclusions rely on formal employment data and may underestimate gender disparities in informal employment. Domestic research by Shen et al. (2024) found that the platform economy significantly improves income and subjective well-being of young and male flexible workers, but did not examine gender heterogeneity in traditional informal employment.

From an age perspective, the ILO (2020) pointed out that economic fluctuations exert greater impacts on youth employment, while Li et al. (2021) constructed a youth employment risk index without incorporating economic cycle factors. At the sectoral level, Dauda et al. (2021) found negative employment elasticity in the agricultural sector in Africa, but did not conduct cross-analysis by gender and age

to explore the heterogeneous dynamic response of informal employment to economic growth.

C. THE BRI AND INFORMAL EMPLOYMENT

Scholarly attention has been paid to the impacts of the BRI on employment structures in participating countries, but existing research focuses overwhelmingly on formal employment, leaving research on informal employment in its infancy. For example, Lin (2020) found that China's Outward Foreign Direct Investment (OFDI) significantly promotes industrial and service employment in host countries, but excluded the informal sector from data analysis. Luo et al. (2022) confirmed the job-creating effect of infrastructure and its promotion of non-agricultural employment based on the China Labor-force Dynamics Survey (CLDS), but this database mainly covers formal employment and some non-agricultural groups, omitting large numbers of informal workers such as gig workers, temporary laborers, and uncontractured construction workers. According to World Bank (2022) statistics, informal employment accounts for an average of 48% of total employment in BRI countries, but empirical analysis of its elasticity characteristics remains absent.

Only a handful of studies have explored regional disparities in informal employment. Lin (2020) found that China's OFDI increases the share of low-skilled employment in Southeast Asia and boosts industrial and service employment, but did not distinguish between formal and informal positions. Pan et al. (2022) further argued that foreign direct investment inhibits the expansion of informal employment through competition, forward and backward linkage, and technology spillover effects, but did not conduct elasticity analysis linked to economic growth. These studies fail to fully reflect the dynamic changes of informal employment amid economic cycle fluctuations, leaving important room for innovation in this research.

The marginal contributions of this study are threefold: First, based on Okun's Law, it constructs an econometric model using panel data of 64 BRI countries from 2010 to 2021, identifying asymmetric impacts of economic cycle fluctuations on informal employment (i.e., divergent effects in expansion and recession). This approach expands the application scope of Okun's Law in the field of informal employment and provides a new analytical framework for follow-up research. Second, it reveals the heterogeneous dynamic response mechanisms of informal employment to economic growth from gender, age, and sectoral dimensions, offering critical implications for designing targeted labor market policies (e.g., employment protection for women, youth, and sector-specific groups) and cross-border industrial chain division. Third, from the perspective of regional cooperation, it systematically examines the elasticity of informal employment to economic growth in 64 BRI countries, filling the research gap of informal employment in the context of regional cooperation and providing empirical evidence for formulating multilateral employment policies

under the BRI.

This study aims to provide theoretical support for employment policy-making in BRI countries and contribute new empirical cases to global research on informal employment. It enriches theoretical outcomes in international economics and labor economics, offers empirical evidence for enhancing informal employment elasticity in BRI countries, and provides experience for inclusive employment. More importantly, it helps improve cooperation mechanisms among BRI countries, advance the high-quality implementation of employment policies, and support participating countries in achieving synchronized inclusive economic growth and employment stability under the BRI framework. All terms related to informal employment follow the standard definitions of the International Labour Organization (ILO), referring to employment without formal labor contracts, social security coverage, or formal enterprise registration. The counter-cyclical informal employment effect is consistently defined as the phenomenon where informal employment rises when sectoral output declines, acting as a buffer during economic downturns.

III. ECONOMETRIC MODEL

In 1962, American economist Arthur Okun proposed a stable negative relationship between actual economic output and unemployment. Based on U.S. data, he concluded that for every 1 percentage point the unemployment rate exceeds the natural unemployment rate, actual output falls 3% below potential output. The International Monetary Fund (IMF, 2010) extended Okun's Law to study the relationship between actual output and employment rate. To explore the link between actual output and informal employment rate, this study constructs the following economic model based on Okun's Law using panel data of BRI countries from 2010 to 2021:

$$\Delta E_{i,t} = \alpha + \beta \Delta Y_{i,t} + \theta_t + \Delta \epsilon_{i,t} \quad (1)$$

Where $\Delta E_{i,t}$ is the growth rate of informal employment in country i from year $t-1$ to t ; $\Delta Y_{i,t}$ is the GDP growth rate from year $t-1$ to t ; parameter β denotes the elasticity of employment rate to economic growth; α represents the change in employment rate when actual output remains unchanged; θ_t stands for time fixed effects; and $\Delta \epsilon_{i,t}$ is the idiosyncratic error term. As Equation (1) is a first-order differential equation, it excludes country fixed effects.

To analyze the asymmetric relationship between sectoral economic growth and employment rate changes, economic growth is decomposed into primary, secondary, and tertiary industries. Based on the growth rate aggregation method proposed by Anderton (2014), which decomposes output growth by expenditure items, this study decomposes economic growth of the three sectors as follows:

$$\Delta Y_{i,t} = \Delta \sum_{s=1}^S Y_{s,i,t} \approx \sum_{s=1}^S \frac{Y_{s,i,t}}{\sum_{s=1}^S Y_{s,i,t}} \Delta Y_{s,i,t} \quad (2)$$

Where s denotes agriculture, industry, and services respectively; $\Delta Y_{s,i,t}$ represents the economic growth rate of sector s .

We revise Equation (1) to allow parameter β to vary across sectors, adopting the following approximation:

$$\Delta E_{i,t} = \alpha + \sum_{s=1}^S \beta_s \phi_{s,i,t} \Delta Y_{s,i,t} + \theta_t + \Delta \epsilon_{i,t} \quad (3)$$

Where β_s represents the responsiveness of informal employment rate to output in sector s ; $\phi_{s,i,t} = Y_{s,i,t} / \sum_{s=1}^S Y_{s,i,t}$ denotes the share of sector s in total economic output of country i . We assume $\phi_{s,i,t}$ is time-varying to ensure the accuracy of the approximation in Equation (2). $\beta_s \phi_{s,i,t}$ is the elasticity of employment rate to output growth in each sector, measuring the change in employment rate caused by a 1% increase in economic growth of sector s . β_s is estimated by regressing employment growth on weighted actual output $\Delta Y_{s,i,t}$, enabling independent examination of sectoral employment responses to output changes.

The employment effect of infrastructure construction under the BRI may exhibit time lags. According to project cycle theory (Pritchett, 2000), large-scale infrastructure projects (transportation, energy, etc.) generally take 1–3 years to generate employment effects from investment to completion. To verify this mechanism, this study introduces lagged infrastructure investment variables into Equation (4), grounded in two theoretical logics: infrastructure projects require time from approval to completion, leading to natural lags in job creation; workers need training cycles to adapt to industrial demand driven by new infrastructure (Moretti, 2012).

$$\Delta E_{i,t} = \alpha + \sum_{s=1}^S \beta_s \phi_{s,i,t} \Delta Y_{s,i,t} + \gamma INFR A_{i,t-1} + \delta Z_{i,t} + \theta_t + u_i + \Delta \epsilon_{i,t} \quad (4)$$

Where $INFR A_{i,t-1}$ denotes the lagged one-period infrastructure investment as a share of GDP (log-transformed) to capture cumulative investment effects; $Z_{i,t}$ is the urbanization rate to control for regional development disparities; and u_i is country fixed effects.

Kim and Park (2019) found that unemployment responds more sensitively to economic recessions than expansions, confirming asymmetric linkages between labor market variables and GDP across cycle phases. Firms tend to lay off workers during downturns and compensate for labor reduction by improving labor productivity, shaped by labor market regulations, hiring, and firing costs. Unemployment responses to economic fluctuations are also constrained by economic structure, demographic structure, and business cycles.

While existing evidence confirms higher sensitivity of unemployment to negative economic growth (Novak & Darmo, 2019), few studies focus on asymmetric responses

of informal employment rates. To examine the elasticity of informal employment rate to GDP growth across economic cycles, we allow β to vary across sectors and between expansion and recession phases:

$$\begin{aligned} \Delta E_{i,t} = & \alpha + \sum_{s=1}^S \beta_{1,s} \phi_{s,i,t} \Delta Y_{s,i,t} \\ & + \sum_{s=1}^S \beta_{2,s} \phi_{s,i,t} \Delta Y_{s,i,t} d_{s,i,t} \\ & + \sum_{s=1}^S \gamma_s d_{s,i,t} + \theta_t + \Delta \epsilon_{i,t} \end{aligned} \quad (5)$$

Where $d_{s,i,t}$ is a binary dummy variable equal to 1 if output of sector s decreases ($\Delta Y_{s,i,t} < 0$) and 0 otherwise; $\beta_{1,s}$ represents the responsiveness of employment rate to positive output growth (expansion) of sector s ; and $\beta_{1,s} + \beta_{2,s}$ denotes the responsiveness of informal employment rate to output decline (recession) of sector s .

Equations are estimated via ordinary least squares (OLS) with robust standard errors to mitigate biases from heteroscedasticity and serial correlation. The panel dataset covers informal employment rates and GDP growth rates of 64 BRI countries from 2010 to 2021, sourced from the World Bank World Development Indicators (WDI) and ILO databases. Descriptive statistics of variables are presented in Table 2.

This study acknowledges potential simultaneity and reverse causality between GDP growth and informal employment, as informal employment constitutes a large share of total output in many BRI countries. To mitigate this bias, we adopt a first-difference specification and control for time fixed effects to absorb common macroeconomic shocks. We also introduce lagged infrastructure investment and a lagged structure model, which further reduce endogeneity concerns by linking current informal employment changes to prior economic conditions. All main findings are robust to these treatments.

IV. EMPIRICAL ANALYSIS

A. VARIABLE SELECTION AND DEFINITION

1) Definition and Data of Informal Employment

Most BRI countries are developing economies, and the statistical caliber of informal employment varies widely across countries due to divergent data sources, definitions, and standards, posing challenges for cross-country comparative research. For example, India's National Statistical Office (NSO) defines informal employment as work in unregistered enterprises or beyond formal labor regulation, covering agriculture, handicrafts, and micro-enterprises (India Informal Sector Survey Report, 2020). The EU adopts a dual classification of informal employment as "undeclared work" and "shadow economy", emphasizing non-compliance with tax and labor regulations (Eurostat, 2016). While China has not issued an official definition of informal employment, it

is practically defined as employment lacking formal labor contracts or labor law protection (e.g., flexible employment and street vending), highlighting its role in enhancing economic resilience.

Given cross-country definitional and statistical discrepancies, this study adopts the ILO's definition and statistics of informal employment. The ILO definition covers precarious employment in both formal and informal sectors (e.g., no contract, no social security) and legal status of economic activities (unregistered enterprises), providing a unified framework for cross-country comparison. ILO data feature high international comparability, comprehensiveness, and standardization, effectively resolving inconsistencies in national statistical calibers and ensuring the reliability and comparability of results. Table 1 compares definitional features and statistical methods of major institutions and countries, demonstrating the unique advantage of the ILO definition for cross-country research. For heterogeneity analysis across groups, this study further selects informal employment rate data for males, females, and workers aged 15–24.

2) Definition and Selection of Economic Cycle Variables

GDP growth rate, as a core indicator measuring changes in aggregate economic output, effectively captures dynamic characteristics of economic activity across expansion and contraction phases. Consistent with classical business cycle theory (Schumpeter's innovation cycle, Keynesian demand fluctuation), GDP growth rate is widely recognized as a key measure of economic cycle fluctuations (Lucas, 1977; Stock & Watson, 1999). This study selects GDP growth rate as the proxy for economic cycle fluctuations for three reasons:

Theoretical applicability: GDP growth rate fully reflects economic cycle fluctuations and provides a reliable basis for dividing expansion and contraction phases, supported by Okun's Law (Okun, 1962).

Data comparability: GDP growth rate features high international consistency and availability (World Bank, 2022; IMF, 2022), making it an ideal proxy for cross-country comparison.

Research practice: GDP growth rate is extensively used as a core indicator in existing literature (Lucas, 1977; Stock & Watson, 1999).

Accordingly, this study selects total GDP growth rate and sectoral GDP growth rates (agriculture, industry, services) of BRI countries as core explanatory variables, ensuring scientificity and comparability of results.

3) Infrastructure Investment Data

Infrastructure connectivity is the core pillar of the BRI. From 2013 to 2023, China's infrastructure investment in BRI countries exceeded USD 1 trillion (White Paper on the 10-Year Achievements and Prospects of the BRI, MOFCOM, 2023). This direct investment is reflected in the rise of host countries' infrastructure investment as a share of GDP,

which more accurately measures policy implementation intensity than indirect indicators (trade, finance).

Consistent with Lewis's dual-sector theory, infrastructure investment is a key driver of the transition from traditional sectors (the main body of informal employment) to modern sectors: it directly creates informal jobs in construction and supporting services, and reduces operating costs of the informal economy by improving transportation and energy infrastructure. Chinese evidence shows that a 1% increase in infrastructure investment reduces the share of informal employment by 0.8% (Zhang et al., 2021).

For data processing, this study uses annual infrastructure investment data from the American Enterprise Institute–China Global Investment Tracker (AEI-CGIAR), covering transportation, energy, and communications. Calculating investment as a share of GDP eliminates biases from country size differences. Given the 3–5 year lag of infrastructure investment effects (Wang et al., 2022), this indicator is well-suited for dynamic panel data analysis.

This variable selection reflects the policy characteristics of the BRI, aligns with theoretical expectations of development economics, and meets the requirements of scientificity, comparability, and timeliness for econometric analysis. We note that the ratio infrastructure investment as a share of GDP may mechanically increase when GDP shrinks during economic downturns, which could create a spurious correlation. In unreported robustness checks, we use the logarithm of infrastructure investment in constant USD to avoid denominator bias, and the positive employment effect of infrastructure investment remains stable. Our main interpretation emphasizes the real investment effect rather than the mechanical ratio change.

4) Descriptive Statistics

Table 2 presents descriptive statistics of core variables, revealing three typical features:

Employment structure: Informal employment in sample countries features “high share, large disparities”: the average rate is 38.4%, ranging widely from 2.5% to 94.7%; youth informal employment rate is the highest (42.4%), and male rate (39.97%) is slightly higher than female (37.23%).

Economic growth: Average annual GDP growth is 3.4%, with extreme volatility (–33.5% to 41.8%); the industrial sector shows the largest fluctuation (standard deviation 8.3) and the service sector the highest stability (standard deviation 1.9).

Infrastructure investment: The share of infrastructure investment in GDP varies drastically (0%–133%), consistent with typical labor market and growth patterns in developing countries.

B. REGRESSION ANALYSIS

1) Baseline Regression

Table 3 reports baseline regression results of Equation (3), showing the impacts of 1% sectoral output growth on employment rates. Agricultural and service growth exert

TABLE 1. Comparison and Summary of Informal Employment Definitions

Institution/Country	Definitional Features	Statistical Methods/Features
ILO	Authoritative definition covering precarious employment in formal and informal sectors	Adopts international standard classifications (ISIC, SNA)
World Bank	Focuses on production and employment in informal sectors, emphasizing its economic role in developing countries	Sourced from enterprise and household surveys
China	Mainly employment without contracts and social security; policy focus on promoting flexible employment	Based on urban-rural labor surveys; flexible but inconsistent data
India	Informal labor dominated by agriculture and handicrafts; highly reliant on rural and low-skilled labor	Sourced from NSO and rural development programs
EU	Focuses on undeclared work and shadow economy; emphasizes compliance with labor regulations	Estimates undeclared work via tax, social security, and labor inspection data

TABLE 2. Descriptive Statistics of Core Variables (Unit: %)

Variable	Definition	Mean	Std. Dev.	Min	Max
ET	Total Informal Employment Rate	38.42	28.11	2.50	94.70
EM	Male Informal Employment Rate	39.97	28.99	1.50	93.90
EF	Female Informal Employment Rate	37.23	28.86	3.00	97.30
EY	Youth Informal Employment Rate (15–24)	42.44	30.14	3.30	97.80
ΔY	GDP Growth Rate	3.39	5.17	-33.49	41.75
ΔY_{agr}	Agricultural GDP Growth Rate	2.48	8.11	-36.88	46.60
ΔY_{ind}	Industrial GDP Growth Rate	3.80	8.32	-44.85	117.67
ΔY_{ser}	Service GDP Growth Rate	0.44	1.92	-7.65	18.36
$INFRA_GDP$	Infrastructure Investment as % of GDP	2.17	12.48	0.00	133.33

TABLE 3. Baseline Regression Results of the Impact of GDP Growth Rate on Informal Employment Rate

	$\Delta ET_{i,t}$	$\Delta EM_{i,t}$	$\Delta EF_{i,t}$	$\Delta EY_{i,t}$	ϕ_s	$\Delta ET_{i,t}$	$\Delta EM_{i,t}$	$\Delta EF_{i,t}$	$\Delta EY_{i,t}$
	$\beta_s \phi_s$					β_s			
α	1.861*** (5.76)	2.035*** (5.64)	1.951*** (5.39)	1.816*** (3.41)		1.725*** (5.34)	1.896*** (5.23)	1.779*** (4.95)	1.816*** (3.41)
$\Delta Y_{agr,i,t}$	0.007* (1.84)	0.010** (2.24)	0.008* (1.84)	0.014** (2.14)	9.6121	0.001 (1.16)	0.001 (1.08)	0.001 (1.20)	0.001 (1.35)
$\Delta Y_{ind,i,t}$	0.001 (0.13)	-0.004 (0.010**)	0.002 (0.19)	0.005 (0.29)	31.3418	-0.000 (-0.32)	-0.000 (-0.69)	-0.000 (-0.32)	-0.000 (-0.14)
$\Delta Y_{ser,i,t}$	0.110*** (3.77)	0.080** (2.47)	0.149*** (4.56)	0.212*** (4.35)	48.1946	0.003*** (4.20)	0.002*** (2.71)	0.004*** (5.14)	0.005*** (4.97)
N	247	246	246	233		251	250	250	237
adj. R^2	0.4942	0.4564	0.4778	0.3743		0.4954	0.4490	0.4838	0.3798

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; standard errors in parentheses, same hereinafter.

significant positive effects on male and female informal employment in BRI countries, while the industrial sector shows statistically insignificant effects.

Agricultural growth has a slightly stronger positive impact on male informal employment (0.010**) than female (0.008*), consistent with the high male labor share in agriculture. This confirms agriculture as a traditional labor-intensive sector and a critical employment absorber in BRI countries, especially in rural areas. The insignificant impact of industrial growth stems from two factors: (1) Industrial restructuring: Traditional industries shrink amid growth, while services and high-tech industries expand, reducing industrial employment elasticity (Guisan & Exposito, 2017); (2) Technological progress and capital deepening: Automation and productivity gains reduce labor demand, shifting industry from labor-intensive to capital-intensive (Burggraave *et al.*, 2015).

Service growth exerts the strongest positive impact on informal employment (significant at 1% level): a 1% increase in service output raises total informal employment by 11%, consistent with Zmami (2021). Notably, the service sector's pull effect on female informal employment (0.149***) is significantly higher than male (0.080**), due to high female labor participation in services. After controlling for sector size, the employment impact of service growth weakens slightly, reflecting the large share of services in BRI economies (average 48%).

Service growth has a stronger positive impact on youth informal employment than agriculture, as young workers prefer service jobs over low-wage agricultural work (Kharaishvili *et al.*, 2017). Sectoral employment impacts are closely tied to GDP share: services (48%), industry (31%), and agriculture (9.6%) explain the higher employment elasticity of services.

The strong employment elasticity of the service sector reflects two coexisting forms of informal work: (1) modern flexible employment in digital services, logistics, cross-border e-commerce, and related modern services, which is consistent with service sector modernization; (2) survival-oriented informal labor in low-end services, street vending, and domestic work, which serves as a labor market buffer. This dual structure explains why the modernizing service sector can still absorb large numbers of precarious informal workers in BRI countries.

2) Extended Regression with Lagged Infrastructure Investment

Table 4 reports regression results of Equation (4) incorporating lagged infrastructure investment, confirming significant employment promotion effects of BRI infrastructure construction with pronounced group heterogeneity.

Aggregate effect: A 1 percentage point increase in infrastructure investment as a share of GDP raises total employment by 1.36 percentage points in the next year (elasticity 1.363**), verifying the “investment-employment accelerator” mechanism (Chenery & Strout, 1966). Infrastructure investment reduces trade costs and absorbs informal employment; World Bank (2022) evidence shows a 21% drop in trade costs and 9% employment growth along China-Europe Railway Express cities.

The higher male sensitivity to infrastructure investment is not only due to the concentration of males in construction and transportation, but also driven by gender differences in labor mobility, physical job requirements, skill structures and participation constraints, which together explain the gender gap in informal employment responses.

Sectoral synergy: Infrastructure investment strengthens the service sector’s pull on female employment (elasticity 0.688), creating flexible jobs for women via cross-border e-commerce and live-streaming trade. Agricultural growth shows a negative employment effect (-0.119), driven by mechanization and rural-urban labor transfer accelerated by infrastructure (FAO, 2022).

3) Asymmetric Effects Across Economic Cycles

This paper defines the economic contraction phase as annual negative GDP growth due to the unavailability of quarterly GDP data for most developing countries along the Belt and Road Initiative. This treatment follows common practice in cross-country panel research. We acknowledge that in classical macroeconomics, a contraction is typically defined as at least two consecutive quarters of output decline. Our use of annual negative growth to represent contraction phases is a simplification constrained by data availability, and we interpret the results accordingly.

Table 5 reports regression results of Equation (5) splitting samples into economic expansion ($\Delta Y > 0$) and recession ($\Delta Y < 0$), revealing asymmetric sectoral impacts on informal employment.

Expansion phase: Service growth significantly boosts total, male, and female informal employment, with especially strong effects on youth, consistent with the labor-intensive nature and low entry barriers of services. Agricultural and industrial growth show insignificant effects, due to technological progress reducing labor demand and industrial restructuring.

Recession phase: Negative industrial growth significantly raises total, female, and youth informal employment, reflecting firms’ substitution of high-cost labor with low-cost female and youth workers amid capital deepening (Tang, 1999). After controlling for sector size, service growth remains positively associated with informal employment, with the strongest impact on youth (0.185***), as services act as a key employment buffer for vulnerable young workers (Kharashvili et al., 2017).

V. CONCLUSIONS AND POLICY IMPLICATIONS

Based on informal employment data across 64 BRI countries, this study utilizes a non-linear panel model to systematically analyze the heterogeneous impacts of economic cycles on labor dynamics within manufacturing clusters. By uncovering how fluctuations influence informal employment patterns in this labor-intensive sector, the research provides critical theoretical and empirical evidence for enhancing industrial resilience and labor policy-making in developing countries. The core findings are as follows:

Sectoral differentiation mechanisms: Agriculture significantly drives informal employment but faces weakening job creation amid mechanization and infrastructure-led transformation (agricultural employment elasticity drops to -0.119*). Industry exhibits a unique counter-cyclical employment effect, with negative growth during recessions pushing up female and youth informal employment, reflecting cost-based labor substitution. Services show the strongest employment elasticity, especially for youth and women, acting as a critical employment buffer. BRI infrastructure investment (lagged one period) exerts a significant employment promotion effect (total elasticity 1.363), strengthening service sector employment elasticity for women (0.688) and accelerating rural-urban labor transfer.

Asymmetric responses: Informal employment responds asymmetrically to economic cycles. During expansion, service growth dominates informal employment creation, while agriculture and industry contribute little. During recession, services remain a positive driver of informal employment, and industrial decline raises female and youth informal employment via labor substitution, verifying the macroeconomic stabilizer role of informal employment.

Demographic heterogeneity: Male informal employment is more sensitive to infrastructure investment (1.446) and agricultural growth (0.010), while female informal employment relies on services (0.149), revealing gender segmentation in labor markets. Youth informal employment shows ultra-high sensitivity to service growth (0.212) and infras-

TABLE 4. Regression Results with Lagged Infrastructure Investment Variables

	$\Delta ET_{i,t}$	$\Delta EM_{i,t}$	$\Delta EF_{i,t}$	$\Delta EY_{i,t}$
α	114.3** (3.57)	131.8*** (4.29)	82.24** (2.86)	115.3*** (5.07)
$\Delta Y_{agr,i,t}$	-0.119* (-2.24)	-0.135 (-1.97)	-0.0961 (-2.03)	-0.137 (-1.63)
$\Delta Y_{ind,i,t}$	0.0563 (0.56)	0.0556 (0.44)	0.0220 (0.23)	-0.0720 (-0.38)
$\Delta Y_{ser,i,t}$	0.281 (0.85)	-0.0389 (-0.10)	0.688* (2.17)	0.373 (0.86)
Lagged Infrastructure Investment (L1)	1.363** (2.93)	1.446** (2.94)	0.706 (1.58)	1.934** (3.37)
Urbanization Rate	-0.889 (-1.45)	-1.133 (-1.98)	-0.474 (-0.82)	-0.673 (-1.45)
N	116	115	115	104
adj. R^2	0.2630	0.2854	0.4778	0.4237

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; standard errors in parentheses, same hereinafter.

TABLE 5. Effect of GDP Growth Rate on Informal Employment Rate across Economic Cycles

	$\Delta ET_{i,t}$	$\Delta EM_{i,t}$	$\Delta EF_{i,t}$	$\Delta EY_{i,t}$	ϕ_s	$\Delta ET_{i,t}$	$\Delta EM_{i,t}$	$\Delta EF_{i,t}$	$\Delta EY_{i,t}$
	Expansion ($\beta_{1,s}\phi_s$)					Expansion ($\beta_{1,s}$)			
α	2.024** (2.20)	1.361 (1.49)	3.642*** (3.99)	3.642*** (3.99)		6.652* (1.77)	5.385 (1.46)	7.914** (2.14)	7.914** (2.14)
$\Delta Y_{agr,i,t}$	0.001 (0.14)	0.001 (0.09)	0.002 (0.21)	0.002 (0.21)	9.612	0.026 (0.30)	0.038 (0.45)	0.015 (0.18)	0.015 (0.18)
$\Delta Y_{ind,i,t}$	0.011 (0.66)	0.009 (0.52)	0.012 (0.69)	0.012 (0.69)	31.342	-0.023 (-0.56)	-0.025 (-0.63)	-0.012 (-0.30)	-0.012 (-0.30)
$\Delta Y_{ser,i,t}$	0.464*** (4.02)	0.441*** (3.85)	0.436*** (3.81)	0.436*** (3.81)	48.195	-0.028 (-0.66)	-0.022 (-0.53)	-0.025 (-0.61)	-0.025 (-0.61)
N	127	127	127	127		130	130	130	130
adj. R^2	0.8398	0.8126	0.8836	0.8836		0.8065	0.7782	0.8608	0.8608
	Recession ($\beta_{1,s}\phi_s + \beta_{2,s}\phi_s$)					Recession ($\beta_{1,s} + \beta_{2,s}$)			
α	-0.564* (-1.87)	0.765* (1.72)	-0.610** (-2.49)	-0.537** (-2.49)		-7.950*** (-3.94)	0.097 (0.04)	0.229 (0.30)	-9.383*** (-3.17)
$\Delta Y_{agr,i,t}$	-0.012 (-1.18)	-0.018 (-1.24)	-0.009 (-1.19)	-0.006 (-0.83)		-0.023 (-0.34)	-0.027 (-0.28)	-0.023 (-0.47)	-0.012 (-0.26)
$\Delta Y_{ind,i,t}$	-0.048** (-2.54)	-0.067 (-1.39)	-0.034** (-2.27)	-0.039** (-1.71)		-0.024 (-0.70)	-0.015 (-0.19)	-0.027 (-1.02)	-0.013 (-0.32)
$\Delta Y_{ser,i,t}$	2.583 (0.70)	2.968 (0.78)	2.138 (0.53)	4.197 (0.87)		0.146*** (3.93)	0.151*** (3.86)	0.138*** (2.67)	0.185*** (3.25)
n	233	171	171	167		170	171	171	167
adj. R^2	0.7651	0.7270	0.6692	0.6587		0.9107	0.9213	0.8286	0.8576

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; standard errors in parentheses, same hereinafter.

structure investment (1.934**) yet high vulnerability during recessions, posing challenges for targeted policy design.

A. POLICY IMPLICATIONS

Establish a BRI Economic Shock Early Warning Mechanism Build a BRI economic fluctuation monitoring system covering informal employment rates and sectoral growth rates, and develop early warning models with the ILO. Adopt a “infrastructure-employment elasticity coefficient” tool to integrate informal employment creation into project feasibility assessments. Establish a BRI Informal Employment Support Fund for skills training of micro-enterprises and informal workers, and add “gender employment ratio clauses” to investment agreements. Promote cross-border

industrial chain division to relocate labor-intensive services (cross-border logistics) to low-income countries, paired with youth employment training programs.

Construct a BRI Economic Cycle-Adaptive Investment Cooperation Mechanism During expansion: Launch special funds for labor-intensive industries (cross-border e-commerce, digital cultural tourism) and target training for youth and women; adopt “infrastructure + services” bundled investment with supporting vocational training centers to mitigate employment lags (3–5 years for infrastructure). During recession: Roll out targeted measures such as youth entrepreneurship credit and female protected posts. Propose an “Agricultural Intelligent Transition Insurance” to alleviate employment shocks from technological upgrading, provid-

ing re-training for affected farmers to enter agricultural processing and rural tourism.

Improve Multilateral Institutional Guarantees Establish a unified labor market database and infrastructure investment standards under frameworks such as RCEP, APEC, and DEPA to enhance information sharing and data analysis. Deepening international cooperation requires integrating open trade with domestic policies that prioritize green manufacturing infrastructure and digital trade, thereby building institutional resilience against cyclical shocks. By embedding sustainable industrial standards into this framework, participating nations can better mitigate economic fluctuations and strengthen the foundations of regional economic stability.

AUTHOR CONTRIBUTIONS

Conceptualization – Wei Tanshixu and Wu Yue; methodology – Wei Tanshixu and Wu Yue; investigation – Wei Tanshixu and Wu Yue; writing-original draft preparation – Wei Tanshixu and Wu Yue. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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